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77

ECOSYSTEM NATURAL CAPITAL ACCOUNTS:

A Quick Start Package for implementing Aichi Biodiversity Target 2 on Integration of Biodiversity Values in National Accounting Systems in the context of the SEEA Experimental Ecosystem Accounts

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Japan Biodiversity Fund

Indian Ocean Commission

European Environment Agency

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ECOSYSTEM NATURAL CAPITAL ACCOUNTS: A QUICK START PACKAGE

For implementing Aichi Biodiversity Target 2 on Integration of Biodiversity Values in National Accounting Systems in the context of the SEEA Experimental Ecosystem Accounts

This document has been prepared in 2014 for the Secretariat
of the Convention on Biological Diversity (SCBD)
by Mr. Jean-Louis Weber (independent consultant)

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RÉPUBLIQUE FRANÇAISE
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FOREWORD BY EXECUTIVE SECRETARY

The Strategic Plan for Biodiversity 2011-2020 and its Aichi Biodiversity Targets provide a framework for action on biodiversity for this decade and beyond. In order to progress towards the achievement, this Plan needs to be assessed on a continuous basis. Comprehensive and robust monitoring systems, from which indicators of progress can be readily extracted and easily interpreted, would greatly enhance our ability to do this.

Biodiversity datasets are scarce for many parts of the earth's surface. *In situ* data is not always available and often have limitations. Earth observation data from spaceborne, airborne and ground-based sensors have a major role to play in improving monitoring systems by complementing conventional *in situ* data collection or by providing other types of information. Furthermore, the greater availability of earth observation data might encourage increased *in situ* data collection efforts, for instance for ground proofing purposes.

This report shows how earth observation technologies can and should fit into systems for biodiversity monitoring, as well as demonstrates how these approaches could further improve relevant indicators for the Aichi Biodiversity Targets. It illustrates a clear track from observations done by remote sensing platforms through Essential Biodiversity Variables to biodiversity indicators and ultimately to the assessment of progress towards the Aichi Biodiversity Targets and ultimately in support of evidence-based decision making. There is clearly huge potential for involving the wide range of current and emerging Earth Observation products in biodiversity monitoring. However, it is imperative that a balance is achieved between innovation in new products and the continuity of existing earth observations. A consistent, comparable readily available time series of biodiversity-relevant earth observations, such as long-term land cover change, is a pressing need. If this need were filled it would greatly enhance our ability to keep biodiversity and ecosystems under proper review and take well informed policy decisions.

This report is intended as a resource for three communities: Earth Observation specialists, biodiversity scientists and policy makers. It aims to create common ground and initiate further dialogue. We hope that it will encourage an ongoing commitment from all readers to realize the full potential of the invaluable set of tools presented in this report and to take every opportunity and creative steps to enhance monitoring and assessment of biodiversity at the national and international level.

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Convention on Biological Diversity

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EXECUTIVE SUMMARY

ECOSYSTEM NATURAL CAPITAL ACCOUNTS: A QUICK START PACKAGE

Ecosystems and Biodiversity in National Accounting

The tenth meeting of the CBD Conference of the Parties, held from 18 to 29 October 2010, in Nagoya, Aichi Prefecture, Japan, adopted a revised and updated Strategic Plan for Biodiversity, including the **Aichi Biodiversity Targets**, for the 2011-2020 period. This plan provides an overarching framework on biodiversity, not only for the biodiversity-related conventions, but for the entire United Nations system and other partners engaged in biodiversity management and policy development.

Of particular interest is Goal A of the Strategic Plan for Biodiversity 2011–2020: : "Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society" and: *By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems*".

This objective should be interpreted in the light of the CBD for an ecosystem approach, "*a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way*", recognizing that "*humans, with their cultural diversity, are an integral component of many ecosystems*".

Making progress now on the implementation of national accounts for ecosystems and biodiversity in their relation to economy and human well being is therefore an urgent priority.

Policy demands for integrated economic and environmental accounts are numerous and recurrent in international discussions as well at the national level. In 2012, the UN Statistical Commission (UNSC) adopted the System of Environmental- Economic Accounting Central Framework (SEEA-CF) as a statistical standard on par with the 2008 SNA, the UN System of National Accounts. However the SEEA-CF does not cover ecosystems and because of growing interest, the UNSC endorsed in 2013 an additional SEEA volume on Experimental Ecosystem Accounting (SEEA-EEA).

The SEEA-EEA is a broad conceptual framework, an important first step towards accounting for ecosystems, their services and resilience, which biodiversity underpins. However, a number of conceptual and practical issues remain to be addressed. A research agenda has been defined as well a process to capitalise on the existing and forthcoming experience gained in countries engaged in testing ecosystem accounting.

The purpose of the this initiative is to provide the additional elements needed by countries willing to start implementing ecosystem accounts now, hence the title a "quick start" package. It includes a structured set of accounting tables and guidance based on practical experiences of compiling ecosystem accounts, in particular in the European Union.

Ecosystem Natural Capital Accounts: A Quick Start Package (ENCA-QSP) is a comprehensive approach applicable to all ecosystems, whether natural or modified by anthropogenic activities, with the purposes of measuring the capability of delivering their services now or in the future, directly to people or as inputs to the production of commodities. ENCA-QSP covers quantitative as well as qualitative aspects of ecosystem structures and functions and ultimately measures degradation which may result from human activities or, when it happens, enhancement resulting from sound ecological management.

As a quick start package, ENCA-QSP acknowledges that not all accounts can be produced in one run. It proposes priorities and a roadmap. A first distinction is made between core and functional accounts. Core accounts are established first, in a comprehensive way, following the basic rules of accounting. They are the accounting infrastructure upon which more detailed and targeted functional accounts are developed according to requirements.

Core accounts are based on a simplified ecosystem model that considers three broad components related to biocarbon, freshwater and to the bundle of intangible regulating and socio-cultural services taken together. A set of four accounts is compiled for each to them. The first table relates to the conventional resource balances of ecosystem carbon, ecosystem water and land cover. The second table provides a precise measurement of the resource which is actually accessible considering risks of depletion and a range of limiting factors. The third table is a thorough analysis of resource use. The fourth table is the calculation of an index of internal ecological unit value combining indexes of sustainable use and composite indexes of ecosystem health. Ultimately these indexes are combined in turn to calculate an overall index of ecosystem capital capability. The calculation can be done for each single ecosystem and ecological capabilities can be added up. In that way an aggregate, the Ecosystem Capital Capability, can be produced at any scale, including at the national level and provide a measurement of performance in terms of ecological value on par with the economic value measured by GDP and similar aggregates.

Functional accounts are not detailed in ENCA-QSP; they are just briefly described in the last chapter. They cover, in particular, accounts of specific ecosystem services in physical units and monetary valuation. They address as well issues like sectors accountability or liability to ecosystem degradation, measured in ecological capability units and the related restoration costs.

One important characteristic of ENCA-QSP is that in principle, the first implementation of core accounts can be done using existing data available in the country or downloadable from the internet. It means that the perspective is to produce quickly a first set of core accounts in order to assess their policy relevance as well as the feasibility and cost of their improvement.

The ENCA-QSP report is composed of 9 chapters. Chapters 1 and 2 describe the overall approach and the ENCA-QSP framework and its relation to the SEEA-EEA. Chapter 3 is devoted to the construction of the data infrastructure needed for accounting. Chapter 4 provides a special focus on land cover mapping and accounting which plays an essential role in integrating ENCA-QSP as a wide range of data are referenced against land cover; land cover is the main area where specific data collection can be considered if good quality maps are not available. Chapters 5, 6 and 7 address in detail the three broad component accounts: ecosystem carbon, water and infrastructure- based services. They include methodologies as well as suggestions regarding possible data sources. Chapter 8 explains the calculation of ecosystem capital ecological value in ecological capability units, the currency used to aggregate all ecosystems. Last, Chapter 9 presents briefly the way forward and how functional accounts.

0. INTRODUCTION

"Because national accounts are based on financial transactions, they account for nothing in nature, to which we don't owe anything in terms of payments but to which we owe everything in terms of livelihood." **Bertrand de Jouvenel, Arcadie, 1968**

0.1 THE CONTEXT

This Convention on Biological Diversity (CBD) Technical Series report, Ecosystem Natural Capital Accounts Quick Start Package (ENCA-QSP), is a contribution by the CBD Secretariat to the process of testing the System of Economic and Environmental Accounts – Experimental Ecosystem Accounts (SEEA-EEA) endorsed by the UN Statistical Commission in 2013. The publication of SEEA-EEA was an important first step towards accounting for ecosystems, their services and resilience, which to a large extent depend on biodiversity. This CBD Secretariat initiative is a second step, motivated by the requirements of the CBD 2010 Aichi Strategy[3], which aims at integrating biodiversity into mainstream policies by 2020.

The CBD objectives for accounting were stated in CBD Conference of the Parties 10 (COP10) Decision X/2 "Strategic Plan for Biodiversity 2011–2020: Strategic Goal A. Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society/Target 2: By 2020, at the latest, biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems".[4]

These objectives should be interpreted in the light of the CBD request for an ecosystem approach, "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way", recognizing that "humans, with their cultural diversity, are an integral component of many ecosystems".

The revision of the System of Economic and Environmental Accounts (SEEA 2003), agreed in 2007 by the UN Statistical Commission, led to the creation of an international statistical standard for accounts for which sufficient experience exists. In 2008, the UN Statistical Commission decided to supplement the standard accounts, now called the SEEA Central Framework[5] , with a second volume on Experimental Ecosystem Accounts.

The 2012 SEEA Central Framework represents an international statistical standard on a par with the Systems of National Accounts (SNA), which do not cover accounting for ecosystems. The Central Framework covers physical resource flows, natural assets and their depletion (physical and monetary), and expenditure on environmental protection and resource management. "Accounting for degradation and other measurement topics associated with ecosystems are not covered in the SEEA Central Framework. The relevant material is discussed in SEEA Experimental Ecosystem Accounts"[6].

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3 *CBD Aichi Biodiversity Targets: http://www.cbd.int/sp/targets (accessed 21 July 2014).*

4 *These important CBD targets have been endorsed by the United Nations General Assembly's Open Working Group on Sustainable Development Goals at its last meeting, 19 July 2014. The proposals of the Open Working Group, which will be submitted for approbation to the General Assembly, state: "Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" which includes: "15.9 by 2020, integrate ecosystems and biodiversity values into national and local planning, development processes and poverty reduction strategies, and accounts". http://sustainabledevelopment.un.org/focussdgs.html (accessed 14 August 2014)*

5 *SEEA 2012 Central Framework: http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf (accessed 21 July 2014).*

6 *SEEA-Central Framework, op. cit. para. 14*

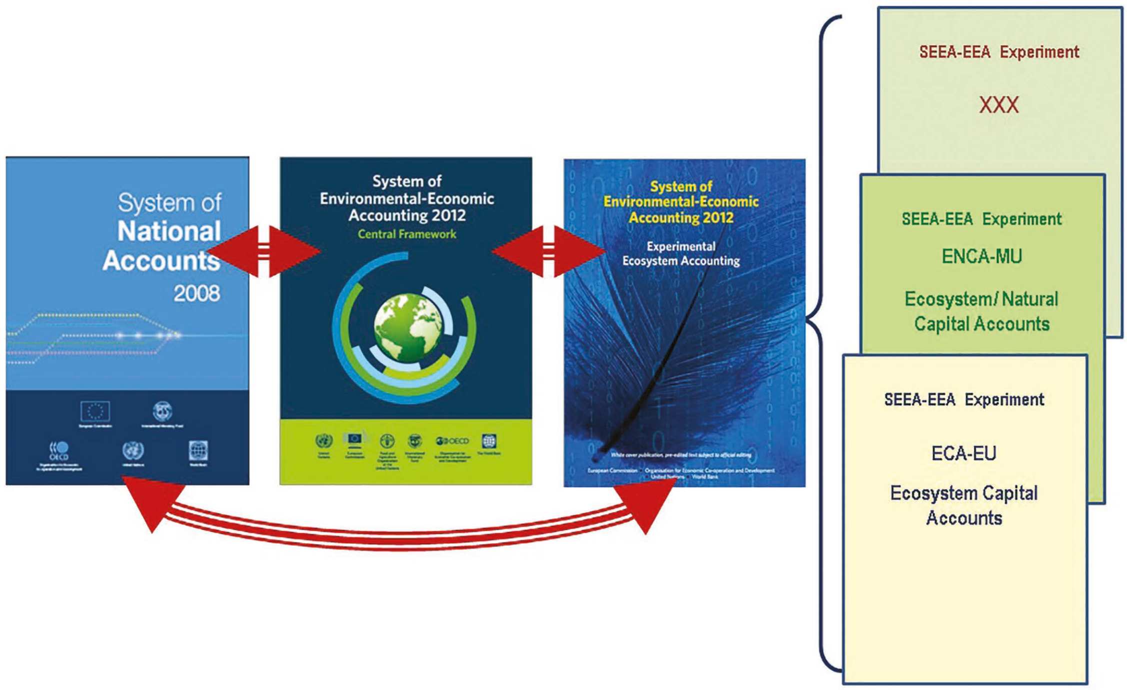
0.1.1 SEEA Experimental Ecosystem Accounting

"The SEEA Experimental Ecosystem Accounting provides a broad conceptual framework for ecosystem accounting. However, notwithstanding the important steps that have been taken, a number of conceptual and practical issues remain to be addressed. To advance ecosystem accounting, work is required to research the conceptual issues that remain to be elaborated or are the subject of discussion. In addition, testing of the conceptual framework will provide valuable inputs in the ongoing development of concepts, methods and classifications on ecosystem accounting. Considering the multidisciplinary nature of ecosystem accounting, the advancement of the research agenda as well as the testing of SEEA Experimental Ecosystem Accounting will require engagement across disciplines and organizations." (SEEA-EEA, Annex I: Research agenda for SEEA Experimental Ecosystem Accounting).

SEEA-EEA provides the conceptual accounting framework for ecosystem accounting, but does not include an integrated set of accounting tables and provides little guidance on how to implement these accounts. In order to stimulate the implementation of ecosystem accounts needed to meet the Aichi Target 2 and the developments needed to progress towards an agreed international standard in this context, the CBD Secretariat has taken the initiative of drafting practical guidelines, based on the general concepts of SEEA-EEA, supplemented by an integrated set of accounting tables, compilation guidance and experience of compiling ecosystem accounts, in particular in Europe.

The UN Statistical Commission has agreed that ecosystem accounts should be developed but, because of multiple approaches to ecosystem services and capital accounting, it is not yet possible to establish an international statistical standard. SEEA Part 2 is therefore experimental and aims at supporting country tests. "It is important that on-the-ground experience be gained through the testing of the accounting framework outlined in SEEA Experimental Ecosystem Accounting. To this end it is expected that the concepts and terminology described here will support testing efforts and facilitate the sharing of experiences in ecosystem accounting." (SEEA Part 2, para. 1.10)

Figure 01: SNA, SEEA Central Framework, SEEA Experimental Ecosystem Accounting and Experiments



Ecosystem accounts are linked to SNA through SEEA-Central Framework regarding the use of ecosystem resources and discharges of residuals. An additional link between SEEA-EEA and SNA is established when ecosystem degradation (or enhancement) is assigned to accountable economic sectors. Based on the general SEEA-EEA guidance, several experimental ecosystem accounts are being tested. The empirical evidence gained in these tests will contribute to moving one step towards an international standard in this area. The ENCA Quick Start package proposes practical guidance for such tests, as well as for starting them.

Box 0.1: A quick assessment of the way ENCA-QSP can meet the CBD requirements

For ecosystem natural capital accounting, the CBD statements (paras. 0.02 and 0.03) assume or require the following:

biodiversity values do not only mean the monetary values of biodiversity entangled in market prices, or non-market values calculated with shadow monetary prices; they are values in a broader sense, functional, ethical, and the accountability to them of the economy. Biodiversity values may not be tradable, but the economy is liable for their maintenance, a cost that is not paid when ecosystems are degraded.

development and poverty: biodiversity is not in conflict with production but is its main support as long as appropriate practices are in place; biodiversity conservation is essential for keeping development on a sustainable path and maintaining the cohesion of rural societies; accessibility to ecosystem services is part of the accounting framework.

national and local: methodologies have to be relevant at both scales; the national scale is not assumed to reflect all local details, issues, and challenges; however the national scale is not just a simple addition of local features. Not everything is transposable from one scale to the other; national accounts need a minimum of standardized methods and classifications as well as some completeness in order to guarantee comparability over space and time; local assessments can develop for some time with little coordination, but their standardization is necessary, just as local policies must interact with national ones.

strategies and planning processes: the long term matters, which in accounting terms is recorded as formation and consumption of capital. Extrapolation of current benefits over time needs to be considered together with the sustainability of the systems which deliver them, with multiple interacting types of capital (produced, financial, human, social, natural/non-renewable, ecosystem, etc.).

incorporation into national accounting, as appropriate: incorporation of biodiversity values "as appropriate" does not necessarily mean calculating green gross domestic product (Green GDP), a very controversial subject; other (more) efficient solutions are possible, such as integrating the unpaid costs of ecosystem degradation into the prices of final demand (as is done in fair-trade schemes) and/or accounting for ecological debts (by governments, businesses, etc.) in physical units and using these accounts in financial mechanisms such as interest payments or risk audits (E-RISC [1]).

integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way: unlike the weak-sustainability paradigm, the substitution of various types of capital is limited: because of the natural and self-renewal capacity of their multiple functions, ecosystems cannot be substituted by produced artefacts; a critical level of natural capital needs be conserved and ecosystem degradation needs be compensated for in an appropriate way in order to finance the restoration of the physical capacities of the ecosystems.

1 E-RISC: Environmental Risk Integration in Sovereign Credit Analysis, A New Angle on Sovereign Credit Risk, UNEP Finance Initiative and Global Footprint Network, 2012 http://www.unep.org/PDF/PressReleases/UNEP_ERISC_Final_LowRes.pdf (accessed 21 July 2014).

0.1.2 The Ecosystem Natural Capital Accounts Quick Start Package (ENCA-QSP)

The name chosen for the ENCA-QSP "distribution" [7] of the SEEA-EEA aims to clearly define its status among a wealth of projects and acronyms. While referring to SEEA-EEA, ENCA-QSP contains some (limited) adjustments and extensions. As it is likely that other projects will include other specific developments or interpretations of the broad SEEA-EEA principles, a specific identifier is needed. Natural capital accounts is broadly used, but not always in an unambiguous way [8]. Ecosystem capital accounting is used by the European Environment Agency in their framework of 2011. Other acronyms refer explicitly to ecosystem services and to their valuation (see 0.12). The initial project name of the Mauritius test accounts was Natural capital/ecosystem accounts that became Ecosystem natural capital accounts (ENCA). Because the general approaches are very similar and highlight the characteristics of the framework, ENCA has been kept for this publication.

The addition of a Quick start package (QSP) to ENCA aims at highlighting the purpose and provisional status of the report. The intention is to stimulate new experiments in the short term with methodologies based, in most cases, on existing data. Quick start also means that such experiments can take place before the completion of the research agenda included in SEEA-EEA 2012, and that the QSP is not a definitive response to the questions left open by the SEEA-EEA, but a working document. Findings from the ENCA-QSP will be put to the discussion forum that the UN Statistics Division (UNSD) intends to convene on an annual basis (from December 2014) in order to take stock of progress, implement the research agenda and start standardizing ecosystem accounting methodologies. The relationship of ENCA-QSP to SEEA-EEA is detailed in Chapter 1.

7 *This terminology echoes the concepts of kernel and distribution(s) used in the open-source world where a common set of programmes is subject to various developments by partners in a community according to their particular needs or purposes, while respecting the overall architecture. Several SEEA-EEA tests are currently being carried out with the same common references but different practical guidelines established for the purpose of compiling accounts in different geographical and institutional conditions, with differing access to data and general knowledge.*

8 *The usual sense (e.g. its use by the World Bank in natural capital accounting) relates natural capital to both the non-renewable resources of the subsoil and to renewable resources. While proposing no precise definition of natural capital, SEEA-EEA suggests similar coverage for natural assets. In another context, such as the biodiversity strategy of the EU, natural capital is equivalent to ecosystem capital only. This is the terminology also used to name the UNSD/UNEP/CBD project on Advancing Natural Capital Accounting (ANCA) for ecosystems. Natural capital can be also understood as an economic production factor or in a broader sense covering non-marketed ecosystem services. Capital can refer implicitly or explicitly to the standard economic theory where capital is equal to the value of discounted future benefits; or capital can be defined as physical systems with capacities and resilience.*

0.2 SCOPE, OBJECTIVES AND TARGET AUDIENCES FOR ECOSYSTEM NATURAL CAPITAL ACCOUNTS

Several approaches to ecosystem accounting have been followed in recent years. Some start from an assessment of ecosystem services, often with the ultimate aim of calculating their economic value and the wealth they represent. Other approaches consider first the ecosystems themselves, their capacity to deliver services in a sustainable way, their resilience and, ultimately, the measurement of ecosystem degradation and enhancement. Accounts in physical units are generally given priority in this case. The two broad approaches are not exclusive. They are linked in many ways since they connect their assessments of ecosystem services and assets to the same ecosystems and the same economic sectors. The System of Economic and Environmental Accounts ¬Experimental Ecosystem Accounting presents an overview and an analysis of these approaches, considering physical flows, physical assets, valuation of flows and valuation of assets, and organizes their convergence.

Variants of SEEA experimental ecosystem accounting are currently being tested in countries and by international and regional organizations. These reflect specific priorities or purposes as well as the variability of environmental conditions from one region to another. Examples include: approaches focused on ecosystem services at the World Bank (e.g. in the WAVES context [9]); work by UNEP's Division of Environmental Policy Implementation (UNEP-DEPI) relating to particular ecosystems or specific contexts such as small island developing states, and in the European Union (EU) with their Mapping and Assessment of Ecosystem and their Services (MAES) and testing of approaches in terms of ecosystem capital productivity and resilience (the Ecosystem Capital Accounts (ECA) project of the European Environment Agency); and recently in a case study on Experimental ecosystem natural capital accounts in Mauritius[10]. The Advancing Natural Capital Accounting project, run in 2014 by UNSD, UNEP – The Economics of Ecosystems and Biodiversity (UNEP-TEEB) and the CBD Secretariat (with support from the Norwegian Government), is expected to address two aspects: ecosystem services, and ecosystem extent and condition.

The QSP does not cover all aspects of ecosystem accounting. The intention is to start with core accounts of the ecosystem, considered as capital contributing to the delivery of services together with other forms of capital, man made, human, social, etc. This means that all ecosystems are encompassed, from the more natural ones to those more modified by human activities. They also include seas, oceans and the atmosphere/climate system. The ecosystem potential to deliver all possible services is measured in terms of sustainable provision of biocarbon and freshwater and of the bundle of intangible services supplied by healthy ecosystems. It includes the services which are incorporated in economic goods and services as well as those services contributing directly to the current and future well being of individuals and the community. Other aspects such as detailed ecosystem services assessment will be dealt with in another step. Although limited in scope, the QSP delivers key indicators of accessibility to ecosystem resources and ecosystem degradation/enhancement. Moreover, its detailed data infrastructure makes it a resource for extensions such as assessments of specific ecosystem services (e.g. by providing a start for basic land-cover and rivers maps).

The ecosystem capital approach allows a start to building up the data infrastructure of ecosystem accounting for a region or a country. This has to be considered as a

9 *Wealth Assessment and Ecosystem Valuation of Ecosystem Services is the partnership launched in 2010 by the World Bank. WAVES supports projects including pilot projects led by Conservation International (CI) under the Ecosystem Values Assessment and Accounting (EVA) which take "a broad and practical approach in incorporating natural capital into decision making consistent with the SEEA" (project being implemented in Peru), and EcoSpace led by the University of Wageningen "using spatial and biophysical modeling to measure ecosystem services in the context of land use change" (project being implemented in Indonesia, the Netherlands, and Norway). http://www.wavespartnership.org/en/waves-policy-and-technical-experts-committee-ptec (accessed 21 July 2014).*

10 *Experimental Ecosystems Natural Capital Accounts Mauritius Case Study, Methodology and preliminary results 2000–2010, Weber J-L., Indian Ocean Commission, June 2014. http://commissionoceanindien.org/fileadmin/resources/Islands/ENCA_Mauritius.pdf (accessed 18 August 2014)*

longer-term investment since most datasets collected and processed for the QSP can be reused to support more detailed assessments (e.g. of specific ecosystem services) from the perspective of future methodological revisions and other policy contexts. Examples are land-cover/land-use datasets that are of great interest for land planning, the biocarbon account which is an input to Intergovernmental Panel on Climate Change (IPCC) calculations, and ecosystem water accounts which allow better integration of hydrological variables and other ecological dimensions at the level of river basins.

Only provisioning services quantifiable in physical units are directly recorded in balances of stocks, inflows, natural outflows and withdrawals for use. The many intangible services, described as regulating services (flood protection, pollution removal, pollination, etc.) or socio-cultural services, are difficult to measure directly and, when feasible, their addition, in physical units or after being monetized, raises problems of completeness and double counting. Therefore, only the capacity of the ecosystem to deliver services in a sustainable way (ecosystem capability) is recorded in the first instance in a core account in ENCA-QSP. Once an overall infrastructure is in place, significant ecosystem services can be mapped, recorded, assessed and even valued in a consistent way, with no commitment to aggregating them to get a full picture.

The ENCA-QSP is intended to provide some guidance for those who want to undertake ecosystem accounting now in their organizations, environment ministries or agencies, development agencies, forest and water agencies, university or research centres, and of course statistical offices. Indeed, a strong recommendation is for close cooperation from the beginning between these organizations and others, since ecosystems relate to so many issues and knowledge of them is disseminated between many organizations. As a leitmotif, the accountant will be asked in all the following chapters to start by seeking the support of specialists in the assessed domains. Then and only then, other data sources, such as international databases, can be used as a provisional way of producing accounts.

Since the valuation of ecosystem services has generated abundant literature, is presented and discussed in SEEA-EEA Chapter 5 and is covered by specific publications (Chapter 9), it is not addressed in this report. Valuation of ecosystem capital based on valuation of services is also not addressed, for the same reason.

The valuation of ecosystem maintenance, avoidance or restoration costs is also not covered in the QSP because not enough work on these issues has so far been done in an ecosystem accounting context. Such costs are more and more frequently calculated in the context of offset or mitigation of nature degradation, enforcement of environmental liability, or programmes of restoration of environmental quality of landscapes or river basins (0.22).

The ENCA-QSP is intended to help to produce first test accounts in a reasonably short period. Such production is essential to assess the conditions (data availability, staff, institutional partnerships, etc.) for future institutionalization. Having results – even provisional and imperfect – is essential for establishing a dialogue at an early stage with the future stakeholders of ecosystem accounts. Stakeholders include the ministries of economy and finance, of development and planning, of environment, and more generally all those who will have to integrate ecosystem accounting aggregates into their own decision-making processes and models, and in management mechanisms[11].

Since the tests of ecosystem accounting will address policy relevance as well as technical and feasibility issues, ENCA-QSP includes proposals for systematically computing account balancing items, the endogenous indicators and aggregates generated by an accounting framework. In SNA, well-known balancing items include gross value added (GVA) by industries, aggregated into GDP, national income, final consumption, and net savings. Because of insufficient consensus on aggregation issues in the SEEA-EEA editorial board, the 2013 document contained a more descriptive level of definition of flows, and of the extent and condition of stocks. Ecosystem degradation is conceptually defined in SEEA-EEA but no practical guidance is given to account for it. The ENCA-QSP application includes practical proposals for computing ecosystem degradation, or enhancement, in order to address the integration of an ecosystem indicator into the set of macro-level variables (GDP and other monetary aggregates, employment, life expectancy, etc.) used in national policy-making.

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11 This is similar to the approach followed for the United Nations Framework Convention on Climate Change (UNFCCC) Kyoto Protocol where the IPCC guidelines propose methodologies of increasing accuracy, starting with rather simple default values allowing the framing of policies.

0.3 POLICY RELEVANCE OF ECOSYSTEM ACCOUNTING

Policy demand for natural-resource accounting is greater than ever, even though there has, so far, been no comprehensive response. In the context of climate change, accounts that are comprehensive in scope but still only partial are produced for carbon to support the Clean Development Mechanism (CDM) and policies such as Reducing Emissions from Deforestation and Forest Degradation (REDD) which has evolved to REDD+ to take stock of possible reverse effects of one-sided carbon policies. Material flow accounts are extensively used in industrial countries to monitor resource efficiency and "green growth", despite obvious limitations regarding impact assessments. Ecological footprint accounts attempt to integrate resource-use stress on a spatial basis, without, however, taking stock of pollution and biodiversity. The water footprint aims at a global indicator of the pressure on water resources resulting from their direct and embodied use, but this only reflects regional differences in water availability, and therefore relative stress intensities, imperfectly.

Ideas of mitigation or compensation for ecosystem degradation are moving ahead, in the context of nature protection policies and the extension of business accounting to include the costs of such degradation. For example, in Europe, the Directive on environmental liability with regard to the prevention and remediation of environmental damage (ELD) establishes a framework to prevent and remedy environmental damage, based on the polluter-pays principle. The Directive defines environmental damage as damage to protected species and natural habitats, to water, and to soil[12]. Such ideas refer to the broader concept of capital maintenance, in this case to ecosystem capital. Other examples are given in Chapter 9 where a section addresses the issue of recording accountability for ecosystem degradation and measuring restoration costs

New deadlines have emerged since the early days of environmental accounting: adoption in 2010 of the CBD Aichi Strategy, with increasing awareness of the need to address adaptability to climate change in addition to mitigation, etc. In June 2012, the United Nations Conference on Sustainable Development reached agreement to launch a process to develop a set of Sustainable Development Goals (SDGs), which will build on the Millennium Development Goals (MDGs) and converge on a post-2015 development agenda.

12 *Directive 2004/35/EC of the European Parliament and of the Council, 21 April 2004.*

Box 02: Post-2015: framing a new approach to sustainable development

Building a foundation for sustainable development

Healthy and productive natural systems.

The world's economic activity, from subsistence to transnational levels, relies on ecosystem goods and services. Common property resources help many of the world's poor to survive and thrive despite social and economic inequities such as insecure access rights. Achieving sustained prosperity for all will require development pathways that respect ecological limits and restore ecosystem health while optimising the contribution of the environment to economic progress.

Independent Research Forum, IRF2015, Policy paper, May 2013 http://sustainabledevelopment.un.org/content/documents/874irf2015.pdf (accessed 21 July 2014)

As long as ecosystems and biodiversity remain a major sustainability issue, their conservation depends on the accountability of the economic agents for their use and on mechanisms to enforce maintenance of ecosystem capability to deliver services now and in the future. Such conservation is more than a protection problem since all our activities may influence the ecosystem. If mechanisms have to be created, they need to be based on agreed targets and verifiable information in order to enforce measures that will create additional costs for some and opportunities for others. Accounts aim to provide such information for use by companies to assess their performance and communicate it to their shareholders, by the public, and by fiscal authorities and the administration in general.

The importance of having an agreed accounting system in place at the start of an ambitious programme has been highlighted by the UNFCCC, IPCC and the Kyoto Protocol, and the global-warming issue as a whole.

Ecosystem accounts are important since they allow an overall understanding of change in relation to human activities. It is as important for countries as for most economic actors. What is at stake is the ecological pillar of sustainable development and, to a large extent, our capacity to adapt to climate change. From this perspective, accumulation of ecosystem degradation generates a risk that has to be covered in one way or another – a problem accepted by many governments and companies, including the insurance sector. As long as this risk is not covered by appropriate compensation, or alleviated, ecological debts are created by those accountable or responsible for such degradation

Degradation of ecosystems is not inevitable. Much degradation can be avoided, even under the pressure of short-term economic constraints, because the net benefits of the processes that cause the degradation are often less than they seem. Much degradation could be avoided if economic actors, companies and households were to pay the full price of what they consume. And much can be restored. In some cases the costs of restoration may seem prohibitive; in others, restoration is affordable and should be encouraged by appropriate regulations and mechanisms. Solutions are beginning to emerge on the basis of various compensation mechanisms that aim to repair or prevent degradation when remediation costs are too high. Ecosystem accounts could support the generalization of ecological management.

0.4 OVERVIEW OF THE DOCUMENT STRUCTURE AND LINKS BETWEEN CHAPTERS

This report has seven chapters focused on the core accounts, plus a shorter presentation of ways to expand their scope, in particular towards assessment of ecosystem services.

Chapter 1 sets the scene for putting the SEEA-EEA conceptual framework to work. It presents the main options taken in ENCA and explains why, in a limited number of cases, SEEA-EEA recommendations are not being followed.

Chapter 2 details the main characteristics of ENCA-QSP.

Chapter 3 describes the data infrastructure needed for ecosystem capital accounting and how it is created. It includes presentation of reference geographical layers and production of the ecosystem accounting unit dataset, which is the first step in the accounting process.

Chapter 4 addresses land-cover mapping and accounting. The accounting template is presented at an aggregated level.

Chapters 5, 6 and 7 present in detail the accounts of the three broad ecosystem services or resources by which the whole ecosystem is summarized: ecosystem carbon, ecosystem water, and the bundle of intangible ecosystem services assessed indirectly as a function of ecosystem integrity and biodiversity. The three accounts are presented following the same pattern of four tables:

- basic balance of stocks and flows;
- total use of carbon (domestic and imported, biocarbon and fossil carbon);
- accessible resource surplus;
- indexes of ecosystem health/distress.

Chapter 5 describes the ecosystem carbon account. Ecosystem carbon is mainly biomass, the biological carbon. It also includes the carbon in the atmosphere, from biological or fossil origin. There is thus a clear connection between ecosystem accounting and the IPCC budgets of emissions and sequestration of carbon (or, strictly speaking, carbon dioxide equivalents, the common unit of IPCC-type budgets and accounts), and with resource efficiency and "green growth" analyses that address the carbon issue. As an annex, the accounting template is presented as a spreadsheet.

Chapter 6 addresses water ecosystems. It relies mainly on the methods and experience gained with SEEA-Water (SEEA-W) of 2007, but from a different perspective: SEEA-W starts from water supply-and-use tables (SUT), but the ecosystem water account starts from the water systems. In particular this implies a systematic breakdown of the accounts by river sub-basins in order to assess water stress as well as the definition of ecosystem accounting units for rivers, which is not done in SEEA-EEA. As an annex, the accounting template is presented as a spreadsheet.

Chapter 7 relates to ecosystem integrity and the bundle of intangible ecosystem functional services that are measured indirectly. Territorial ecosystems and rivers are analysed separately, then integrated into the computation of an aggregate indicator that measures total ecosystem infrastructure potential. Finally, this indicator is combined with a composite index summarizing the diagnosis of ecosystem health, of which change in species biodiversity is an essential component. As an annex, the accounting template is presented as a spreadsheet.

Chapter 8 proposes a synthesis of the three basic accounts of ecosystem carbon, ecosystem water and the ecosystem functional services, using a common unit to measure the ecological value of any ecosystem and calculate total ecosystem capital capability at different scales. As an annex, the accounting template is presented as a spreadsheet.

Finally, Chapter 9 lists the steps that would lead to a complete integrated framework. First it requires the establishment of ecological balance sheets of credits and debts (like carbon credits and debits in IPCC accounting), which requires definition of ecosystem state in relation to agreed rules and reference values, and definition and measurement of the accountability of sectors for degradation or enhancement. Second, the chapter addresses the problem of mapping and assessing supply and demand for ecosystem services. Third, valuation methodologies are addressed as examples of established practices.

The accounting tables presented and commented in this report can be downloaded in spreadsheet format from http://www.cbd.int/accounting

Annex to the Introduction:

Economic environmental accounting: an historical background

As far back as the first national accounts by the Physiocrats (France, 18th century), accounting for a natural resource has been a recurrent subject of interest. Focussed for a long time on rent calculation for land or mines, or on forest management, resource economics re-entered the field of accounting with the development of input-output analysis of resource use (Leontief) and early attempts to produce a vision of the economy reinserted in its environment (Georgescu-Roegen, Odum, De Rosnay, Passet, Naredo and others…). The question of accounting came to the fore at the time of the 1972 United Nations Conference on the Human Environment (de Jouvenel 1968, Peskin 1972 in Norway, and later in the USA, Repetto with the World Resource Institute), with pioneer projects in Norway, Canada, Costa Rica, France, Indonesia, the Netherlands, Norway, Philippines, Spain, etc.

The 1992 United Nations Conference on Environment and Development was another milestone, with the demand included in Agenda 21 that the environment is recorded in national accounts [13]: "*Consideration should also be given to the present concepts of economic growth and the need for new concepts of wealth and prosperity which allow higher standards of living through changed lifestyles and are less dependent on the Earth's finite resources and more in harmony with the Earth's carrying capacity. This should be reflected in the evolution of new systems of national accounts and other indicators of sustainable development.*" Agenda 21.

It resulted in 1993 in the quick publication of the first System of Environmental Economic Accounting (SEEA 1993) and the creation of the UN London Group on Environmental Accounting, a "city group" of experts created to allow practitioners to share their experience and guide the ongoing tests of environmental accounts linked to the SNA. Because the first SEEA was not fit for implementation, the London Group decided in 1998 to revise it, in particular to give a better balance between monetary accounts (the quasi-exclusive focus of SEEA 1993) and accounts in physical units being developed in many countries. It resulted in SEEA 2003, which was broadly endorsed by all international organizations and widely used by statistical offices keen to test the new methodology.

Important in this period was the development of material balances and input-output analysis to measure the "industrial metabolism" of (industrial) economies and their performance regarding consumption and waste of materials and energy; the 2005 Millennium Ecosystem Assessment; and the carbon balances starting to be produced in support of the Clean Development Mechanism of the Kyoto Protocol. Policy echoes were magnified by the 2006 Stern review [14] that measured the cost of inaction regarding climate change in terms of GDP loss. Stern in turn triggered the launch in 2007 of The Economics of Ecosystems and Biodiversity (TEEB) global initiative by the G8 (with the support of the German Government, the European Commission and UNEP). This proved to be much more than a review and has explored the multiple ways in which relationships between the economy and nature could be addressed. There was also progress in two decades of academic research, steered in particular, but not exclusively, by the International Society for Ecological Economics (ISEE). At the international policy level, most notable recent initiatives have been Green Economy (UNEP), Green Growth (OECD), WAVES (World Bank) and the CBD Aichi-Nagoya Strategy.

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13 *Agenda 21, 4.11., UNSD, 1992 http://sustainabledevelopment.un.org/content/documents/Agenda21.pdf (accessed 21 July 2014).*

14 *The Stern Review: The economics of climate change, 2006 http://mudancasclimaticas.cptec.inpe.br/~rmclima/pdfs/destaques/sternreview_report_complete.pdf (accessed 21 July 2014).*

Back in the statistical realm, the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA) was established by the UN Statistical Commission (UNSC) at its 36th session in March 2005, with the objectives of mainstreaming environmental-economic accounts and related statistics, elevating the SEEA to an international statistical standard and advancing its implementation. Two revisions resulted from this initiative: FDES1984 (the Framework for the Development of Environmental Statistics), and SEEA 2003. Considering the SEEA handbook, the initial request to UNCEEA was to select and if necessary revise chapters of SEEA 2003 that could be considered mature enough and to edit them as an international standard. This resulted in the drafting and adoption by UNSC of the SEEA Central Framework (SEEA-CF) in 2012 that can be considered as a satellite account of SNA 2008.

In parallel the UNCEEA was invited by UNSC to prepare a second volume addressing ecosystem accounting in order to encourage "international and regional agencies and countries wishing to test and experiment in this new area of statistics". This important step was the result of the echo of the MA and TEEB and the increasing policy demands mentioned above, and of the continuous efforts developed since the early 1990s to approach economic-environmental accounting from the ecological end. Early initiatives were taken at the international level by United Nations Economic Commission for Europe (UNECE), followed by Eurostat, which resulted in a special session devoted to land and ecosystem accounting in the 1996 Special Conference of the International Association for Research in Income and Wealth (IARIW) held in Tokyo on environmental accounting in theory and practice. At this session papers were presented by Eurostat, Brazil, Germany, Japan and the UK. The UNECE work was at the core of the European presentations and raised enough attention for ecosystem accounts to be later incorporated, albeit in a very modest way, into SEEA 2003. It gave support for further developments in Europe, in particular at the European Environment Agency, which published a report on land accounts in 2006 and was for this reason invited to participate in the UN Committee of Experts on Environmental-Economic Accounting (UNCEEA) and asked to co-steer the edition of the new SEEA volume on ecosystem accounts, together with the World Bank and the UNSD Statistical Division.

A first conclusion from this short and incomplete review is that, despite continuing demand from policy makers and activities going back to the 1980s, and the publication of a first international handbook in 1993, an accounting standard equivalent to the UN SNA is not yet in place. From the very beginning, SNA 1953 presented an integrated picture of income generation with an aggregated indicator, national income, directly usable in macroeconomic policies. It was a short document (36 pages) with an annex of 12 tables. In contrast, EEA has generated several general and sectoral manuals and many case studies and applications, for example SEEA 1993, 2003 and now 2012/2013, World Bank Genuine Savings, OECD and Eurostat Material Flow Accounts, and reports on "total wealth" [15] (World Bank) and "inclusive wealth" [16] (UNU-IHDP and UNEP). As for SEEA, the 2012 Central Framework represents an international statistical standard on a par with the SNA, but this does not extend to accounting for ecosystems.

15 *The World Bank, 2011. The changing wealth of nations : measuring sustainable development in the new millennium, http://siteresources.worldbank.org/ENVIRONMENT/Resources/ChangingWealthNations.pdf 2011.*

16 *IWR, UNEP, UNU-IHDP. 2012. Inclusive Wealth Report 2012, Cambridge University Press, Cambridge, UK. http://cl.ly/1r3v2V3P3T1h422S1225 (accessed 21 July 2014).*

1. A QUICK START PACKAGE FOR PUTTING THE SYSTEM OF ENVIRONMENTAL-ECONOMIC ACCOUNTING - ECOSYSTEM TO WORK

1.1 PRIORITIES FOR THE ECOSYSTEM NATURAL CAPITAL ACCOUNTS QUICK START PACKAGE

Not all natural capital accounts can be covered in a single run. The **Ecosystem Natural Capital Accounts Quick Start Package** (ENCA-QSP) focuses on core ecosystem accounts which are represented with a rather simplified framework needed for implementation purposes. The implementation of the core accounts is the highest priority as it is an important piece of information directly usable in policy making as well as the way to address more specific issues in a consistent manner and build up an efficient information system.

The accounts for sub-soil assets are covered in the System of Environmental-Economic Accounting Central Framework (SEEA-CF) and will not be addressed in ENCA-QSP – despite the responsibility of intensive use of fossil resources for emissions of carbon dioxide (CO_2) to the atmosphere and pollution in general. Only the use of fossil carbon is part of ENCA and recorded, as shown in Chapter 5.

Ecosystem services and capital valuation have attracted attention in recent years, with methodologies developed or collated in different contexts. There is no need to develop guidelines for valuation in the QSP. This does not mean that valuation is excluded but that it will be done as a subsequent addition to the first physical accounts, using the best available methodologies.

For physical ecosystem accounting, not all possible accounts of their components will be produced. The system can be described in a more-or-less analytical way. Depending on the issues considered, fine detail may be needed at the microscopic scale (genetic diversity, monitoring of biomarkers and micro-pollutants) or a more holistic view may be preferable, or a combination of the two. This is not just related to data availability or the cost of data collection, but also to the kind of information being sought.

Ecosystem accounts aim primarily at describing the impacts of human activities on the reproductive capacity of nature. In that respect, ENCA-QSP proposes a diagnosis based initially on a limited number of variables. An analogy can be made with primary health care or preventive medicine where simple but complete check-ups allow first an assessment of the overall health status of a population and then the detection of individuals or regions with health concerns requiring further medical investigation. An efficient way of building a system of ecosystem capital accounts is to combine an overall picture of ecosystem states and trends with detection and assessment of hotspots and prevalence areas. This underpins the distinctiveness of core accounts, exhaustive and regularly updated from functional accounts that address more specific issues such as precise accounting of ecosystem services. This cannot always be done top-down and in many cases requires more explicit, site-based assessments.

1.2 SETTING PRINCIPLES

Meet the policy demand(s)

Ecosystem accounts are statistical tools; they should not be tied to any particular political objective but should support policies with meaningful, objective and verifiable data. This does not mean that policies should be ignored or policy demands rejected. Indeed, many policies, including public policies, could benefit from ecosystem accounts. This has implications not only, or mainly, for environmental policies but also, and perhaps as a priority, for mainstreaming decision-making in the economy, development and planning, which should all benefit from access to operational indicators able to broaden the evidence base upon which decision are made. This has several consequences. First, the accounts must not ignore expressed or implicit demands. Second, since the new indicators aim to support evidence-based decision making, quality assurance is particularly important and uncertainties duly documented and reported. Third, classification and aggregation of data are never completely neutral, and underlying assumptions and their consequences need to be explicit and discussed so as not to mislead the decision maker. Fourth, the policy agenda has to be considered.

Regarding macro-economic decisions, data need to be updated on at least an annual basis and should not be more than one year old. Time-series are also useful for understanding past trends, to feed models and to anticipate developments. When material constraints limit the possibility of producing up-to-date accounts on a continuous basis, interpolation and nowcasting methodologies – where the very recent past, up to the present, is assessed with a combination of observations, when they are available, and estimates produced by models generally used for forecasting – may have to be used to meet the policy timetable.

Be outcome-oriented

Ecosystems differ and available data differ, but the fundamental diagnosis needed is the same: capability, degradation, steady-state or enhancement, accountability. At this Quick Start stage, relevance matters more than accuracy. It is important to define first what should be done in principle, and then, and only then, what can be done in practice.

Use existing data available in countries and/or international databases

Most of the data needed for producing a first set of accounts already exists. Some may be of insufficient quality, and most will require adjustment because they have been collected for various purposes, at various dates. The first accounts will certainly not be perfect but will meet the two main functions of any accounts: to inform on performance and to inform on the quality of the information. In many cases, cross-combining heterogeneous data allows better estimates, as does producing time-series, since annual variations can be better interpreted and outliers eliminated. Systematic assessment of data consistency in the ecosystem accounting framework provides guidance for its improvement and for overall improvement of the environmental information system. This obviously suggests that data collection should be streamlined and the quality of data and statistics improved. This certainly has a cost but should also be considered from the benefits side, in general terms, as providing a better evidence base for decision making, as well as, in a more specific way, providing easier access to reliable and consistent data for various studies which support government actions. *Ad-hoc* data collection for such studies currently can cost half or more of the total budget, and improvement of the national databases needed for accounting should certainly result in net gains.

Because of its structural role, the availability of high quality land-cover stocks and change maps (Chapters 3 and 4) requires particular attention and their absence may be a problem. A time-series of land-cover change over at least the past 10 years – or better, 20 years or more – would allow better understanding of essential processes such as urban sprawl, deforestation and changes in agriculture, which in turn would help to assess data quality and the completeness of other variables. Maps of land-cover exist which can be used for basic descriptions of landscapes, but they can only be used for accounting if they can be associated with land-cover change. When this condition is not met, a programme of land-cover mapping will be needed at an early stage of an ecosystem accounting project.

In this respect, the newly revised 2013 *Framework for the Development of Environmental Statistics* (FDES)[1] is designed to provide a broad range of data for accounting. Its guidelines have been tested in 25 countries and provide a methodological background for environmental statisticians in national statistical offices or ministries. The primarily national scope of environmental statistics may limit their use for ecosystem accounting as far as reports are concerned, but statisticians trained with FDES acquire knowledge of the nature of the environmental data available and where to search for them, making them particularly well-suited for ecosystem capital accounting.

First produce accounts of ecosystem capital capability and ecosystem services in physical units, then value ecosystem services and restoration costs

As stated in the SEEA-EEA Introduction, "*accounting for ecosystems in physical (i.e. non-monetary) terms is a key feature of the SEEA-EEA. (…) Approaches to accounting for ecosystems in monetary terms (…) are also described recognising that this raises additional complexities relating to valuation. In this regard measurement in monetary terms for ecosystem accounting purposes is generally dependent on the availability of information in physical terms since there are generally few observable market values for ecosystems and their services*" (SEEA-EEA, para. 1.09).

Indeed, valuation of ecosystem services on the basis of overall physical accounts simplifies the work of the economist, who no longer has to collect data on the physical environment, and allows interpretation of results in the broader context of multiple ecosystem functions and resilience.

1 http://unstats.un.org/unsd/environment/fdes.htm *(accessed 21 July 2014)*

1.3 CHOOSING AN OPERATIONAL ACCOUNTING FRAMEWORK

A framework to integrate ecosystem components, ecosystems between themselves and ecosystems into the economy

The various accounts presented in SEEA-CF have their own consistency given by the SNA itself, which is a coherent representation of the economic system. There does not, therefore, need to be full integration between SEEA-CF tables. The ecosystem approach poses a different constraint since diagnoses require a holistic vision of systems. Treating ecosystems singly would be both incomplete and misleading, since interactions are part of the picture. This does not mean that all ecosystems need to be considered at the same time and with the same level of accuracy, but that a vision of the whole system should be present from the start, knowing that the details will vary from one area to another, depending on the issues, priorities and data. For example, coverage should encompass all ecosystems, not only natural habitats, and include agro- and urban systems as well as the oceans and the atmosphere, even though some of the descriptions may initially be minimal.

A framework interoperable with other frameworks – no need to duplicate data collection

Ecosystem capital accounts have their own data requirements and multi-thematic frameworks. However, they should not be produced from data collected only for the sake of accounting. One reason, mentioned above, is the need to make use of what already exists for reasons of efficiency and cost. A second, perhaps more important, reason is that ecosystem capital accounts aim at influencing policies by supplying information that broadens their vision and considers trade-offs with ecosystem maintenance issues. That is why it is important that, when the data reflect a reality described elsewhere, they are clearly compatible with the data and statistics used for the purpose of ecosystem accounting. For example, crop harvests recorded in the biomass account are computed from agriculture statistics. The added value of ecosystem accounting in this case is the downscaling of statistics to agriculture land cover, ideally in cooperation with the ministry of agriculture.

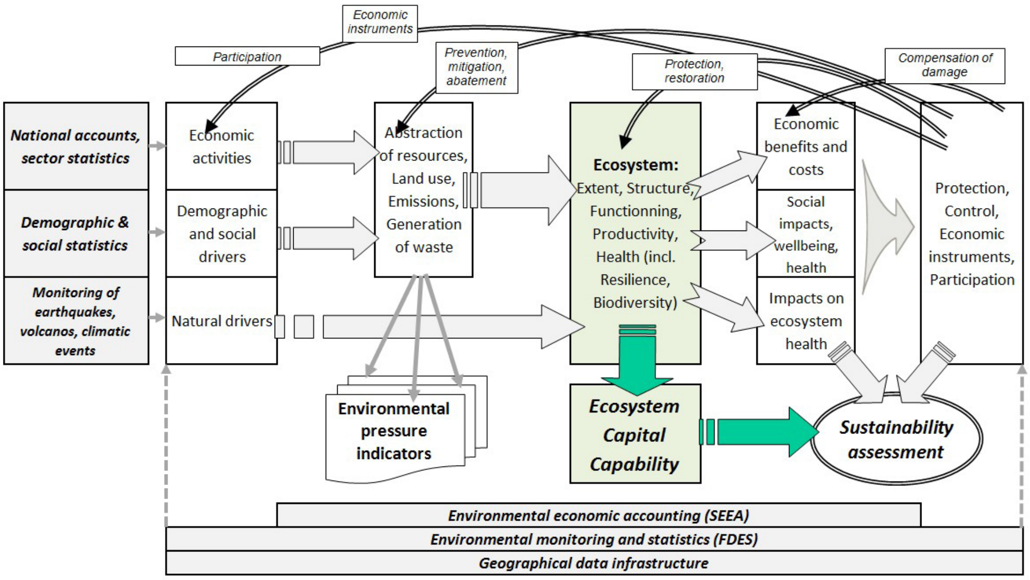
Interoperability with existing information frameworks has to be ensured, in particular for:

- official land-cover maps;
- meteorological data;
- population statistics;
- economic statistics (agriculture, forestry, fishery, tourism);
- water databases and statistics (directly and via SEEA-Water when it exists);
- reporting to UNFCCC on CO_2 emissions, carbon sequestration;
- national, regional and international reporting on nature conservation and databases on biodiversity;
- environmental statistics (UN FDES 2013).

Ecosystem accounts are fed with data and statistics primarily collected for other purpose, some of them used to produce indicators and state of the environment reports. Ecosystem accounts are syntheses that need to be interpreted in the context of these various frameworks, particularly regarding environmental statistics. Figure 1.01 shows how the DPSIR[2] framework, which underpins environmental statistics (FDES 2013) and state of the environment reporting, interacts with environmental accounts. The area covered by SEEA-CF relates mostly to pressures and their connection to economic drivers, while the entry points of ecosystem accounting are primarily state and impacts.

2 *Drivers, Pressures, State, Impacts, Responses.*

Figure 1.01: The DPSIR framework, environmental accounts, statistics and policies



Be open to developments, extensions and to support models

The ENCA-QSP framework should be evolutionary and modular, and support developments of its own as well as other analytical activities and models. Internal developments include domains such as urban systems, oceans and soil. It should also be possible to downscale the framework to regional and local levels of government and to companies. This is possible because of the clear distinction between core accounts, which are fully integrated, and functional analysis[3], where the integration and aggregation constraints are less cumbersome. For example, in core accounts, double counts are excluded while overlaps are possible between functional analyses.

Valuation is one of the domains not developed in the current QSP, although it is an intrinsic part of ENCA. There are two reasons for this. The first is that much work on the subject has been done and does not need to be duplicated. Methodologies for valuation have been explored in depth and in a comprehensive way in TEEB and programmes such as the World Bank/WAVES and UNEP-DEPI, and in the academic world, which are important sources of information. The second reason is that, as in SEEA-EEA, QSP gives priority to physical accounting so that well-developed physical accounts can release analysts and economists from the task of basic data collection and facilitate their use of valuation methodologies. Principles of valuation of ecosystem services and assets are addressed in Chapters 5 and 6 of SEEA-EEA. This is not to suggest that valuation should be excluded from tests but that this should be done after and with the support of physical accounts.

In the same way, ENCA-QSP will make the efficient use of models easier, leaving analysts to implement their modelling tools. Examples of such models that are potential beneficiaries of ecosystem accounting include INVest[4], ARIES[5] or QuickScan[6]. In principle, models help to produce assessments from data, and ENCA can play the role of supplier. Indeed, modellers may have developed modules for assimilating or estimating the data they need as a result of having to work without relevant data in appropriate formats. Such data can be reused for accounting, as long as they are inputs to and not outcomes of the model, which would result in tautologies.

The ENCA-QSP proposes endogenous operational indicators of accessible resources and total ecosystem capability. The accounting database should also facilitate the production of other indicators such as: the human appropriation of net primary production (HANPP), the benchmark for which is the theoretical natural net primary production (NPP) potential in the absence of any anthropogenic pressure; the ecological footprint; water footprint; and ocean health.

3 *This distinction also exists in SNA 2008. Satellite accounts are functional analyses.*

4 *http://www.naturalcapitalproject.org/InVEST.html (accessed 21 July 2014)*
5 *http://www.ariesonline.org/ (accessed 21 July 2014)*
6 *http://quickscan.pro/ (accessed 21 July 2014)*

1.4 THE CHOICE OF THE ECOSYSTEM NATURAL CAPITAL ACCOUNTS FRAMEWORK

Several tests of ecosystem accounting are under way, with various approaches and aims, but few integrated ecosystem accounting frameworks yet exist. The ecosystem capital accounts (ECA) tested in Europe and the similar ecosystem natural capital accounts (ENCA) tested in Mauritius are of this type. The framework is extremely simplified in terms of ecosystem complexity, with the aim of fast-track implementation. Both ECA and ENCA refer to SEEA-EEA, of which they are operational developments produced for tests. From a data perspective, they rely on standard tables and classifications that expand the SEEA-CF physical flows and assets accounts from an ecosystem assessment perspective, regarding in particular the necessary geographical breakdowns.

In terms of data, the principle of ENCA is to make as much use as possible of existing available data in the country or in international databases. Duplication will be avoided, and conversion from existing data sets done systematically. For example, ENCA bridges with SEEA-Water, of which they are an extension, and IPCC land use, land-use change and forestry (LULUCF) guidelines to facilitate the reuse of data collected for UNFCCC reporting. This consistency of datasets means that the data collected for ENCA will be easy to reuse in different contexts or for different frameworks. Ecosystem natural capital accounts have been tested, and the resulting experience will be very helpful to newcomers.

Last but not least, ENCA proposes aggregates such as accessible resources, total ecosystem capability, net accumulation of ecosystem capital capability (+renewal, -degradation), ecological credits and debts. These aggregates, being defined at any scales and aggregated up to the country level, can be used for macro-economic analysis. The QSP guidelines will therefore be based on ECA/ENCA.

1.5 HOW DOES ENCA-QSP RELATE TO SEEA?

The SEEA is composed of a SEEA-CF augmented by two other parts of the SEEA, namely the SEEA Experimental Ecosystem Accounts (SEEA-EEA) and the SEEA Extensions and Applications.

The SEEA-CF general model for physical accounts can be summarized as stocks-flows-stocks, where stocks are made up of non-renewable and renewable resources, and flows increase (renewals) or decrease (withdrawals) the stocks. Physical flows are recorded according to the physical supply and use table (PSUT) framework derived from the SNA SUT template used for commodities. Asset definition is mainly that of SNA 2008, where *"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"*. In the SEEA-CF (para. 2.17), "*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. Although they are naturally occurring, many environmental assets are transformed to varying degrees by economic activities*". And "*this focus reflects the material benefits from the direct use of environmental assets as natural inputs for the economy by enterprises and households. However, this focus does not consider the non-material benefits from the indirect use of environmental assets (e.g., benefits from ecosystem services such as water purification, storage of carbon and flood mitigation)*" (para. 2.18).

In SEEA-CF, the definition of asset boundaries is the same as in SNA[7] regarding accounts in money, but enlarged in physical accounts to take stock of natural resources for which no economic owner is clearly identified, e.g. unregulated fish stocks in international waters, or which are of no economic value. In addition, land is isolated from soil in asset classification. Expenditures relate to environmental protection and resource management.

SEEA-EEA is a comprehensive conceptual framework covering physical as well as monetary accounts. From the practical point of view of implementation, important points are:

- in most cases, accounts in physical units precede valuations in money terms;
- statistical units for ecosystem accounting should be defined as spatial units; basic statistical units (BSUs) should be defined as grid-cells and ecosystem accounting units (EAUs) as functional units;

7 *"1.46 In monetary terms, the asset boundaries of the SEEA Central Framework and the SNA are the same. Thus, only those assets – including natural resources and land – that have an economic value following the valuation principles of the SNA are included in the SEEA-CF.*

"1.47 In physical terms, the asset boundary of the SEE–CF is broader and includes all natural resources and areas of land of an economic territory that may provide resources and space for use in economic activity. Thus the scope in physical terms is not limited to those assets with economic value. It is recommended that those environmental assets that have no economic value are clearly distinguished". SEEA-CF, 2012.

- ecosystem extent (quantity) and condition (quality, health, resilience) should be measured together;
- the ecosystem accounting framework should be integrated with SEEA-CF and SNA.

ENCA-QSP is an application that is necessary to operationalize SEEA-EEA, which, at this stage, is a broad conceptual framework. Since an international standard on ecosystem accounting is not expected until more empirical experience has been collated and the research agenda announced in SEEA-CF carried out, tests can only be run on the basis of interim technical guidelines, of which ENCA-QSP is one.

There are no major divergences from the broad principles of SEEA-EEA and, if there are differences, they are made explicit. In particular, some interpretation and development is needed in ENCA-QSP before an operational integrated framework can be implemented. Annex I lists the main specific points of possible divergence.

One ENCA-QSP development relates to the operational definition of ecosystem accounting units (EAUs). Rivers are not described as EAUs in SEEA-EEA, which considers only areas, not linear features. The solution adopted in ENCA-QSP refers to the solution proposed in SEEA 2003 and taken by SEEA-Water of 2007[8] for water quality accounts (Chapters 3 and 6). River system units (RSUs) are subsets of the whole river network enclosed within the limits of a river basin or sub-basin; they are composed of homogeneous river reaches as defined in SEEA-Water. Regarding terrestrial ecosystems, EAUs are systematically described at three different scales: land-cover ecosystem units (LCEUs), socio-ecological landscape units (SELUs), and river sub-basins[9]. Ecosystem units for marine coastal areas are also introduced in ENCA as marine coastal units (MCUs) for which bottom cover can be mapped similarly to inland areas.

In addition to SEEA-EEA, ENCA-QSP introduces a structure common to the three basic accounts, balancing items (Introduction, para. 0.20), and aggregation rules in order to produce an aggregate of total ecosystem capital capability. In that respect, there is more emphasis on flows and their renewal in ENCA-QSP than in SEEA-EEA, where they are presented mainly as the positive and negative elements of increases and decreases of stocks. An absence of change in stocks frequently hides important differences in the amount of services provided during the accounting period. This is the case, for example, for annual crops and for rivers whose runoff is often several orders of magnitude greater than their stock. A specific aggregate is therefore introduced in ENCA-QSP to measure the resource that is accessible or exploitable as a result of annual flows and previous accumulations, e.g. in reservoirs and managed forests.

This adaptation of some SEEA-EEA rules is necessary for the consistency of ENCA, where an holistic measurement of quantities and qualities is needed for calculating accounting aggregates.

For EEAs in Europe (developed by the European Environment Agency with Eurostat support) and now in Mauritius, the SEEA-EEA general recommendations have been interpreted as follows:

- physical accounts are for land cover, biomass/carbon, water and ecosystem functional services (depending on ecosystem integrity and biodiversity);
- statistical units are: BSU grids of 1 ha and 1 km2 (Europe) and 10 m x 10 m and 1 ha (Mauritius); EAUs are: land-cover ecosystem functional units, socio-ecological landscape units, river basins and sub-basins, river systems, and marine coastal units;
- basic resource balances are combined with diagnoses of ecosystem health;
- integration means total integration with the economy, the integration of interconnected ecosystems and the integration of ecosystem components, combining quantities and qualities. This requires the use of a common unit, playing a role equivalent to money in economic accounting and valuation. This composite unit is called the ecosystem capability unit (ECU) and measures the sustainable capacity of ecosystems to deliver their services. Increase corresponds to enhancement, and decrease to degradation.

8 *System of Environmental-Economic Accounting for Water, ST/ESA/STAT/SER. F/100, United Nations publication, 2007, http://unstats.un.org/unsd/envaccounting/seeaw/seeawaterwebversion.pdf (accessed 21 July 2014).*

9 *With possible additional subdivision according to relief and altitude or ecological regions.*

1.6 ROADMAP

The roadmap for implementing ENCA-QSP has two stages: first putting in place the institutional setting, then putting in place the data infrastructure, computing the core accounts (the QSP) and developing functional accounts and analyses. The production itself can be described in five steps, Table 1.01.

Table 1.01: Five steps for producing ecosystem natural capital accounts

Objective	Datasets/ Accounts	Tasks for the accountant
Step 1: Create the data infrastructure needed for accounting		
Collect reference geographical datasets and create the database of Ecosystem Accounting Units	Geographical features/zonings 1. Physical boundaries (coastline, river basin and sub-basin limits, climate zoning, elevation classes) 2. Administrative boundaries (municipalities, districts, regions) 3. Transport network 4. Hydrological network, rivers, aquifers 5. Sea/fisheries zoning(s) 6. Regular grid(s) for accounting (1 ha and 1 km2)	Collect from relevant organisations the basic geographical layers that will structure the physical accounts. Check their consistency (geometry, projection). Produce a set of regular grids (based on official geographical standards). Create the database of Ecosystem Accounting Units (EAUs) for terrestrial ecosystems, rivers, marine coastal units and other sea accounting units. (N.B. it requires using a land-cover map for the baseline year).
Step 2: Collect the basic datasets		
Collect the basic datasets for ecosystem natural capital accounting: monitoring data and statistics	7. Land-cover change (including marine coastal areas) 8. Meteorological data 9. Hydrological data 10. Soil data 11. Data on forest stocks and growth 12. Population data 13. Regular agriculture, forestry and fishery statistics 14. Data/statistics on water use 15. Indicators on species and systems biodiversity	Produce a consistent multi-annual (10–20 year) land-cover map/database using satellite images and other sources available (forest maps, cadastre, buildings and roads...). Collect and organize the various sets of data needed for accounting. Official data sources are given priority: official statistics, meteorological data, hydrological data...where available, accounts produced for IPCC reporting, REDD+, SEEA Water... are important inputs. Satellite data sometimes as second best.
Step 3: Produce the core accounts		
Produce the core ecosystem natural capital accounts, measure total ecosystem capability, assess degradation or enhancement	Land-cover change account 16. Ecosystem carbon account 17. Ecosystem water account 18. Ecosystem integrity and functional services accounts 19. Ecosystem overall capability account (including exchanges between ecosystems)	Compile the accounts with basic data collected at Step 2, additional data for specific items and physical data modelling. Geo-process datasets. Estimate missing data. Integrate the accounts.

Objective	Datasets/ Accounts	Tasks for the accountant
Step 4: Functional accounts in physical units		
Functional analysis of ecosystem capital and services in physical units	20. Accountability of economic sectors for ecosystem capital degradation /enhancement 21. Ecosystem degradation embedded in trade 22. Ecological Balance Sheet (in ECU) 23. Social demand for ecosystem services (by ecosystem units, municipalities, regions...)	Targeted, detailed analysis to be carried out with statistical offices, planning agencies, environment agencies, the research sector etc. Compilation of the ecological balance-sheet. Mapping and assessing ecosystem services.
Step 5: Functional accounts in monetary units		
Functional analysis of ecosystem capital and services in monetary units: measurement of unpaid degradation costs; valuation of ecosystem services	**24. Unpaid remediation costs:** 25. accountability of economic sectors for ecosystem capital degradation/enhancement 26. Ecosystem degradation embedded in trade 27. Ecological Balance Sheet in money terms 28. Adjustment of Final Demand from unpaid costs 29. **Monetary value of key ecosystem services** 30. Total (direct and indirect) value added by ecosystem services (agriculture, forestry, fishery, water, tourism etc.	Economic analysis of remediation costs (restoration works, alleviation, opportunity costs of reducing pressure on ecosystems etc..). Economic analysis of ecosystem services monetary value. Input/Output analysis of Value Added induced by ecosystem services; sustainability assessment
Steps 1 to 3 have to be done for all ecosystems and sectors. Steps 4 and 5 can focus on one particular ecosystem, service or economic sector.		

Producing successful ecosystem accounts is mainly a matter of institutional cooperation. In most countries the statistical office has an important role to play due to its experience in national accounting and its statistical databases. It may have experience of geographical information systems (GIS) but will have to access more geographical information. The ministries and/or agencies of environment and sustainable development also have a key role to play because they are both data holders and stakeholders interested in the accounts in the context of their relationships with other ministries, particularly of economy, finance and planning. In terms of data, ministries of environment usually collect data on biodiversity from administrative agencies, academics and non-governmental organization (NGO) networks. In many countries they are partners with the national statistical office for the production of environmental statistics in general. Cooperation with the mapping and or cadastral agency is also important, particularly if there is a need to improve the land-cover change database – the main exception to the rule of reusing existing data; a space agency should also be associated if one exists. The technical ministries in charge of agriculture, forestry, fisheries and water and meteorology also need to be involved. Since the purpose of ecosystem capital accounting is to produce effective and efficient aggregated indicators for sustainable development and economic growth, accountable for its impacts on the ecosystem, the main ministries should be part of the process. Because accounts may influence policies, and because increasing attention is being paid to ecological risks, businesses should also be invited to participate. Last but not least, the work should be scientifically sound and scientists should therefore also be involved. Organizing such a partnership from the start is essential to prevent the accounting project being blocked by missing data.

Putting the data infrastructure in place consists of organizing data collection and pre-processing it, in particular regarding geographical projections, harmonization of boundaries and completeness; production of the land-cover map which will play an important role in structuring the whole accounts; and definition and implementation of statistical units for accounting with land-cover and other geographical data. It is likely that the first data-gathering and integration attempts will reveal inconsistencies between some datasets and possibly gaps. These will have to be filled provisionally and partners invited to revise their own databases if needed. The need to check data quality in a strict way is one of the merits of accounts, and this part of the work can be considered as a side-benefit of the project.

The core accounts to be implemented will encompass:

- land-cover accounts, the foundation;
- the three broad resource accounts:
- biomass carbon account;
- water ecosystem account;

ecosystem functional services account, measured indirectly as a function of the integrity of landscape and river infrastructure and biodiversity.

For these three resources, quantitative balances will be derived partly from SEEA-CF or established from the various datasets made available by the accounting partners. The specific work when CF accounts exist will be first to supplement them with the items needed to calculate the accessible resource (the resource that can be used without depletion), and second to proceed to the geographical breakdowns needed to address the statistical units defined at the beginning.

Synthesis of the accounts is an important step in terms of final delivery of ENCA headline aggregates: total ecosystem capability and net accumulation (renewal minus degradation) measured in ECU. These aggregates stand at the same level as SNA's net worth and GDP and can be used to assess the accountability of the economy for the ecosystem and the ecological sustainability of development. Technically, calculation of ECU values for is one of simple arithmetic once the quantity (impacts of use) and quality (health) indexes have been computed

Functional accounts are no less important than core accounts, and can even be considered as indispensable steps to making accounts fully operational. Their implementation is driven by policy demand related to key ecosystem services, specific ecosystem problems or local issues. Therefore, while functional accounts are built on core accounts, their implementation should start as an immediate continuation of the core accounts.

The main areas covered by functional accounts are:

- functional analysis of private and collective demand for ecosystem services (in specific physical units and ECUs); the three broad services on which core accounts are based can be detailed here, following the Common International Classification of Ecosystem Services (CICES)[10] but with no obligation for exhaustiveness and aggregation; implementation should start from policy priorities;
- valuation of selected ecosystem services, based on the previous ecosystem service assessment in physical units;
- functional analysis of sectoral liability for ecosystem degradation (in ECUs); the functional accounts are in addition to Resource Use recorded following SEEA-CF;
- sustainability assessment of total value added generated directly and indirectly by agriculture, forestry, fisheries and water supply;
- establishment of the ecological balance sheet of credits and debts in ECUs by ecosystem and sectors;
- valuation of ecosystem degradation and renewal or restoration costs, and establishment of an ecological balance sheet in money terms.
- ENCA-QSP will focus on core accounts – the first three steps of Table 1.01; functional accounts will be described briefly in Chapter 9.

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10 *CICES is the provisional Common International Classification of Ecosystem Services (SEEA-EEA, op. cit. Section 3.3)*

Annex

Examples of a few points on which SEEA-EEA and ENCA-QSP differ

The ENCA-QSP is an extension of SEEA-EEA with the purpose of making it operational in terms of accounting tables, compilation guidelines and policy-relevant outputs. However, there are a few differences: from the perspective of the SEEA-EEA research agenda, these differences are points which are still open for discussion, with the expectation that experience gained in the practical tests will help making the right choices. Examples to be listed are the following:

- SEEA-EEA refers to ecosystem assets while ENCA-QSP prefers the term of ecosystem capital to insist on the need for aggregated accounts for which a common unit of measurement is proposed – an issue explicitly delayed in the SEEA-EEA. Anyway, the SEEA-EEA acknowledges that in general the terms "*may be considered as synonymous*" (SEEA-EEA Glossary p.162).
- Regarding the standard assets accounting model (and the underlying capital model), SEEA-EEA and ENCA-QSP are in full agreement about the serious limitations to its relevance in the ecosystem context. They are clearly presented in SEEA-EEA (section 4.2.4, in particular paras. 4.47–4.50). However, there is a difference on the consequences drawn. The SEEA-EEA maintains the close reference to the model "*used to account for produced assets in the SNA and as applied to the measurement of individual environmental assets in the SEEA Central Framework*" (SEEA-EEA 4.44) where assets value is calculated from an "*expected flow of benefits (in terms of capital services […].)*" (SEEA-EEA 4.45).

  In ENCA, ecosystem capital ecological value is measured in terms of its capability to deliver services (Chapter 2). Capability is not assessed on the basis of the measurement of all possible ecosystem services as could suggest the reference to the standard capital model. Instead, capability is calculated from the measurement of three broad functions (or aggregated services) and of ecosystem health (resilience, vigour, integrity…).
- Produced biomass in agriculture or in managed forests is measured differently in the SEEA-EEA and in ENCA. For the SEEA, the fact of being produced (in the SNA sense) makes this biomass non-natural and leads to its exclusion from provisioning ecosystem services in CICES and from ecosystem assets. ENCA-QSP considers instead that produced biomass is still the result of photosynthesis and should be considered as joint economy-nature production. Ecosystem assessments such as the Millennium Ecosystem Assessment (MA 2005) and TEEB, EU-MAES [11] include all food, fibre and bio-energy in provisioning services. The possibility of a divergence on this point is envisaged in SEEA-EEA para. 3.45 which reads: "*If a choice is made to use an alternative boundary for the measurement of ecosystem services related to crops and other plants …*" and recommends to take care of double-counting risks in that case.

11 *MAES: Mapping and Assessing Ecosystem Services. See Chapter 9.*

2. CHARACTERISTICS OF ECOSYSTEM NATURAL CAPITAL ACCOUNTS

2.1 AN INTEGRATED ACCOUNTING FRAMEWORK

2.1.1 Ecosystem capital degradation or improvement, (and their counterparts in terms of ecological debts or credits), are at the core of the ENCA accounting framework.

The central concept of ENCA is the measurement of the sustainable capacity of ecosystems to supply the services needed by humankind and to assess human accountability for ecosystem degradation by inappropriate or free-rider management, or for ecosystem conservation, restoration or enhancement. Degradation is the sum of depletion of the renewable resource and the loss of other potential services that may affect the owner of the ecosystem asset or the community as a whole. When degradation can be imputed to economic actors, it is a non-paid cost (an externality) that corresponds to a consumption of ecosystem capital. This ENCA approach goes one step further than SEEA-EEA that does not deal with aggregation issues.

The ENCA approach to degradation starts not from the loss of ecosystem services but from the capability of the ecosystem. Capability encompasses ecosystem productivity as well as health, in terms of robustness, organization, resilience, dependence on artificial inputs, and disease prevalence. For resources used by extraction, capability assessment requires recording the amount that is accessible in a sustainable way, not the stock itself or the total stock plus inflow. It takes into account that part of the resource is needed by the ecosystem for its own renewal and that only part is sustainably exploitable. The accessibility of resources that are not depletable is measured indirectly, in terms of the integrity and health of the systems which generate them. They are all the intangible services that depend on ecosystem function, integrity and biodiversity, the regulating and cultural services in the SEEA-EEA provisional CICES interim classification. In that way, risks of omission or double-counting are avoided.

Degradation is the decrease, for which human activities are responsible, of capabilities between two dates. This means that a distinction is made between deterioration resulting from natural disturbances and degradation from anthropogenic factors[1]. Increases in ecosystem capability are recorded as enhancement when they result from human activities[2], natural improvements being recorded separately.

Breakdown of degradation and enhancement by SNA sectors and industries is carried out in later steps, after QSP. As long as degradation results from an unpaid economic cost (an externality) that is passed to others (current or future generations), it is a debt. In a symmetric way, investment in ecosystem restoration can partly be recorded as a reduction of debt (when considering degradation that has taken place in a recent period) or as a creation of credit, which can be taken into account in mitigation mechanisms. Recording of ecological credits and debts is an adjunct to SEEA-EEA. Currently, SEEA considers ecosystems as assets for which depletion or degradation is recorded as decrease in stock (or increase in the case of a positive change). ENCA follows this treatment only for the depletion of assets that corresponds to a loss for their owner. Ecosystem degradation is more than just a loss for asset owners since it results in a loss of potential services for others and for the community[3]. It is therefore right to record it as a debt created by the unit responsible for the degradation, and a credit in the case of enhancement.

Since ecosystem degradation is a measure of physical consumption of ecosystem capital, it can be valued as

1 *This is consistent with the recording of forest fires in IPCC guidelines for LULUCF as well as the SEEA-EEA definition that states that ecosystem degradation "is the decline in an ecosystem asset over an accounting period due to economic and other human activity. It is generally reflected in declines in ecosystem condition and/or declines in expected ecosystem service flows".*

2 *Chapter 9 gives additional indication of how enhancement is recorded in the ecological balance sheet, either as a reduction of debt (in the case of restoration from previously recorded degradation) or as a new credit (in the case of a creation of capability by an acknowledged programme.*

3 *This treatment echoes the analysis by Graciela Chichilnisky of ecosystems as "privately produced public goods" in her article on North-South trade and the global environment (The American Economic Review, 1994).*

the cost that ecosystem owners should pay to restore it (Chapter 9). In this case, restoration costs that should be paid are estimates, in monetary terms, of consumption of ecosystem capital. As consumption of fixed capital recorded in the SNA (CFC), CEC itself is an estimate, not a direct measurement. The separate recording of CEC in physical units and in money means that if an economic actor – or a country – undertakes ecosystem restoration and pays for it, it will not extinguish the physical debt in a mechanical way. In some cases, despite restoration expenditure, some physical degradation remains and some ecological debt is maintained. In other cases, restoration costs may have been overestimated and the debt will be extinguished before the end of the restoration programme. In any case, the benchmark is physical degradation. This dual measurement is similar to the Kyoto Protocol approach where commitments to reduce emissions of CO_2-equivalents are expressed in physical units, not as an amount to pay – although payments do exist in the Clean Development Mechanism (CDM).

2.1.2 Account integration follows general accounting principles

Accounts are not a mere collection of tables with numbers. They were invented to keep track of and summarize the multitude of transactions in daily economic activity, to control recording as well as final results, and to produce reliable assessments of the overall performance and situation of economic agents. The most important principles that underpin accounting systems are double-entry accounting (control), definition of clear balancing items (performance and wealth assessment), and completeness of recording of the reliability of the accounts. This is an important property of national as well as of corporate financial accounts, as stated in the International Financial Reporting Standards of the International Accounting Standards Board[4].

Double-entry accounting is a basic book-keeping technique which allows control of the exactness of the accounts and measurement of performance in terms of profit or loss, and wealth; it has a fundamental role: internally, and for an entity (company, government, country) to communicate with its stakeholders, business partners, fiscal authorities, control bodies, citizens, etc. It requires transactions to be recorded for the same amount in the accounts of the two transactors (or sectors in the case of national accounts) as well as in the corresponding internal accounts (for example between book sales and book clients). All transfers between systems, or between sub-systems within a system, follow this principle in ecosystem accounting.

Balancing items are the differences between the two sides of an accounting table (supply and use, input and output, credit and debit, assets and liabilities, etc.)[5]. They have a clear meaning and the structure of any account is designed to calculate balancing items which reveal the performance of the entity for which accounts are established: profit or loss, revenue, income (the revenue net of all costs incurred), net worth, etc. In national accounts, most aggregates are balancing items: GDP, National Income, Operating Surplus, Disposable Income, Net Savings, Net Worth, etc. In ENCA, balancing items are Net Accessible Resource, Total Ecosystem Capability, Ecosystem Net Degradation (net of Enhancement), and Net Ecological Debts (net of Credits).

Completeness: in addition to recording actual and verifiable transactions, accounts may need to make estimates of what cannot be directly observed. The main example is capital depreciation[6] that is consumption that takes place over several accounting periods, which has to be split and distributed over them appropriately. Rules for estimating depreciation (or consumption of fixed capital in SNA) are strictly defined and their application controlled since it finally affects the amount of benefits[7] to be taxed and/or distributed to shareholders.

Despite the importance of the completeness and reliability of accounts, in the case of natural resources the principle is only applied in a very limited way in accounting standards. Corporate financial accounts record depletion of subsoil assets and only of timber and fish stocks as a depreciation items; ecosystem degradation is not considered in that way. The SNA records depreciation of natural assets as a bottom-of-table adjustment to their volume in the asset account (Annex I).

2.1.3 Integration of core accounts and functional analysis

Ecosystem natural capital accounts make a clear distinction between core accounts and functional analyses or functional accounts. Such a distinction is also made in SNA where core integrated accounts are supplemented by accounts targeted on specific purposes.

4 *"To be reliable, the information in financial statements must be complete within the bounds of materiality and cost. An omission can cause information to be false or misleading and thus unreliable and deficient in terms of its relevance" IASB (2007), International Financial Reporting Standards (IFRSs) 2007: Including International Accounting Standards (IASs) and Interpretations as at 1 January 2007, International Accounting Standards Board 2007, ISBN 1905590261, 9781905590261*

5 *See SNA 2008, 1.14 http://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf (accessed 21 July 2014)*

6 *Another estimated variable is the "fair value" of companies calculated from their expected future benefits when the actual market of such assets is too narrow to reveal the "right" price.*

7 *or of accounting losses exempting the company from payment of taxes and distribution of benefits.*

"*Functional analysis: In order to analyse the purpose of transactions, it is necessary to apply a functional classification to the basic transaction. For example, instead of disaggregating household consumption by type of product, it may be disaggregated to show how much is spent on food, housing, health, recreation and so on.*

For government consumption a distinction may be made between consumption related to law and order, defence, health or education, for instance. As compatible but different classifications are used according to the sector concerned, these partial analyses by purpose cannot be integrated in a single table and, in most cases, no exhaustive total for the total economy can be calculated in the central framework." (SNA2008, para 2.154).

The SNA satellite accounts are functional analyses.

Functional accounts of ecosystem services: in ENCA, the multiplicity of services that can be produced by a single ecosystem is recognized, and integration and aggregation rules defined accordingly. Core accounts should be exhaustive and follow the general principles of double-entry accounting. This is possible only by considering ecosystem capacity to deliver broad categories of services. In principle, biomass and water accounts can be subdivided into elements that are additive, but this is not the case for functional services which overlap between themselves as well as with biomass and water. The ENCA solution for the core account is to focus on change and consider the potential of ecosystems to deliver services, not the services themselves. Ecosystem services are further analysed in functional accounts where supply and social demand are recorded. Because they relate to the core accounts, ecosystem service accounts take stock of the capability (health, condition, etc.) of the ecosystems that generate them. The most important ecosystem services can be addressed as a priority in the context of the overall ecosystem account. This ENCA presentation acknowledges that ecosystem services are multiple, of variable importance and not fully additive because of measurement issues and overlaps. Functional accounts have the advantage of flexibility and relieve ecosystem services accounting from formal constraints that cannot be met. Valuation of ecosystem services starting from physical ecosystem service accounts is presented in functional accounts.

2.1.4 Account integration within the ecosystem

Integration of basic balances: in SEEA-ENCA, quantitative balances of stocks and flows measure the possible impact of resource extraction on ecosystem reproductive capacity. It corresponds to what is calculated as sustainable yields in forestry and fisheries and to physical depletion measurement. This is carried out following SEEA-CF recommendations. There is a difference however: while SEEA-CF is primarily built up by institutional units (as with SNA) and addresses natural assets as stocks and flows of generic resource categories (water, timber/forest, fish stocks), SEEA-EEA is based on different statistical units – the ecosystems described as spatial entities. Natural assets in the sense of either SNA or SEEA-CF can be attributed to these spatial entities.

Accounts are established for each ecosystem unit, resource by resource, which allows the capture of local problems or hotspots that may or may not be compensated within the ecosystem (for example, is carbon sequestration which leads to loss of biodiversity acceptable) or by the good performance of other ecosystems (for example, can losses in one place be compensated by improvements elsewhere). Even though the overall quantitative balance of each single resource is positive at the country level, local imbalances may reveal structural dysfunction.

Integration of quantities and qualities: the quantitative balances do not capture all the elements necessary to assess ecosystem health; others need to be integrated which are more difficult to quantify, record and analyse directly in accounting tables. They are often called qualitative in contrast with the quantitative variables. In ecosystem accounts, such variables are used to make a diagnosis that is integrated into the framework as adjustments to stocks of basic resources, to reflect qualitative degradation. The aggregate, which measures the sustainable capacity of the ecosystem to deliver services, will reflect quantities as well as qualities.

2.1.5 Integration with the national accounts

SEEA ecosystem accounts are first integrated into SNA via the SEEA-CF, as explained previously.

In ENCA, ecosystem accounts are also integrated into SNA via the calculation of sectoral accountability for ecosystem degradation. This is measured first in physical units, and can be valued on the basis of restoration costs. In this case it has the same meaning as consumption of ecosystem capital (CEC) which should be added to the SNA consumption of fixed capital (CFC). Consumption of ecosystem capital is not just consumption of ecosystem resources but also the loss of potential for future services that results from ecosystem degradation. As long as the exploitation of ecosystem resources is sustainable, there is no CEC: natural processes renew the ecosystem capital. Consumption of fixed capital is seen either as degradation or obsolescence of capital items, or in terms of loss of future capital services. The measurement of CEC from the loss of future ecosystem services valued in monetary terms is not impossible according to standard economic theory, as long as all ecosystem services are properly valued and discounted. In practice, this approach faces many difficulties related to valuation of services and assets and aggregation[8].

In ENCA, the solution proposed is to measure CEC first in physical units (as a loss of ecosystem capability to deliver services) and then to assess the restoration costs on the basis of observed practices in forestry, agronomy, water management, nature conservation, etc. Consumption of fixed capital and CEC are both estimates (not mere statistics) and have, *a-priori*, similar statistical quality. They are, however, different as long as CFC is budgeted in the national accounts as an additional consumption identical to depreciation recordings by economic agents while CEC is just an unpaid externality. Consumption of fixed capital is part of the revenue or gross income of economic agents or nations. Because CEC is not covered by any payment or depreciation allowance, it needs to be balanced outside the income accounts by recording a financial item – a debt.

When CEC in money can be computed, there are two options for recording this unpaid cost: subtraction from net production and/or income, or addition to final demand currently measured at the purchaser's prices, in order to calculate it at full cost[9]. These options are discussed in Annex I.

A different way of integrating ecosystem and economic accounts uses what are called hybrid accounts or combined physical and monetary presentations in SEEA-CF[10]. The interest of this approach is that input-output tables (I-OT) in monetary terms can be merged with the same items in physical units for key natural resources and for pollutant emissions and waste generation in order to show how much is used (or generated) directly or indirectly. Since macro-economic models frequently use I-OT, environmental variables can also be integrated into outlooks, scenarios and plans. Considering ecosystem capital accounts, the connection established with SEEA-CF is relevant for biomass/carbon, water and greenhouse gas (GHG) emissions.

Another possible hybrid account, also based on input-output (I-O) analysis, considers the sustainability of the regular market activities that depend on ecosystem services. Input-output analysis allows identification of GVA that is induced directly and indirectly by ecosystem services. Since spatial analysis indicates the places from where total induced value added (VA) originates and whether or not there is ecosystem degradation there, an indicator of ecological sustainability of marketed commodities and related activities can be developed from ENCA. In the case of food products, total induced VA encompasses agriculture and the chain from field to fork: transport, agro-food industry, wholesale and retail distribution and restaurants.

2.1.6 Integration and aggregation

Economic accounts, private, public or national, deliver aggregates in monetary terms. Beyond the technical aspect of having one common accounting unit[11] (or numeraire[12]), it is important to note that money expresses the value of any good, service or asset, whatever the measuring unit used for assessing its physical quantity. The price given by transactors on the market for a unit quantity reflects a bundle of qualities which may differ for both sides: scarcity, cost of production, usefulness, utility, emotional value, etc. This general equivalence allows the collection of statistics, aggregation of individual components and computation of macro-economic headline indicators.

This universal aggregation would not be possible with physical variables for which equivalences are not provided by an external authority in the way that the market does for money and (market) values. Important physical aggregates do exist, for example for population, employment and energy, but they are all built on specific equivalence functions. Aggregation is ultimately of values that express quantities and their equivalence. It is therefore clear that a common accounting unit is necessary both for integrating ecosystem accounts and for delivering headline indicators. Ecosystem natural capital accounts therefore propose to calculate ecological value of ecosystem capital on the basis of both quantity and quality.

Ecological value is a broadly used concept (see the example of LEFT in Box 2.01 and the Econd methodology, 2.34 and Annex II), although not normalized. The ENCA-QSP considers the ecological value of the ecosystem capital, not of ecosystems in general. It is close to the definition given in the TEEB Glossary of terms, where ecological value is distinguished from economic valuation:

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8 SEEA EEA Chapters 5 and 6 review valuation possibilities and limitations.

9 If CEC embodied in imports is also recorded and added to the domestic CEC, calculating the full or complete cost of final demand would echo the concerns of consumer movements aiming at organising fair-trade distribution where low prices of imported products are not the mere consequence of excessively low remuneration of producers, social conditions below international standards, children's labour or non-respect of the environment.

10 SEEA CF, Section 6.3, Combining physical and monetary data

11 The researchers of the Wenworth Group of Concerned Scientists (WGCS) in Australia call their "Econd" unit a common "currency" (2.34 and Annex II).

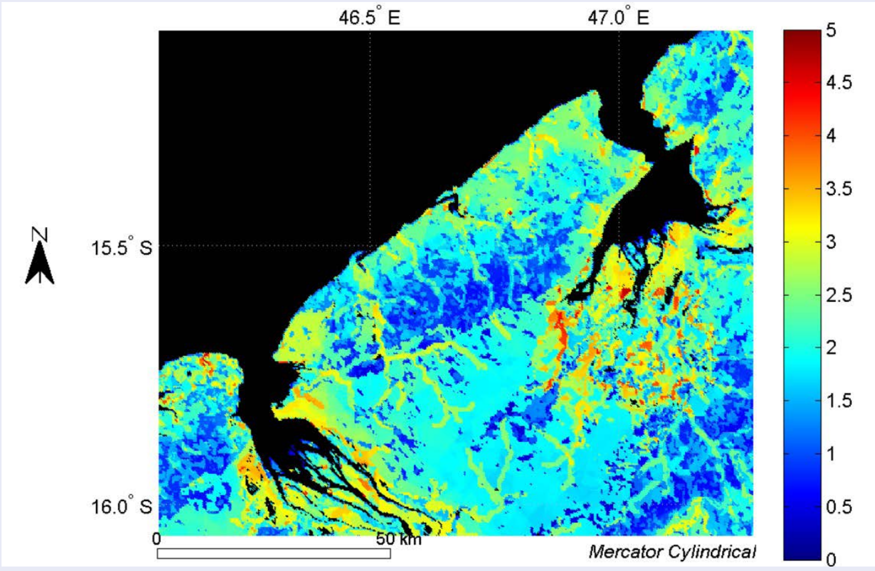
12 "The numeraire is the money unit of measure within an abstract macroeconomic model in which there is no actual money or currency. A standard use is to define one unit of some kind of goods output as the money unit of measure for wages." Source: About.com Economics, http://economics.about.com/cs/economicsglossary/g/numeraire.htm (accessed 29 July 2014)

- Ecological value: non-monetary assessment of ecosystem integrity, health, or resilience, all of which are important indicators to determine critical thresholds and minimum requirements for ecosystem service provision;
- Economic valuation: the process of expressing a value for a particular good or service in a certain context (e.g. of decision-making) in monetary terms.

Box 2.01 Calculation of ecological values with the LEFT tool

LEFT is the Local Ecological Footprinting Tool developed by the Oxford University Biodiversity Institute. Its purpose is "assessing ecological value of landscapes beyond protected areas" to give an early warning to land planners regarding areas of high ecological value areas.

"The method uses existing globally available web-based databases and models to provide an ecological score based on five key ecological features (biodiversity, fragmentation, threat, connectivity, and resilience) for every 300 m pixel within any given region in the world" http://www.biodiversity.ox.ac.uk/researchthemes/biodiversity-technologies/assessing-ecological-value-of-landscapes-beyond-protected-areas-left/.



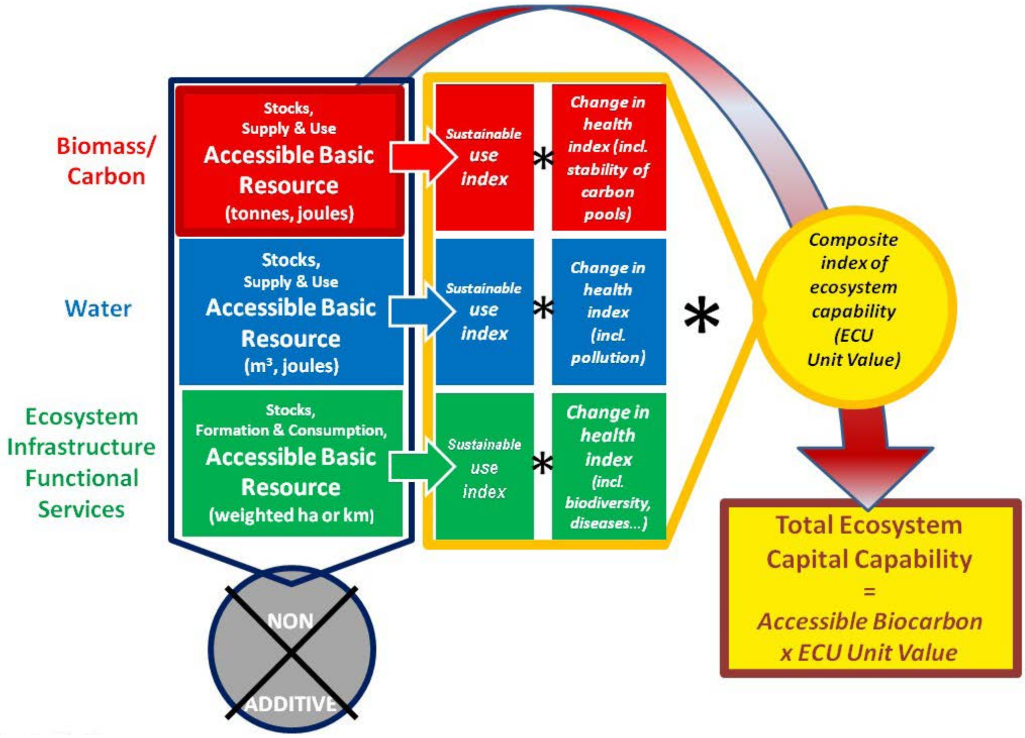
This map presents the summary ecological value of a LEFT study site in Mahamavo, Madagascar (2012). Red areas indicate high relative ecological value; blue areas indicate a lower relative ecological value.

Source: http://www.biodiversity.ox.ac.uk/wp-content/uploads/2012/09/Mahamavo_GBIF.pdf (accessed 18 August 2014)

The unit used to measure ecological value in ENCA, the ECU, allows quantification of ecosystem degradation or enhancement. In that way, a shift is made possible in decision making from specific adjustments on the basis of stand-alone indicators to a macro approach for balancing the macro-economic indicators[13]. The calculation of ECU values is summarized in Figure 2.01

13 SEEA-EEA describes, in general terms, the idea that different indexes of ecosystem characteristics may be combined through the use of a common currency or composite index, but provides no specific advice in this area. One reason for this is a lack of consensus about how to aggregate ecosystem variables. The proposed ecosystem capital capability aggregate and the use of ECU metrics for its measurement should therefore not be considered at this stage as within the scope of SEEA-EEA but as an extension of it. In ENCA, this extension is needed for calculating total ecosystem capital capability and its degradation or enhancement.

Figure 2.01: Calculation of ecological value of ecosystem capital in ECU



In the form in which they are given, the basic accounts in tonnes or joules (biomass/carbon), cubic meters (water) or weighted hectares (land and biodiversity) cannot be added up. Instead, indices that are dimensionless can be combined to produce a composite index of ecological unit value (equivalent to an ecological price) expressed in a currency unit equivalent, the ECU. The procedure is the following: each of the three quantitative accounts of accessible resource is summarized by a basic index of sustainable use. This basic index is the ratio of accessible resource to use; it should be ≥ 1; if not there is resource depletion. In addition, each of the three basic quantitative indices is adjusted with qualitative indices that reflect changes in health (stability of carbon pools, water pollution, species biodiversity, etc). For a given ecosystem, the physical quantity (in tonnes, m^3, joules or hectares) of a basic accessible resource multiplied by its ECU price-equivalent is its total capability, its ecological value. This value will reflect any change in quantity (sustainability of use) or quality (health) of its components.

For example, a reforestation programme that puts stress on water resources and is accompanied by a loss of species biodiversity, at least in the first years, will be measured as an increase in biomass/carbon but possibly as decrease in ECU value. To bridge the gaps revealed by performance measured in ECU, a form of management is needed which takes into account the three basic ecosystem dimensions together, rather than focusing on one resource only.

Ecosystem capability unit values (price-equivalents) can be multiplied by any of the physical quantities of a basic accessible resource to calculate values of capability-biomass/carbon, capability-water or capability-biodiversity functional services but the three values obtained can still not be added together; one of them has to be chosen, depending on the purpose of the accounts. Considering the overall trade-off between the economy and ecosystems, the proposal for ENCA is to give prominence to ecosystem carbon for calculation of total ecosystem capital capability. By doing this, the ecosystem aggregate connects more directly to a range of major issues such as food security, energy demand (particularly for biofuels), resource-use efficiency and global warming.

Compared to shadow prices in monetary terms, ECU unit values (price-equivalents) have similarities as long as they allow comparison and aggregation of the values of heterogeneous objects. However, ECU unit values do not meet the general condition of complete substitutability of commodities and assets that underlies monetary shadow prices. In policy terms, the perspective of monetary valuation of ecosystem services and assets is weak sustainability where the objective is the maintenance of total income and wealth. The ECU is designed to measure distances to targets for ecological sustainability, which implies that there is a restricted substitutability between ecosystems and other forms of capital. The perspective of ecological valuation in ECU is strong sustainability. The ECU aims to measure the ecological value of ecosystems while shadow prices in money terms aim at generalizing (beyond actual markets) their economic value.

An ECU is a construct; it is conventional and has to be acceptable to many players, policy makers, businesses, and citizens as a useful representation that can be taken into account in order to assess their accountability for ecosystems that they are using as public goods. The format therefore has to be clear in its formulation, verifiable in terms of measurement, and fair in terms of its implications. The ECU concept and format are discussed further on in Annex III.

An ECU calculation is rather easy once the building blocks are in place. Various formulas can be tested to assess the sensitivity of the index. This is important since an aggregate item, such as total ecosystem capital capability, must measure degradation and enhancement in a way that allows it to be used in national or corporate accounting frameworks.

The need for a currency for measuring ecosystem condition is also advocated by the Wentworth Group of Concerned Scientists in Australia: *"presenting complex information using different indicators for a range of different assets is confusing even to experts. Just imagine how impossible it is to non-experts who rely on this information to make judgements with all this complexity. The simple truth is they can't, and so are forced to resort to opinion, and as a result we have conflict when we should have agreement. The creation of a common environmental currency provides the opportunity to simplify complexity without reducing the scientific standards that create this information. In doing so environmental condition accounts can fundamentally change our understanding of development and environment."* (Cosier, 2013). The currency is called Econd and measures, on a scale from 0 to 100, the distance between the present condition of ecosystems of any type and a benchmark, at any scale. The benchmark is set with reference to the condition of Australia at the time of its discovery by Europeans.

In Econd, condition is measured following the ecosystem health theory developed by David J. Rapport [14], to which ENCA also refers. Rapport characterizes an ecosystem distress syndrome which can be identified by a diagnosis based on a limited list of symptom types based on the idea of organization (integrity, functioning), vitality (robustness, productivity) and resilience. Disease prevalence (capacity to host healthy populations) and dependence on artificial inputs are included in the diagnosis. Chapter 7 discusses the ecosystem health metaphor in terms of analogies and differences with the health of organisms, in the same way as population health is used in social science.

Both ECU and Econd address the same problem in environmental accounting: aggregation. They integrate environmental accounting and assessment of ecosystem health measured with reference to a benchmark. There is a difference, however, in the choice of the reference benchmark needed for calibrating the measurement. Econd is measured with reference to an historical situation corresponding to natural potential degraded by human activities[15]. An ECU is benchmarked using social targets. Degradation of ecosystem capital in ECUs is primarily on an annual basis, as is consumption of fixed capital. The second benchmark refers to policy targets for environmental state, as set out in regulations, laws and conventions. Such policy targets are generally defined by government agencies in charge of the environment on the basis of scientific assessments and a social debate involving NGOs; they are ratified by parliaments. Historic benchmarks may be adopted as targets but, more often, targets are set by taking the irreversibility of change and possibilities for restoration into account. Because natural potentials have different meanings in different parts of the world, an ECU is *a-priori* preferred to Econd for ENCA-QSP accounting.

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14 Rapport, D.J. and Singh, A. 2006. An Ecohealth-based framework for state environment reporting, Ecological Indicators 6. pp. 408–429, Elsevier, the Netherlands, and

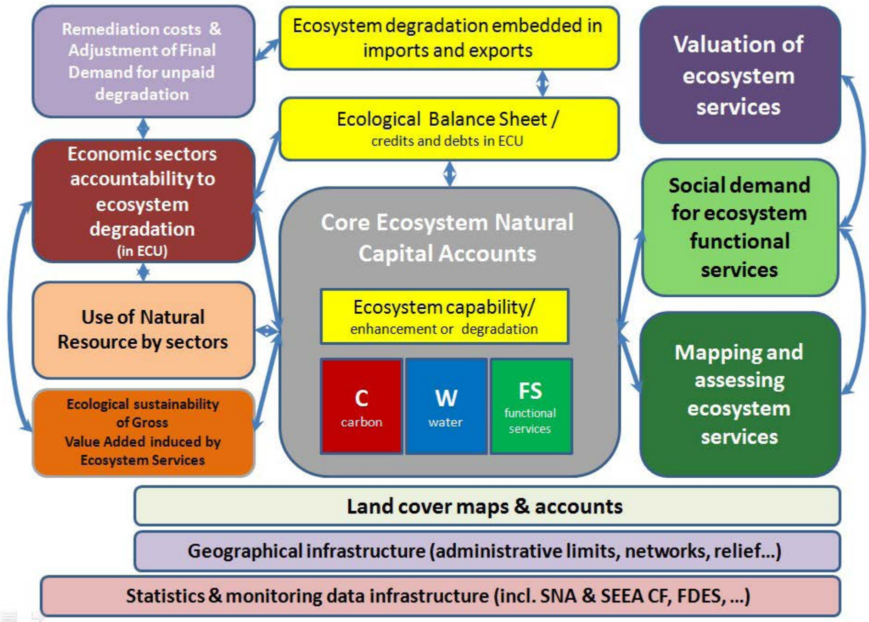
David J. Rapport and Walter G. Whitford, 1999, How Ecosystems Respond to Stress, BioScience, Vol. 49, No. 3, pp. 193–203, American Institute of Biological Sciences, http://www.jstor.org/stable/1313509 (accessed 21 July 2014)

15 This approach is similar to the potential net primary production (NPP) used as a benchmark for measuring the human appropriation of NPP (HANPP) indicator. It refers implicitly to the concept of climax used in ecology, "the final stage of biotic succession attainable by a plant community in an area under the environmental conditions present at a particular time" (Encyclopaedia Britannica).

2.1.7 Structure of ecosystem natural capital accounts

The structure of ENCA (Figure 2.02) is a data infrastructure and four groups of tables. The data infrastructure is made up of geographical reference layers (administrative limits, networks, relief, etc.), monitoring data and statistics (including SNA and SEEA-CF, FDES, sector statistics, etc.). The second group is the core accounts; this supports the ecological balance sheet which records credits and debts of domestic and foreign origin. On the left side is the third group that relates more closely to SNA, in particular tables of resource use and ecosystem degradation by sectors. On the right, the fourth group of tables covers the full range of ecosystem service accounts: supply by ecosystems, social demand and valuation.

Figure 2.02: Structure of ecosystem natural capital accounts



2.2 A SIMPLE, ROBUST INFRASTRUCTURE

2.2.1 Definition of statistical units for accounting

Theoretical and observation units

Since the statistical units on which SNA are based (enterprises, households, government bodies, etc.) do not record ecosystem degradation[16], there is a need to define appropriate units for that purpose, based on the characteristics of the ecosystems themselves.

At this stage, it is important to distinguish between theoretical units, which sustain the analytical framework, and observational units, which are proxies that may be used for practical reasons to collect data.

Theoretical statistical units for ecosystems are characteristic systems in which natural and socio-economic elements interact to transform ecosystem functions into goods and services. In the literature, they are called socio-ecological systems, socio ecosystems, geo-systems, eco-complexes or socio-ecological production landscapes (the Japanese *satoyama* and *satoumi*). They are functional units producing bundles of elementary ecosystem services and can be approached at different scales.

16 *They record resource depletion only in the best cases (timber or fish stocks), since it affects their own wealth, but not the degradation of ecosystem functions, which is a loss for others or the community – an externality.*

Figure 2.03: Examples of socio-ecological systems: *satoyama* and *satoumi*

1. Satoyama (left) is a mosaic of both terrestrial and aquatic ecosystems comprised of woodlands, plantations, grasslands, farmlands, pasture, irrigation ponds and canals with an emphasis on the terrestrial ecosystems.
2. Satoumi (right) is a mosaic of both terrestrial and aquatic ecosystems comprised of seashore, rocky shore, tidal flats, coral reefs, and seaweed/grass beds with an emphasis on the aquatic ecosystems.
3. Satoyama and satoumi landscapes are managed with a mix of traditional knowledge and modern science (reflective of the socioecological contexts).
4. Biodiversity is a key element for the resiliency and functioning of satoyama and satoumi landscapes*

* *Satoyama-Satoumi Ecosystems and Human Well-being: Socio-ecological Production Landscapes of Japan – Summary for Decision Makers. United Nations University, Tokyo, Japan, 2010* http://archive.ias.unu.edu/resource_centre/SDM-EN_24Feb2011.pdf *(accessed 29 July 2014)*

The idea of socio-ecological systems (SESs) relates to the realization that it is impossible to understand nature without society, and society without nature. SESs are complex adaptive systems. Many broadly equivalent definitions exist, for example: *"A social-ecological system consists of a bio-geo-physical unit and its associated social actors and institutions. Social-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context."* (Glaser *et al.* 2008). SES is a powerful concept which generates important research in the context of resilience and adaptation, for example with respect to climate change.

To be considered in accounting, however, theoretical SESs needs translation into statistical categories which can be identified in practical terms. The solution is to use mapable spatial units as observation units: geo-systems, land-cover units, functional administrative units, ownership units, etc.

The SEEA-EEA, 2.49 defines "*The statistical units of ecosystem accounting are spatial areas about which information is collected and statistics are compiled.*" A distinction is made between "*basic spatial units (BSU), land cover/ecosystem functional units (LCEU) and ecosystem accounting units (EAU)*" (para. 2.50). For implementation purposes, ENCA interprets and further defines these types of units.

Assimilation grids (BSUs): a range of data is available as images where grid or raster files record a geographical reference and a value for each cell, for example a radiometric value in the case of remote sensing. These grids range in scale from a few centimetres (ortho-photography and very high resolution), to a few metres (high-resolution satellite images), to hundreds of metres (medium resolution), to one kilometre (low resolution) or a few kilometres (some meteo data). Basic spatial units can be such raster or grid cells, but can also encapsulate statistics aggregated or downscaled accordingly. When needed, vector-based layers can easily be converted to grids[17]. In ENCA, the accounting grids are defined in

17 *The European CORINE Land Cover (CLC) map is produced by photo-interpretation of satellite images and its typical products are polygons that shape land-cover units or land-cover change. The CLC database is disseminated in its vector format and in two grid (or raster) formats. The first is produced by rasterization of the vector files with pixels of 100 m x 100 m that are close to the original geographical resolution of the map. Another layer is a raster at 250 m x 250 m which can be used when less accuracy is needed, with the advantage of faster computations. Finally, CLC data are generalized in a 1 km x 1 km grid using the CORILIS methodology where each individual layer is smoothed to have values in the neighbourhood and reduce artefacts resulting from the gridding process. The 100 m, 250 m and 1 km grids conform strictly to the standard defined in the INSPIRE European regulation. Since other European as well as national institutions use the same standards, gridded data can be exchanged in a very safe way and previous tasks of re-projection eliminated.*

the range of 10 m to 100 m (or 1 ha grid) for land cover, to 100 m to 1 km (the 1 km^2 grid) for data assimilation.

Analytical units (EAUs) used in ENCA are spatial objects defined at different levels: rather homogeneous ecosystem provisioning service units (e.g. land-cover ecosystem units (LCEU), socio-ecological systems (e.g. socio-ecological landscape units (SELU), and basic topographic areas (e.g. river sub-basins) where broad interactions can be captured.

Land-cover/ecosystem functional units (LCEUs) are bio-physical geographical objects, which can be mapped, as recommended in SEEA 2.50. In ENCA, they include spatial areas as well as linear features such as rivers and ecotones.

Ecotones: although seldom used so far in accounting and not developed in the ENCA-QSP, another category of bio-physical geographical objects to be considered is ecotones, the borders between land-cover units. Coastlines, river banks, and borders between forests and fields are ecotones. Since many species need more than one type of land cover, ecotones are rich in biodiversity[18]. Their accounting is an important enhancement when accounting for ecosystem spatial biodiversity which cannot be reduced to a statistic of surfaces.

Land cover vs. land use: since land cover is an image of ecosystems and land use together, there is no strict distinction in terms of statistical units. The distinction between land cover and land use is more about content and the way of collecting data. With possibly multiple uses of any given plot of land, mapping them in a strict way is generally not possible and the land-cover map is often used as a proxy for the main use. Land cover, except when mapped at the highest spatial resolution, describes areas that are more or less heterogeneous or mixed. Land-use statistics, collected through administrative surveys or area sampling, therefore provide useful attributes to land cover, used for accounting.

Sea-bottom cover: by extension of land cover (in the narrow sense), coastal areas for which sea-bottom cover can be mapped include LCEUs that reflect sea algae and grass beds, coral reefs, etc.

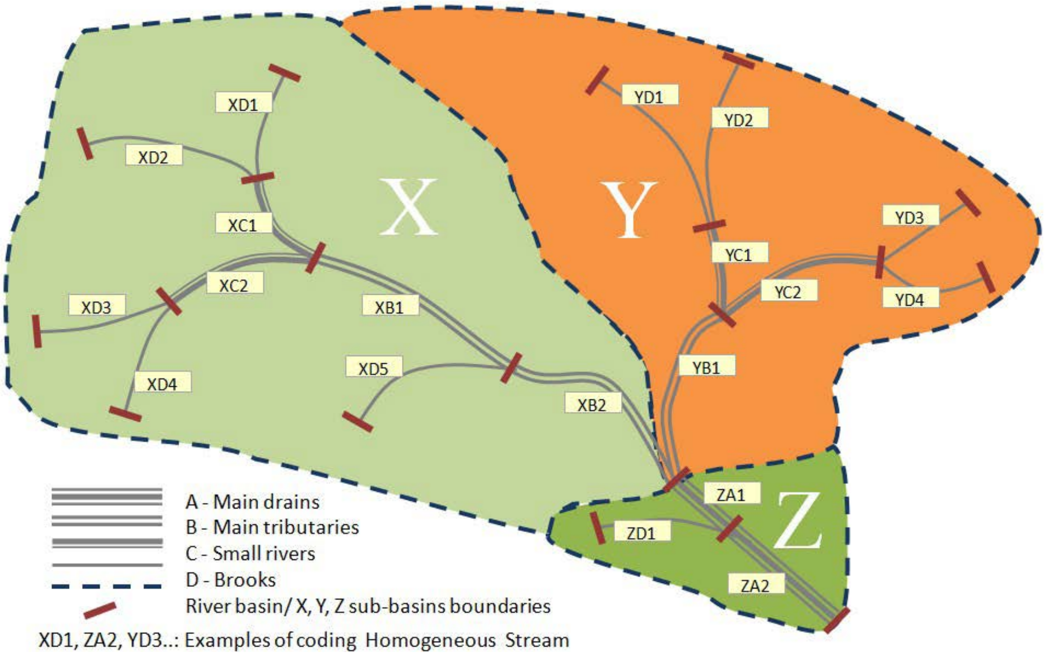
Rivers are another type of spatial unit subdivided into homogenous reaches, in the way proposed in SEEA-Water Chapter VII on water quality accounts[19]. Homogenous stream reaches (HSRU) are segments between two confluences. They are measured in kilometres and in a standardized river measurement unit (SRMU) initially called standardized river kilometres (SRKms)[20], defined as 1 km x 1m^3 x 1 second-1. It allows aggregation of rivers from the very small to the very large, the value of the former being set by their length, of the latter by their discharge. They are used in SEEA-Water to weight water quality indexes established from monitoring point stations and for ecosystem capital accounting. Homogenous stream reaches are classified according to their rank in the Strahler graph, and to their size. SEEA-Water proposes four classes of river reaches: main rivers (main drains), main tributaries, small rivers and brooks. Homogeneous stream reach units (HSRU) belong to river system units (RSUs) that are subsets of the whole river network, enclosed within the limits of a river basin or sub-basin (Figure 2.04).

18 *"In landscape ecology, an ecotone is the border area where two patches meet that have different ecological composition. The ecotone contains elements of both bordering communities as well as organisms which are characteristic and restricted to the ecotone." Source: R. Graves in Earth Encyclopedia, http://www.eoearth.org/view/article/152345/ (accessed 14 July 2014).*

19 *SEEA Water, Chapter VII, Water Quality Accounts http://unstats.un.org/unsd/envaccounting/seeaw/seeawaterwebversion.pdf (accessed 14 July 2014).*

20 *Also called standard river units (SRU) in the SEEA-Water. To avoid risks of confusion of SRU with RSU, ENCA uses SRMU instead of SRU.*

Figure 2.04: River basins, rivers and homogeneous stream reaches



Land-cover ecosystem units (LCEUs) are rather homogeneous and well-correlated with provisioning services. But they are not sufficient alone to describe ecosystem functions and the services which depend on more than one LCEU, like most regulating and socio-cultural ecosystem services, hence the need for units of a higher level of complexity: RSUs (described above in the presentation of river units), SELUs and MRUs.

In practical terms, socio-ecological landscape units (SELUs) and marine ecosystem coastal units (MCUs) are defined by a combination of geo-physical and land-cover/land-use features. Compared to ecosystem classifications, they are at a highly aggregated level, a simplification needed for statistical purposes. The choice of geographical zones for integrating ecosystem accounts depends mainly on the geographical context. It is not possible at this stage to propose a single standard, but common principles can be stated.

Regarding inland ecosystems, SELUs are based on relief and dominant land cover. Relief is used to map river basin and sub-basin limits and altitude classes correlated with climate. River basins and sub-basins define the boundaries of RSUs, which are recorded separately from landscape SELUs. As SELUs can be decomposed by LCEU, RSUs are decomposed into homogeneous stream reach units (HSRU) (Figure 2.04).

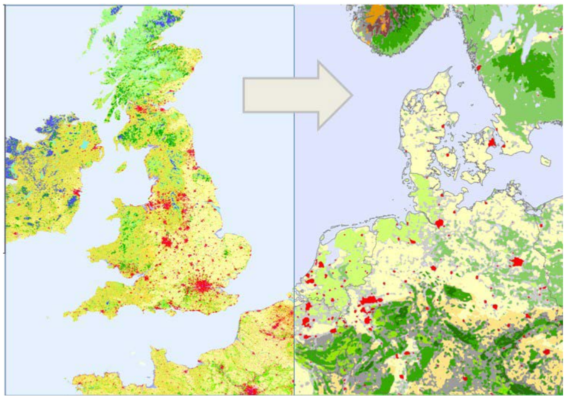
River basins can be subdivided according to relief in order to distinguish, for example, inland coastal zones, lowlands, uplands and mountains. In geographical contexts where groundwater is the main resource, basins can also be subdivided according to aquifers limits.

The bio-physical component of SELUs is computed from the LCEU map which is generalized to produce dominant land-cover types. The methodology is presented in Chapter 3.

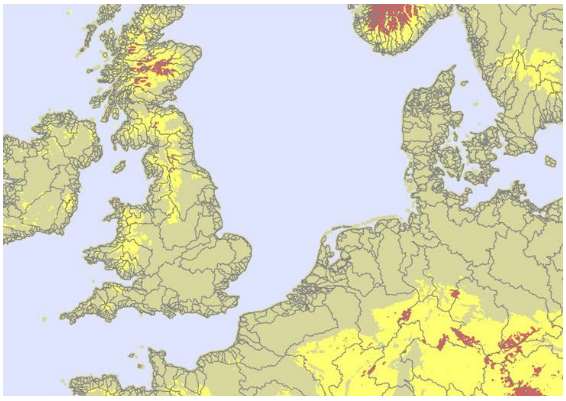
The SELU methodology has been implemented in two different contexts, in Europe and in Mauritius, with variants regarding geographical scales and selection of dimensions. In both cases, dominant land cover types have been computed and intersected with river basin limits. Figures 2.05 and 2.06 illustrate the approach followed.

Figure 2.05 The production of SELU for ECA Europe (EEA)

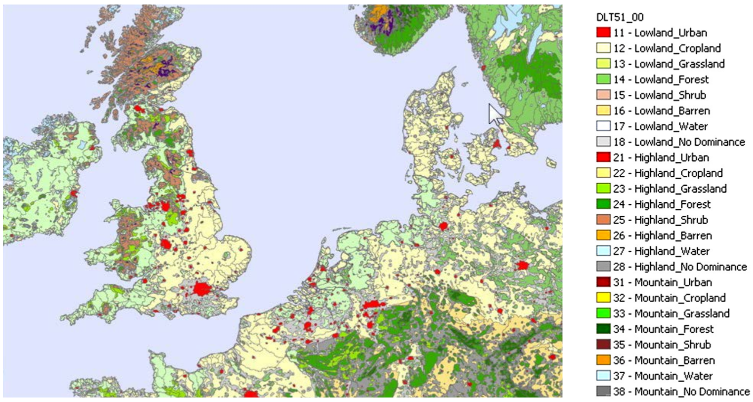
From land-cover units to ecosystem landscape units



River basin/sub-basin limits and three altitude classes

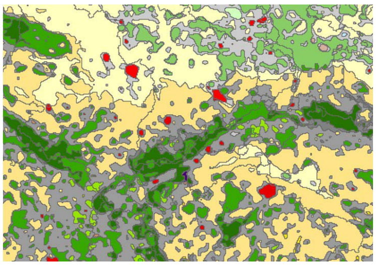


SELU map

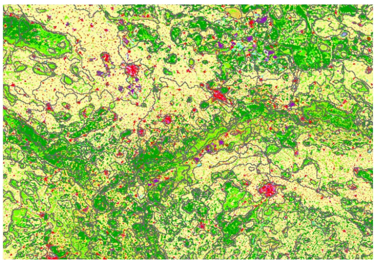


In ECA EU accounts, SELU definition combines dominant landscape types (criteria > 50% of cells of the 1 km2 grid), three altitude classes (lowland, highland and mountain), and sub-basin limits. Inland coastal SELUs can easily be extracted for defining the inland coastal zone. Marine coastal ecosystem units have not yet been mapped.

SELUs (a region in Central Europe)...



...their composition in LCEUs...



...and land-cover change 2000-2006

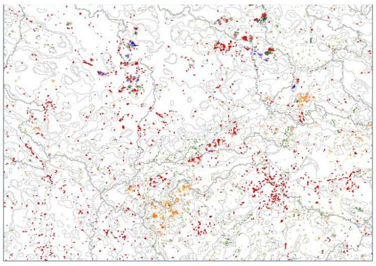
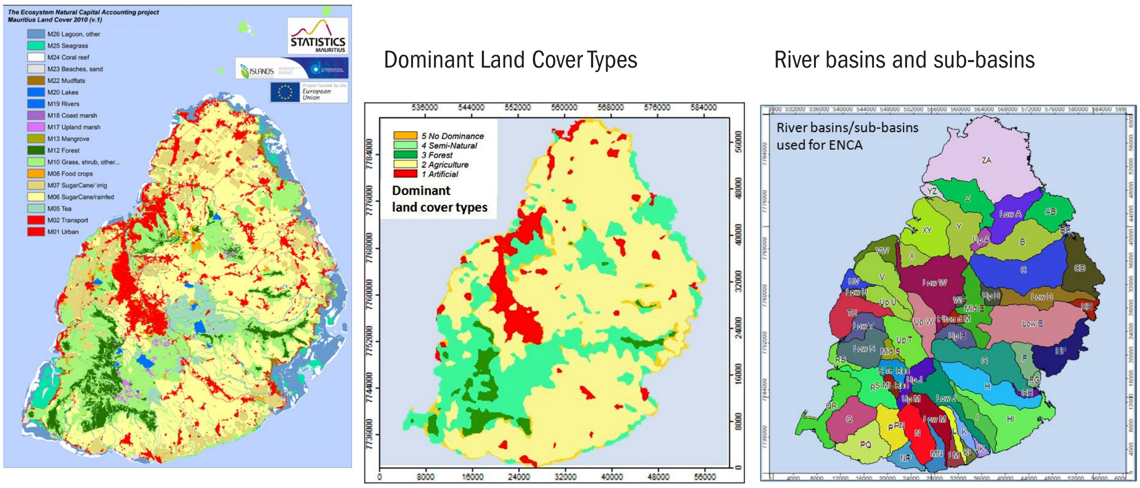
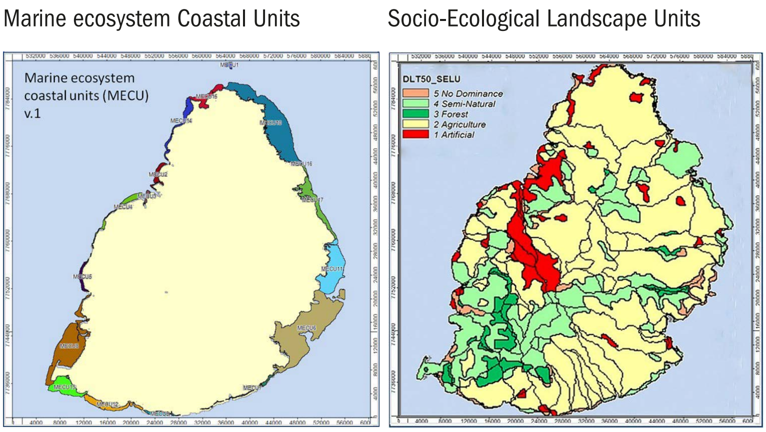


Figure 2.06: The production of the SELU map and directory for ENCA Mauritius (preliminary version 2013)



In the case of the Mauritius test accounts, only dominant land-cover types and river sub-basin limits have been used for defining SELUs. Dominant land cover has been compiled in the 1 ha grid, using the >50% criteria with five classes: artificial, agriculture, forest, semi-natural and natural land and no Land cover dominance. Additional zoning according to relief has still to be included. Marine coastal ecosystem units (MCUs) and their composition according to seabeds have been extracted directly from the land-cover map.



The reference to ecosystem accounting units is important for understanding accounting results since it gives a clear context for analysis. For example, a given amount of urban sprawl in a predominantly urban area will be very different from the same amount in an agriculture landscape or, of course, in a forested area. Zones where no dominance has been identified are of particular interest since they may be at an early stage of transition.

Additional criteria can be included, such as possible access to groundwater – important in arid regions. Boundaries of administrative entities such as natural parks may become SELU sub-categories, rather easily since they are generally rather homogeneous. Other zoning such as bioregions, ecozones or ecoregions and existing ecosystem maps can be taken into account. Because of differences in scale, and to avoid producing excessive number of intersections, these categories will in general be better reflected in the classification of SELUs than in the definition of their boundaries.

The data model used for ENCA, where data are primarily assimilated by embedded grids, gives flexibility for reporting by SELUs, river basins, and administrative units – countries, regions, zonings used for planning, etc.

2.2.2 Use of regular data sources

A Quick Start requires the use of existing data, even though they may in many cases be insufficient, rather than waiting for ideal data to be available. The objectives of the QSP are to support a dialogue with stakeholders with concrete data in order to help them to understand the potential of the accounting tool, and at the same time to help the producers (statisticians, geographers, economists, scientists, etc.) to understand the actual needs and priorities of potential stakeholders. The first results will be imperfect but will help to identify where more work needs to be done, because of the social usefulness of the accounts, and the statistical and scientific quality expected by actual users.

In principle, no collection of new primary data is needed for the QSP, rather the pooling of data collected for other purposes by various organizations. This includes, in particular, data collected (and processed if relevant) for other programmes – IPCC, Meteo, FAO, Earth Observation by satellite, national environmental and socio-economic statistics, surveillance and monitoring programmes, etc. An exception to this principle may be for land cover. Accounting for that requires both maps of stocks and good-quality monitoring of changes. In most cases, simple subtraction between two maps may be misleading since real change may be confused with noise resulting from mapping imperfections. Because of the importance of land-cover information for accounting, and of having consistent time-series of the main changes (urban development, deforestation and afforestation, change in agriculture landscape, etc.), it may necessary to improve or revise the land-cover data currently available. This point is discussed in Chapter 4 where possible solutions are proposed, depending on what is currently available in the country and in international programmes. Because data are often collected for purposes other than accounting, their relevance will have to be checked.

Socio-economic statistics are extensively used for accounting: local/regional statistics on human settlements, population, agriculture and forestry, fisheries, etc. Because they are official statistics, they are familiar to policy makers in their respective areas, which facilitates their understanding of the corresponding ecosystem capital variables. For ENCA, these statistics will be collected at the most detailed scale available (municipalities, countries, regions) and reprocessed in relation to land-cover/land-use in order to feed the standard grid (the "primary spatial units" (PSUs) of the SEEA-EEA). When socio-economic statistics exists, they must be the primary input to accounting.

Another body of data for accounting is the sets of environmental statistics collected by many national statistical offices around the world or environmental agencies in other countries. The 2013 revision of the UN Framework for the Development of Environmental Statistics (FDES) involved several environmental accountants in its Working Group to ensure the best consistency between programmes. Environmental statistics are therefore another important data source for accounting.

Monitoring data are diverse, depending on countries. The regular networks relate to meteorology, pollution, biodiversity and human health. Regular surveys, such as forest surveys carried out every 5–10 years, are also important sources since they produce comprehensive assessments which can be used to calibrate baseline accounts. The ENCA framework does not specify what particular data to use, which is the responsibility of national agencies and scientists. But it does explain the purpose of the accounting variables (the expected outcome) in order to help specialists to submit the best-available monitoring results as inputs to the accounts.

Earth observation by satellite is an extensive source of data collected with many instruments (satellite-borne sensors and coordinated ground-truth systems), for various monitoring purposes (land cover, vegetation in general, forests, wetlands, climate variables, water condition, etc.) by many agencies, which are now coordinated within the intergovernmental Group on Earth Observations' Global Earth Observation System of Systems (GEO/GEOSS) programme. One important aspect is that large datasets for long periods are made available free by several of these agencies, and are easy to use as data inputs for the QSP and often later.

The source of geographic background data (administrative boundaries, topography, relief, road and river networks, etc.) is typically mapping agencies and often water agencies and ministries of land and public works. As with statistics, priority should be given to official geographical data. Since they are used in the geographic information system (GIS) departments of many technical ministries, these data are a legal or *de-facto* standard and their respect when accounting will facilitate further use by stakeholders. One particular issue is that the regular grid (or system of grids) needs to be defined, produced from scratch if it does not already exist[21], and validated by the authorized agency (origin, projection system and reference geoid). This grid, with which ENCA-QSP databases and accounts are managed, will be systematically used later for data exchange between partners.

2.2.3 A straightforward data model combining grids for data assimilation and geographical objects for data integration

Data inputs are of a great variety including regular socio-economic statistics, data from monitoring stations of water, air, biodiversity, health security, periodic studies by sampling, inventories, images from Earth observation satellites, and observations from amateur botanists and bird watchers. Data also include results from physical models (in the meteo realm in particular) as well as coefficients and default values estimated by research.

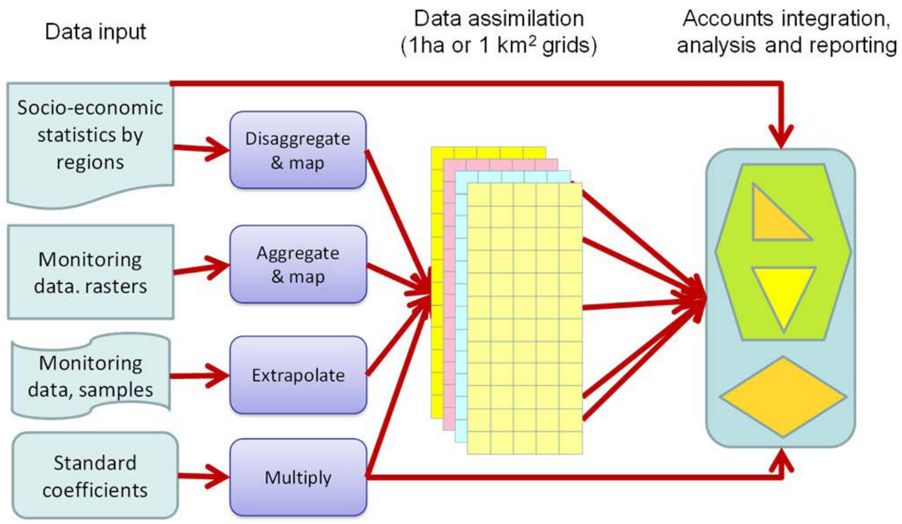
As far as possible, data are converted to grids (rasters) and stored at various sizes; typically 10 m, 100 m, 250 m and 1 km. Grids facilitate a range of calculations needed for accounting; including Gaussian smoothing used for

21 *The INSPIRE Directive of 2007 establishes an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment. It includes a standard grid, which is now used in a routine way.*

neighbourhood analysis and statistical generalization of high-resolution data. Statistics collected by institutional units are downscaled to grids.

Ecosystem accounting units (LCEUs, SELUs, MCUs, RSUs, HRSUs, river basins and other spatial units) are geographical objects. In GIS, they are recorded as polygons or polylines with attributes, which are their identifier, their classification and all the data stored mainly as raster files and extracted for the purpose of producing accounts.

Figure 2.07: The ENCA Data Model: Main data flows for compiling accounts



2.2.4 Implementation not bound to any specific software packages

The software packages used for ecosystem accounting are:

- spreadsheets;
- database management systems (optional initially);
- GIS, vector and raster or grid processing capacities;
- statistical analysis software (optional);
- satellite image processing system (optional).

Commercial software packages and open-source freeware packages can be used for ecosystem accounting in a professional way. The choice of a solution depends on the IT policy of the organization in terms of investment in software and maintenance and training issues (and costs). In already well-equipped organizations, there is no particular problem under this item. Organizations without one or more packages may be able to use freeware packages. All packages should run on a good laptop and the database should be of around a few hundred gigabytes (several hundred if it includes high-resolution satellite images for long time-series). Commercial as well as free software packages have user-friendly interfaces, which allow quick start, but training may be necessary, in particular regarding GIS computations. Satellite image processing will require specific skills, but pre-processed images do not present major difficulties, compared with other GIS datasets.

Annex I:

Ecosystem capital degradation and consumption of capital in national accounts

In SNA 2008, depletion of natural resources is essentially recorded as a write-down in the accumulation account, an "*other change in volume*"[22]. Consumption of natural capital, which would be the flow counterpart of depletion, is not part of the core SNA accounts although its possibility is discussed in Chapter 20 in that context as the optional measurement of capital stocks on the basis of capital services theory[23]. The aim is to improve measurement of stocks, regarding in particular issues linked to the productivity of the factors. Natural resource valuation is addressed in paras. 20.46 to 20.50, but taking into account its consequences for the calculation of SNA aggregates (in particular deducing natural capital consumption from Net Income and Net Savings) is not envisaged: "*Clearly this leads into the area of so-called green accounting and the possibility of allowing for consumption of natural capital as well as consumption of fixed capital in an alternative presentation of national accounts in a satellite account*" (SNA 20.40). Only one short paragraph in the SNA satellite accounts Chapter 29 mentions this possibility.

The SEEA Central Framework therefore expands the SNA 2008 proposal and defines measurement rules in physical units and valuation principles for depletion. *"Depletion relates to the physical using up of natural resources through extraction. In monetary terms it represents the decline in future income that can be earned from a resource due to extraction"* (SEEA CF para. 5.69). While physical depletion relates to the enlarged scope of natural assets, asset valuation and monetary depletion strictly match the SEEA definition: *"In the Central Framework, consistent with the SNA, the scope of valuation is limited to valuing 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 course 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 CF para. 5.32). One of the consequence is that ecosystem degradation relates not only to the extraction of one resource within one asset, but also to the associated loss of a bundle of other services produced by the ecosystem, and to external impacts on other neighbouring, regional and even global ecosystems (for example the effects of GHG emissions on the climate/atmosphere ecosystem are degradation).

Ecosystem degradation due to human activities is recorded in SEEA-EEA. ENCA records degradation (and enhancement in the same way) of all ecosystems in physical units as a loss (or gain) in capability, which is the sustainable capacity to deliver services. The services considered are the depletable resources recorded in SEEA-CF as well as all other services potentially made available by ecosystem functions. Such other services are in many cases not "*extracted*" or delivering "*benefits*" to "*economic holders*". For the economic owner, their degradation is in most cases an externality, which means a cost to others or to the community, a cost that he does not have to pay himself. When these other services are important for the renewal of the ecosystem itself, or for the broader ecosystem into which it is embedded, they can be considered as "public goods".

Measuring ecosystem capital according to the "standard" economic theory, where capital value equals the Net Present Value of expected benefits, requires estimates of the market value of non-marketed services, using monetary shadow prices. If this valuation is done, it is in principle possible to calculate Total Wealth or Inclusive Wealth. Ecosystem wealth is in this case part of this aggregate, and degradation is similar to depletion, a counterpart of economic depreciation measured as a loss of benefits. An important consequence of using monetary shadow prices is the need to accept complete substitutability between ecosystem capital and other forms of capital and to restrict ecosystem degradation to its consequences in terms of loss of welfare.

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22 *"For example, the depletion of a natural resource as a result of its use in production is recorded in the other changes in volume of assets account, together with losses of fixed assets due to their destruction by natural disasters (floods, earthquakes, etc.)". SNA 1.47*

23 *SNA 2008, Chapter 20: Capital services and the national accounts*

Options to adjust national accounts aggregates from natural capital depletion and degradation

If depletion of natural economic assets and degradation of ecosystem capital can be estimated and valued, the amount could be used to adjust the SNA aggregates. There is not one single possibility but two options.

The first option would be to subtract natural economic asset depletion as well as ecosystem capital degradation from net domestic product or net national income and subsequent aggregates (operating surplus and net savings). This subtraction is similar to that of consumption of fixed capital (CFC) which is also subtracted when shifting from aggregate gross to net values. This is what is done with resource depletion in SEEA-CF: a deduction from net income, as suggested in SNA 2008, Chapter 20, *Capital services and the national accounts*. However there is a difference between the two adjustments. Resource depletion is part of the revenue generated by production and improperly recorded as income while it should be assessed as a loss of economic assets of the producers. Ecosystem degradation refers to loss of functions that relate more to future renewal capacity and the broad range of services, which are mainly public goods. This additional loss is not for the owner of the assets but for others. It is an externality and is not part of its revenue – nor of GDP. If subtraction of depletion from net product or income may make sense, using the same method with ecosystem capital degradation would be artificial and the final adjusted aggregate of uncertain meaning in operational terms.

The second option for recording consumption of ecosystem capital is to add this unpaid cost to the final demand of goods and services. The adjusted consumption aggregate would reveal that purchase prices do not cover the full or complete cost of the consumption. In this approach, degradation embedded in goods imported from countries that degrade their ecosystems should be recorded in the same way and added to domestic degradation. In terms of the message, calculating the full cost of final demand suggests that it should be paid[24]. Note that considering net savings, the adjustment would be the same as when adjusting product or Income instead of final demand.

With both options, unpaid ecosystem maintenance costs should be balanced by an appropriate item since they are not included in the total revenue. This cost of ecosystem maintenance is in fact transferred to others, from private to public, and to future generations: it is therefore a debt which should be recorded as creation of ecological debts in the balance sheet.

24 *If CEC embodied in imports is recorded and added to domestic CEC, calculating the full or complete cost of final demand would echo the concerns of consumer movements aiming at organizing fair-trade distribution where low prices of imported products are not the mere consequence of excessively low remuneration of producers, social conditions below international standards, children's labour and non-respect of the environment.*

Annex II:

About the Econd currency

"A system of environmental (ecosystem) accounts should be built around a common unit of measure which is capable of assigning a value for all environmental assets and indicators of ecosystem health.

The adoption of a system of environmental (ecosystem) accounts based on reference condition benchmarks creates this common currency for ecosystem health. This means that an environmental asset, such as a forest, can have both a monetary value and an ecological value. The result is a transparent system of accounting where the impact of economic activity (both positive and negative) on environmental health can actually be measured."

"In the same way that nations describe their economic currencies with a title (a Dollar, Yuan, Euro, etc), it is also useful to give the unit of measure for ecosystem health a title. In this paper we call the unit of measure for ecosystem health an Econd.

An Econd is an accredited measure, metric or model between 0 and 100 that reflects the health of an environmental asset or an ecosystem indicator based on a reference condition benchmark."

A Common Currency for Building Environmental (Ecosystem) Accounts

Peter Cosier and Jane McDonald, Wentworth Group of Concerned Scientists

Paper LG/16/22, 16th meeting of the London Group on environmental accounting, 25–28 October 2010, Santiago, Chile

http://unstats.un.org/unsd/envaccounting/londongroup/meeting16/LG16_22a.pdf (accessed 14 July 2014.

"We can measure degradation by measuring the condition of our environmental assets. Condition is a scientific measure of the capacity of an environmental asset to continue to deliver benefits to society and incorporates elements of both the quantity of an asset (the area of a forest for example) and the quality of that asset (for example, the diversity of plant and animal species that inhabit that forest).

We need an agreed, practical and affordable way for measuring the condition of environmental assets (rivers, soil, native vegetation, groundwater, etc.) at all scales at which economic and policy decisions are being made.

If you don't measure it, you can't manage it.

In 2008, the Wentworth Group of Concerned Scientists and other experts in science, economics, statistics and public policy in Australia, developed the Accounting for Nature model to place scientific information about the condition of our environment into an accounting framework.

The primary purpose of environmental accounting is to address the concern that people can't make decisions that will lead to a healthy and productive environment, if we don't have a system of environmental accounts that link the maintenance of our natural capital into every day economic decisions.

The Accounting for Nature model does this by using the long established science of reference benchmarking to create a common (non-monetary) environmental currency that allows us to:

1. Compare the relative condition of one environmental asset with another, and

2. Aggregate information at different scales and for different assets."

Accounting for Nature: A Common Currency for Measuring the Condition of Our Environment

International keynote address by Peter Cosier and Carla Sbrocchi , Wentworth Group of Concerned Scientists

OUR PLACE, State of the Environment 2013, Environmental Defence Society Conference, 7–8 August, 2013

Auckland, New Zealand

http://www.edsconference.com/content/docs/2013_presentations/Cosier,%20Peter%20130808%20FINAL.pdf (accessed 14 July 2014).

Annex III:

Discussion of the ECU concept and format

Any unit-equivalent is conventional and requires consensus, which means agreement on the purpose (the consequences of the new measurement), clear methodology stating unambiguously what is equivalent to what and how it is calculated, some guarantee of measurability, and comparability and quality of data[25].

As with other aggregates of this kind, ECU refers to benchmarks which are an expression of a reference value. Similar references are used for biodiversity indicators, definitions of the Econd currency (Chapter 7) and of HANPP (Chapter 5) which all refer to a pristine situation. However, for assessment of river basin management and restoration exergy costs, Naredo calibrates the Ecointegrador[26] measurement against stated policy targets. This second solution is preferred in ENCA for ECU calculations, particularly in countries where past modifications of ecosystems are irreversible.

For ECUs, the accounting principles give the first benchmark value. From an accrual perspective, the true income must be measured net of all costs, including the maintenance of capital which should include actual expenditure as well as an estimate of capital depreciation, that is not paid but for which an allowance is recorded year after year in accounting books. A first target is therefore maintenance of ECC. Decrease of ECC is similar to capital depreciation or consumption of capital, in the sense where national accounts define the consumption of fixed capital (CFC). Consumption of ecosystem capital (CEC) is measured in ECU. Since it is a non-paid cost and no allowance is done, CEC is a measure of debt creation. Similarly, increase in ECC is formation of ecosystem capital, an accumulation; assuming an appropriate institutional setting, ECC can be recorded as either a reduction of debt or an ecological credit.

The accrual accounting approach does not prevent acknowledgment of other benchmarks or target values. It can be a natural pristine state defined by science, as proposed in Econd accounting, a more contingent historical reference or an optimal target under present circumstances. The ENCA-QSP refers to targets set in laws, regulations or conventions since they are based on science while also reflecting the social values of ecosystems and biodiversity, and encompasses consideration of the irreversibility of change in many places and the affordability of restoration costs. Such target values may be defined and agreed nationally or globally, such as the +2 oC of IPCC, and can be the basis for measurement of additional debts and/or allocation of credits.

25 *The REDD+ MRV – Measurement/Reporting/Verification" activity follows such principles (Chapter 5, section 5.2.2., Figure 5.10 and Box 5.16)*

26 *Manuel Naredo J. M. and Valero A., (eds.), (1999), Desarrollo económico y deterioro ecológico. Colleccion Economia e Naturalezza, Fundacion Argentaria e Visor, Madrid, Spain. See in particular Part 3, downloadable from http://www.fcmanrique.org/publiDetalle.php?idPublicacion=113 (accessed 18 August 2014). In recent works on water accounting in Spain, Naredo refers to the European Water Framework Directive target of restoring the good environmental quality of river basins, calculates exergy costs of water use (regarding in particular induced consumption by irrigation and water pollution); such physical costs can be translated later on into monetary costs. http://www.upo.es/ghf/giest/GIEST/otros_documentos/867_PonenciaKD_Naredo.pdf (accessed 14 July 2014)*

Aggregate versus composite indicator

Ideally, aggregates should result from simple additions and subtractions. In national accounting, aggregation of observed transactions results in aggregates such as GDP or final consumption at purchaser's price, which are computed from statistics independent of any statisticians' opinions as long as the input values are defined by the market. For that reason, combining genuine aggregates with composite indicators where equivalence-functions between components are conventional has always been the subject of dispute. However, the problem should not be exaggerated. Even national accounts use non-observed components. The most important case is consumption of fixed capital (CFC) that cannot be recorded as a statistic but is estimated instead from complex econometric modelling. Consumption of fixed capital is deducted from gross production (e.g. gross national product, GNP) to estimate the net income aggregate (e.g. net national product, NNI).

In fact, the problem with composite indicators or aggregates is in their soundness and usefulness. Clarity of the underlying equivalence-function is in this respect essential since hidden assumptions can be extremely misleading. The quality of the measurements also has to be clearly assessed and ensured and the results have to be verifiable.

Regarding ECUs and ecological values, the explicit purpose is to measure the change in ecosystem capability to deliver services, degradation or enhancement and to assess the benefits and accountability of sectors in order to support implementation of policies and mechanisms to conserve the values of ecosystems and biodiversity. Ecological valuation of nature in ECUs is another way of defining shadow prices based on biophysical variables, different from shadow pricing in monetary terms used to express the economic value of natural capital. If appropriate, fiscal, financial or trading mechanisms can be defined for ECU values as they are for CO2-equivalent values; such mechanisms could foster ecosystem maintenance by integrating the actual non-paid costs of degradation into economic calculations.

The method of calculating ECU values in the context of ENCA-QSP acknowledges the difficulty, and at some stage the impossibility, of adding different physical units and/or making a meaningful total of ecosystem carbon, water and ecosystem infrastructure potential. Instead, indices of change of state in terms of intensity of use and health can be calculated and combined in an overall assessment. Such indices measure ecological unit values. They are the equivalent of prices in ECUs that can be applied to each accessible resource component of an ecosystem. There will be measurements of ECU-carbon, ECU-water and ECU-ecosystem infrastructure potential. In each case, each single measurement in ECUs reflects what happens to the component itself and its impacts on the other two.

However, even expressed in ECUs, the three components cannot be added to produce an aggregated ecological value of the ecosystem. The solution is therefore to select one of the components to represent the overall (or by default, total) ECC. Because of the importance of biomass as a measure of the quantity of living matter and the resource for food, materials and energy as well as climate-biosphere interactions, the proposal is to select ecosystem carbon to represent overall ECC.

3. THE DATA INFRASTRUCTURE

The SEEA-ENCA Quick Start Package (QSP) aims at starting to implement ecosystem natural capital accounts without delay. The first step will be a double test: of the relevance of the accounts for stakeholders, and of their feasibility for the institution(s) in charge of their production.

The first test will allow assessment of whether the accounting model delivers the information required for current and future policies, and of whether it can be adopted by players such as ministries of economy and finance and of planning, agriculture, forestry and fisheries, and of course environmental agencies. This is essential for setting the priorities for a second phase of development, in particular regarding functional analysis, which will depend strongly on national circumstances.

The second test will be of feasibility. Experimental accounts can definitely be produced from existing data but their quality depends on the quantity and quality of the inputs. One high merit of an integrated national accounting framework with double and quadruple accounting is that it requires the cross-checking of data sets compiled by many organizations for many different purposes. When data gaps are not too important, the statistician proceeds to what is called arbitration between two more numbers. When gaps are more serious, an explicit adjustment item can be introduced to balance the table. In both cases, identification of gaps helps to check quality and improve future data collection.

The following chapters of this report address technical and data issues. They do not pretend to be definitive. Conditions, practices and skills vary from place to place and technological change accelerates obsolescence. Attention should therefore be not on the data as such, but on the capacity of the data to match the requirements of the accounts. Better data, meaning more accurate, quality-assessed and controlled data, will make better accounts, without losing sight of their relevance to the accounting framework.

It is important to note that the primary user of these guidelines is the person involved in the production of ENCAs, who may not be a specialist in the data and their processing. Make a quick start is therefore in the hands of the accountant, who, ideally, will try to establish partnerships with specialists in the various domains involved. The technical guidelines of Chapters 3–7 aim at providing the accountants with a language for expressing their demands to the specialists. And ultimately, if some specialists default, the guidelines enable the accountants to make a start themselves, at least for a first try. In such a case, the initial results will need to be submitted to specialists for review and to help them understand the nature of the demand for data. Therefore, first choice as well as second-best choice (but easier to access) data will generally be required.

National versus international datasets. Ideally, SEEA-ENCA should be produced using national datasets, validated by national agencies and in use in the country. Access to such data may be a problem if they do not exist in the country or if they exist but are made available with restrictions and/or are disseminated on a commercial basis at prices beyond the budget of an experimental project. The first stage of putting in place an institutional partnership and governmental decisions may lead to solutions to these problems, albeit with some delays. Therefore, following the rationale of Quick Start implementation of experimental ecosystem accounts, access to data made freely available at the global level by many agencies should first be considered. In recent years, such access has been facilitated by programmes such as GEO-GEOSS (Figure 3.01).

Box 3.01 GEO/GEOSS

The Group on Earth Observations (GEO), established in 2005, is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS). GEO is a voluntary partnership of governments and international organizations. It includes 87 governments and the European Commission. In addition, 61 intergovernmental, international, and regional organizations are participating. Data are distributed within GEOSS on an open-content basis. Many areas related to ecosystem accounting are addressed by GEO programmes.

http://www.earthobservations.org/index.shtml (accessed 14 July 2014)

Useful geo-datasets can be downloaded from many places. Some are disseminated together with software packages, others can be found directly on the web. The GEO partners, mostly space organizations, have developed their websites and made a huge amount of data easy to access. International organizations such as the Food and Agriculture Organization of the United Nations (FAO) also disseminate geo-data useful for accounting. In many cases these include times-series, an important benefit regarding accounting needs, as well as providing possibilities for quality assessment of the products. In the following chapters, international data sets are indicated as options; this will mean that, in the absence of more precise national data, it will be possible to make a start with international data. This will not mean that no precautions need to be taken. In general, global datasets are of good quality but there may be some problems, for example data quality may vary form place to place, and there may be local problems. A control is therefore necessary at the national level before the data is used. Another problem is that some global datasets do not meet ecosystem accounting requirements. This is particularly the case for global land-cover change data that are very fragile at the pixel level. Recent theme-by-theme approaches (instead of multiple land-cover classes), particularly forests and urban, seem to produce better results, but verification remains necessary. There is intense activity and progress in the domain of geo-data, with new products being put on the market every year. High-resolution commercial products may be available in some countries when details are requested for particular ecosystems.

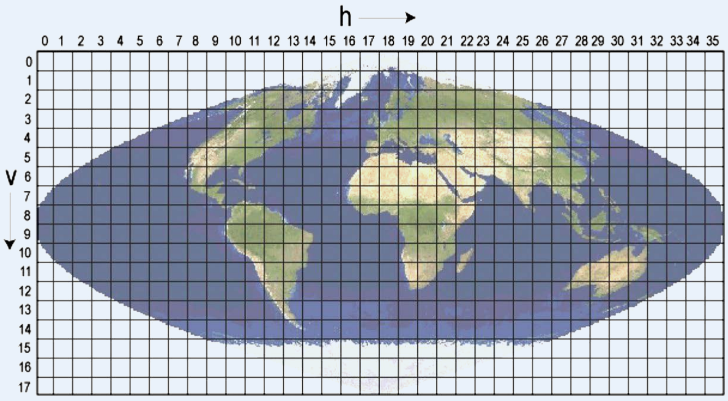
Ecosystem natural capital accounts combine monitoring, statistical and geographical data. It is therefore important to start by defining the typical scale (or scales) on which accounts are to be produced.

In Europe, the ENCAs produced by the EEA present a broad picture of more than 30 countries within a standard grid of 1km x 1km cells. Aggregation is done by socio-ecological landscape units (SELU) and river sub-basins (about 600 units for all of Europe).

3.1 REFERENCE GEOGRAPHICAL LAYERS

The following paragraphs list the data to be collected at the start of the project and their characteristics: national datasets, which should be given priority, and data that can be downloaded from national agencies or international organizations when national data are missing. Since there are many possible sources, these indications are suggestions for making a start rather than formal recommendations.

Box 3.02 Downloading geo-data from the web, an example



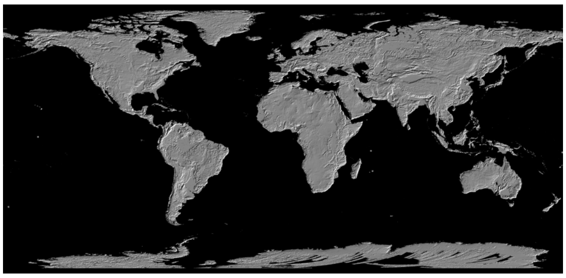
Downloading data from the web, with knowledge of where to go and a few principles related to formats, projection systems and the way data are organized, is nowadays rather easy. Format and projections issues are mentioned below –the advice of a GIS expert may save time at the start. The same recommendation can be made for data organization (the "tiles"), but those wanting to find some data themselves should do so, knowing that they will need to find the tiling system used on each website. The technical specification and metadata attached to the various datasets should also be downloaded to provide information about quality.

3.1.1 Physical topography

Coastline: Official coastline files are, in principle, available from mapping agencies. However, due to periodic updates or different definitions (administrative vs. physical), different coastlines may be used by different institutions; the issue should be settled since accounts need only one. In principle the reference should be the land-cover map which refers to the coastline at low tide and shows related intertidal flats.

Elevation: Digital elevation models (DEMs) provide information on altitudes and slopes, used when mapping ecosystem accounting units (EAU/SELU) in order to take into account the relief (plains, upland, mountains, etc.). High-resolution DEMs are generally available from national agencies. If there are problems of copyright or cost, it may be possible to use data downloaded free from the web for the QSP. Because their use at this stage is to contribute to the design of SELUs, the accuracy of these DEMs is in general sufficient – 30 m in the case of the ASTER GDEM (given as an illustration) or the DEM produced from the *Endeavour* Shuttle Radar Topography Mission (SRTM) programme of NASA (http://www2.jpl.nasa.gov/srtm/)

Figure 3.03 Examples of DEM freely downloadable from the web



Source: http://asterweb.jpl.nasa.gov/images/GDEM-10km-BW.png (accessed 18 August 2014)

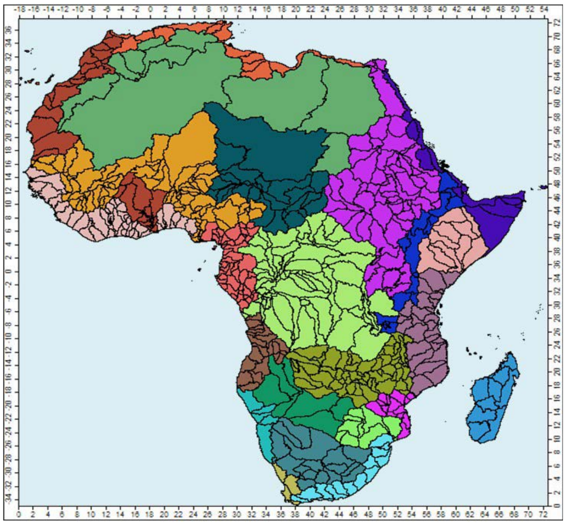
As a contribution from METI of Japan and NASA of USA to GEOSS, ASTER GDEM V2 data are available, free of charge, to users worldwide from the Land Processes Distributed Active Archive Center (LP DAAC) and J-spacesystems.

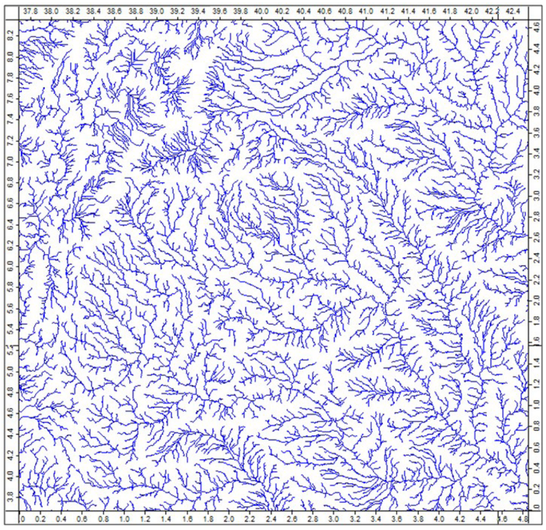
http://asterweb.jpl.nasa.gov/gdem.asp (accessed 29 July 2014)

The SRTM Tile Grabber is an interface produced by Derek Watkins. It attempts to facilitate downloads of elevation data from the Shuttle Radar Topography Mission (SRTM) of the NASA. Clicking on red tiles on the Globe allows downloading their corresponding data. Each tile comes in GeoTIFF format at 90-meter resolution (6000x6000 pixels).

http://dwtkns.com/srtm/ (accessed 20 August 2014)

Figure 3.04: River hydrological basins and sub-basins of Africa and rivers (extract)





Downloaded from the FAO GeoNetwork page (left) and http://www.fao.org/geonetwork/srv/en/main.home?uuid=e54e2014-d23b-402b-8e73-c827628d17f4 (accessed 18 August 2014).

the WWF HydroSHEDS at USGS (right) http://hydrosheds.cr.usgs.gov/datadownload.php?reqdata=15rivs (processed with SAGA GIS) (accessed 18 August 2014).

River hydrological basins or catchments limits are in general available from water agencies, which are the best source. If no national map of this type exists, it can be produced with good quality from the DEM but this is specialist work. For sufficiently large countries, it is possible to use the HydroSHEDS product developed by the Conservation Science Program of the WWF, the global conservation organization[1] from which FAO/AQUASTAT has derived the datasets accessible on the FAO GeoNetwork webpage (http://www.fao.org/geonetwork/srv/en/main.home).

River maps and river basin limits can be obtained from national sources (water agencies or mapping agencies) and by default from the WWF-HydroSHEDS/FAO-AQUASTAT source. Some of the datasets are purely graphical and may pose further problems for hydrological calculations and modelling. Priority should be given to river datasets where reaches (arcs in GIS language) are connected, with referenced origins and ends, together with the Strahler stream order[2] of each arc of the river network, plus a river basin attribute. Connections to lakes are also required. These conditions are met by HydroSHEDS, ECRINS, the European geo-database of rivers basins and rivers used for water accounting, and usually but not always by national databases. These digital maps will be used to produce the river basins, rivers and homogeneous stream reaches data infrastructure described Chapter 2, para 2.50 and Figure 2.04.

3.1.2 Other background layers

Other background layers to be collected relate to soil and geology, bathymetry, meteorology and administrative boundaries, for which population and socio-economic maps and local statistics, which are more and more frequently available from statistical offices, can immediately be associated.

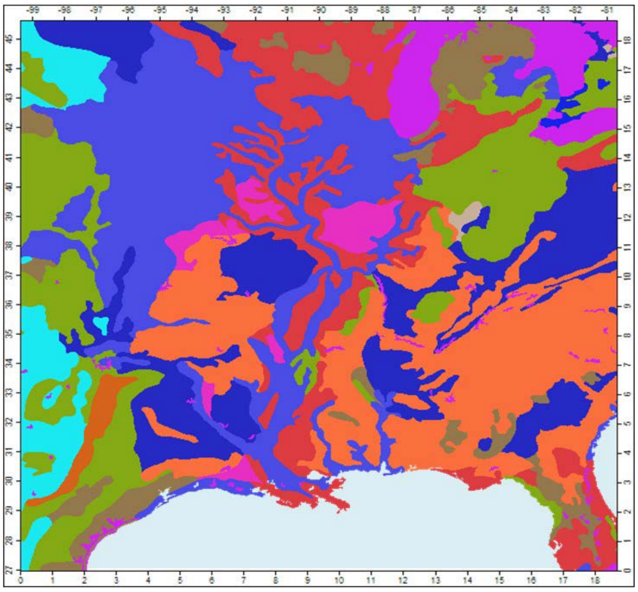
Soil maps are used in a very specific way in ENCA. In principle, soil is not used in defining SELUs, partly because this would multiply the number of classes significantly and partly because the soil maps that are generally available are at a very different scale from the other elements; the intersection of the soil layer would generate a large number of fictitious units, which are in fact mere outliers. Instead, soil data are used in the carbon accounts, and possibly in the water and landscape accounts. Typical variables are soil organic carbon, generally given as a percentage that requires knowledge of soil depths (by default, accounts are by convention restricted to the 30 cm top layer where the most important processes take place), the density of soil, and its content of stones. Erosion is also an important variable to be monitored or assessed using models based on the soil map. Soil maps exist in most countries; they are generally complex and need the assistance of a soil

1 *Data downloadable at http://hydrosheds.cr.usgs.gov/dataavail.php (accessed 14 July 2014).*

2 *In hydrology, the* Strahler stream order *is used to define stream size based on a hierarchy of tributaries.*

scientist to extract the few (important) variables recorded in the accounts. At the international level, it is possible to download the FAO Digital Soil Map of the World and the database produced by the International Institute for Applied Systems Analysis (IIASA) with FAO and other partners involved in soil monitoring, called the Harmonized World Soil Database (HWSD). The scale of these maps is rather coarse, but they remain thematically complex and the accountant will again initially need some guidance for using them.

Figure 3.05 Extract from the FAO Digital Soil Map of the World



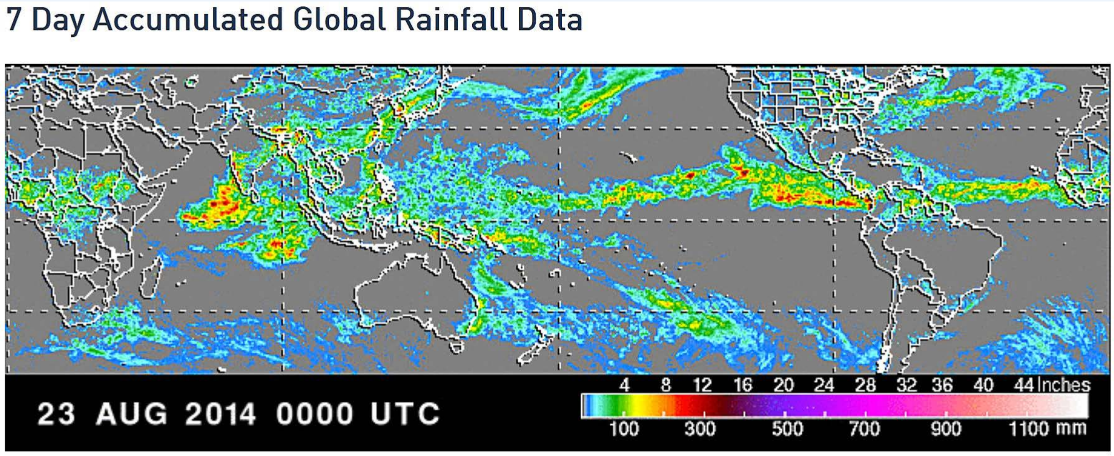
Meteorological data play an important role in compiling water accounts and calculating net primary production of biomass. Most of the data needed for accounting are collected and analysed by meteorological offices, and the additional work needed for accounting is in general limited if a partnership with them is established.

One difficulty, however, is likely to remain: calculation of actual evapotranspiration (ETActual) which requires complex modelling, for which estimates from the MODIS Global Evapotranspiration Project (MOD16) can be used. This product, developed by the Numerical Terradynamic Simulation Group of the University of Montana for NASA, is available on an eight day, monthly and annual basis for 2000–2012 (the most recent complete year at the date of writing) at http://www.ntsg.umt.edu/project/mod16 (accessed 18 August 2014).

When meteorological offices are not in a position to deliver all the data needed or when they can only deliver raw data, the accountant may be able to estimate the minimum needed: the spatial assessment of precipitation in the assimilation grid. In that case, the solution will be to combine isohyets (areas with the same amount of precipitation) and point observations from monitoring stations. Both isohyets and representative monitoring stations data will have to be supplied by the meteorological office. As ETActual will be assessed using MODIS 16, it is not necessary to engage in complex calculations, and other meteorological data used for this type of modelling (temperature and wind) are not needed. In case of particular difficulties in rapid collection of the rainfall data, data collected by satellites can be used. A possible source is the Tropical Rainfall Measuring Mission (TRMM) which has been delivering multi-satellite precipitation analysis (TMPA) products[3] since January 1998, with near-global (50° S - 50° N) coverage http://trmm.gsfc.nasa.gov/data_dir/data.html (accessed 29 July 2014).

3 *In Expert Group Meeting on Water Accounts and Statistics in New York, 2014, the TRMM monthly 3B43 products were mentioned as the most appropriate to be used for accounting purposes.*

Figure 3.06 Example of TRMM rainfall data



Source: http://pmm.nasa.gov/TRMM/realtime-3hr-7day-rainfall (accessed 29 July 2014)

An international satellite mission was launched by NASA and JAXA in February 2014. It sets new standards for precipitation measurements worldwide using a network of satellites coordinated by the Global Precipitation Monitoring Core Observatory[4].

Another source of meteo data is the so-called reanalysis distributed by the European Centre for Medium-term Weather Forecasts (ECMWF). They contain variables on total precipitation and evaporation supplied on a daily basis on a long time-period. The ERA interim database of ECMWF is based on meteorological modelling and, despite low spatial resolution, data can be useful to control other inputs http://data-portal.ecmwf.int/data/d/interim_full_daily/ (accessed 18 August 2014).

When satellite data are used to account for precipitation, it is still necessary to adjust them to ensure that accounts of total rainfall equal the totals computed by the national meteorological offices. This total, which is official data, is calibrated with more *in-situ* monitoring data than global models. It is used for official reports and applications such as national SEEA-Water. Rainfall data monitored by satellites will be used in this case to downscale the official totals to the accounting grid.

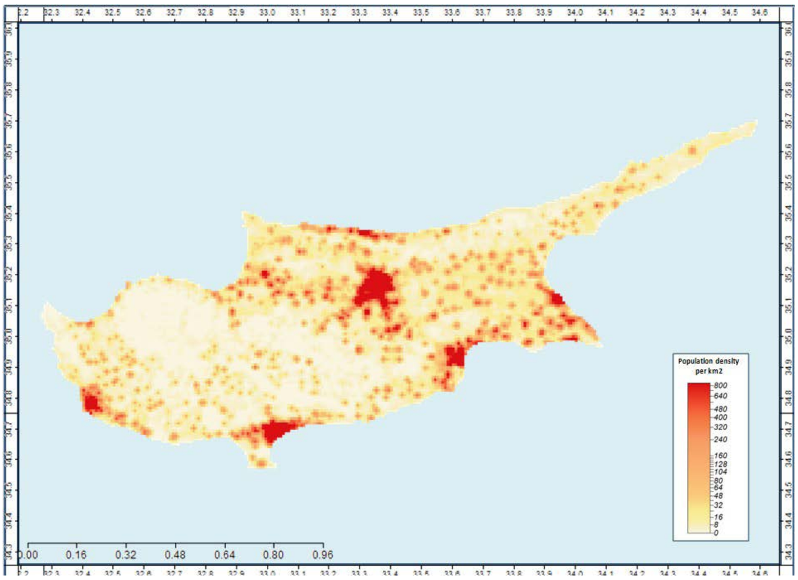
Bathymetry is standard information needed to support the delineation and mapping of the sea ecosystem coastal units. It has to be collected from relevant national institutions. As default, the General Bathymetric Chart of the Oceans (GEBCO; downloadable from the British Oceanographic Data Centre (BODC) website https://www.bodc.ac.uk/data/online_delivery/gebco/) can be used to map the continental shelf and grossly map the marine coastal ecosystems (resolution of the online datasets 1/2 arc-minute, equivalent to ~ 2 km at the equator, ~ 1 km at the 45th parallel).

Administrative boundaries of municipalities, counties, regions, etc., need to be collected from national mapping agencies or statistical offices. If several sets exist, preference should be given to the one used by the statistical office since its coding system will be used later. Such boundary geo-files may be disseminated on a commercial basis, which may require a special arrangement or payment for a licence. A practical initial solution may be to extract this layer (with the assistance of a GIS expert) from the Open Street Map, a cooperative open-source project where high quality geo-data can be found for many countries (http://www.openstreetmap.org).

Background local statistics are geo-data, referenced to small administrative units (municipalities, wards, etc.), and should be collected at an early stage of the ENCA-QSP project. The more important ones are population from censuses, updated for intermediate years. Population data will be used for resampling accounting grid data such as use of municipal water and wastewater discharged. They will also be used for analysing the social demand for ecosystem services. In some countries, statisticians have started downscaling population data to regular grids. When it exists, this information should be collected as a priority; otherwise, downscaling population statistics to the accounting grid will have to be carried out during the accounting project. For large countries, an option may be to use the LandScan data of population downscaled to the 1 km2 grid, produced by the Oak Ridge National Laboratory (free inside the USA, available for a fee elsewhere – http://web.ornl.gov/sci/landscan/index.shtml).

4 *GPM data available from September 2014 from NASA's Precipitation Processing System at http://pps.gsfc.nasa.gov. (accessed 29 July 2014)*

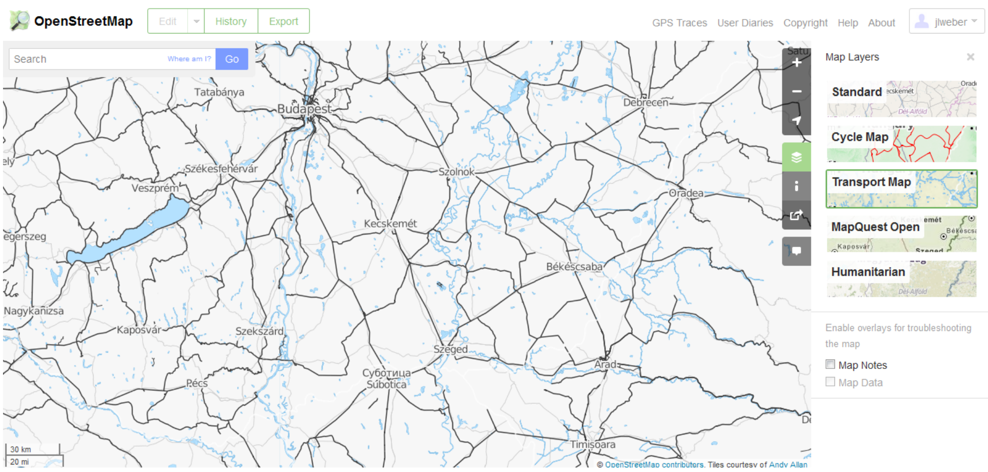
Figure 3.07 A sample of LandScan population data; Cyprus 2011



Source: http://web.ornl.gov/sci/landscan/landscan2011_sample.shtml (accessed 18 August 2014).

Roads and railways are also important features. In core accounts, they are important elements for assessing ecosystem fragmentation. In functional analysis, they are elements for assessing people's accessibility to ecosystem services. Data can be obtained from national agencies. It is important to list roads by size to calculate fragmentation. In case of difficulty, downloading data from the Open Street Map website is a possibility.

Figure 3.08 Example of a large roads layer available in OpenStreetMap



Source: http://www.openstreetmap.org/#map=8/46.740/19.814&layers=T (accessed 29 July 2014)

3.1.3 Land cover

Land cover has a special status in the ecosystem accounting framework. It is an image both of biophysical features and of land use. It is therefore correlated with many aspects of socio-ecological systems: ecosystem extent and spatial pattern, ecosystem services including food, timber, etc., fauna and flora habitats, human settlements and infrastructures. Because land-cover information is comprehensive and regularly updated, it allows focus on priority concerns or areas without losing sight of the broad picture and of emerging problems.

In ecosystem accounts, land-cover data is initially used for defining the ecosystem accounting units (SELU) which are in some ways landscape units where land-cover types coexist in particular combinations: from exclusive coverage, through dominance, to a blend with no dominant character.

Land cover then helps with mapping the origin of the ecosystem services, in particular the provisioning services which are generated by rather homogeneous land units. For this reason, land-cover data are often used in agriculture statistics to assess crops, either by multiplying surfaces by yields or as a basis used to stratify sampling surveys by area. More generally, land-cover maps are used as a quick source of information for many topics related to land.

Land-cover change reveals much on the processes that take place on Earth. Land-cover change over long periods is extremely instructive in itself and can be used to track the change in many other environmental variables.

The power of land-cover information was multiplied by the launch of the Earth observation satellites in the early 1970s that started to deliver regularly updated, objective data, exhaustively covering land and oceans. The development of GIS and image processing technology has made land-cover data familiar to the public through watching weather maps on TV or searching for housing or holidays on a map web browser. The amount of data collected by the many satellites that have been launched is huge and their applications widespread. But data are not all, they have to be interpreted and analysed to be transformed into information and knowledge – and into accounts.

In ENCA-QSP, Earth observation will not be considered with all its multiple (and constantly changing) facets but as an essential input to producing land-cover data and compiling land-cover change accounts, critical for ecosystem accounting. It therefore affects the choice of appropriate methodologies for interpreting the input data from remote sensing tools for the production of sound accounts. This choice results from several decades of experience of the scientific community, in particular the space and mapping agencies, and the stakeholders who have invested in the technology for their own purpose, in particular for food security, forest monitoring and environmental protection.

Chapter 4 discusses land cover and land-cover accounts in detail, addressing land-cover mapping and land-cover change mapping as well as specific issues of land cover of mappable marine ecosystem coastal zones and of rivers.

3.2 PRODUCING THE GEOGRAPHICAL LAYERS OF STATISTICAL UNITS

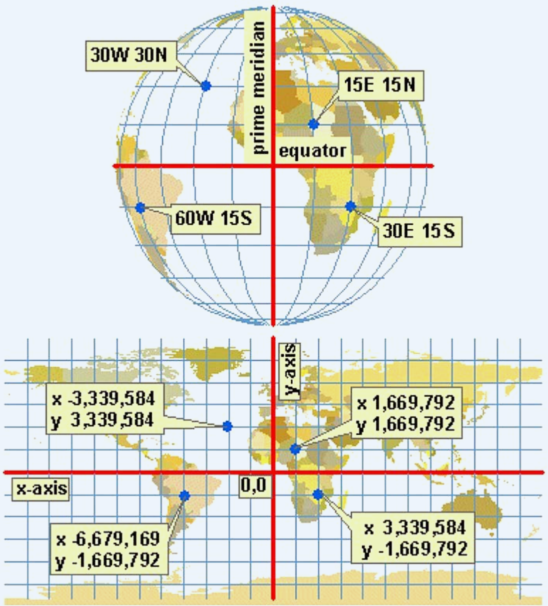
3.2.1 Gridding the data

Input data: several of the datasets presented in the previous section are grids or rasters. This may be an asset for future work but there are related difficulties that need to be resolved.

The first relates to different raster formats available from data suppliers, and different formats used by the GIS packages used by the accountant. In principle, all conversions are possible from one format to another and conversion programs are part of common toolboxes or modules. But some suppliers may use exotic, unusual or proprietary formats that are not recognized by the most popular GIS packages. Dedicated programs which will do the conversion to one of the most commonly used formats can be found on the web but these may be difficult to run and may require the assistance of an IT expert. Nonetheless, conversion to the working grid format has to be done.

The second difficulty relates to projection systems, which may differ from one dataset to another. Geographic information system packages have all the tools needed to proceed to geographical projections or to projection conversions (re-projections). The projection parameters are the projection system (UTM, Lambert, Kruger-Gauss, etc.), the longitude and latitude of origin and the reference ellipsoid used. There are many possibilities but no solution is perfect and optimizing depends both on the latitude and on the application (what is good for navigation is often less good for measuring surfaces and vice versa). In terms of outcome, differences in projection may result in gaps of 100 m or more and result in errors. It is therefore essential to use the official projection system of the country and project or re-project the input layers accordingly if necessary.

Box 3.09 Illustration of the geographical projections issue



Top: Round data is described with meridians, parallels, and latitude-longitude values.
Bottom: Flat data is described with x,y units. Projection parameters use both kinds of descriptions. The projection at the bottom is Plate Carrée.

Source: a lecture at City University of New York downloaded from http://www.geography.hunter.cuny.edu/~jochen/GTECH361/lectures/lecture04/concepts/Map%20coordinate%20systems/Projection%20parameters.htm (accessed 18 August 2014).

Assimilation grids: these have to be defined in vector as well as raster formats, depending on the requirements of the GIS package used. Depending on the size of the country or region, the types of landscapes and the detail needed, assimilation grids will range from 10 m to 1 km, with intermediate scales of 100 m and 250 m. Assimilation levels will be strictly embedded, which means that the numerical value of a higher level will in many cases contain the statistics of a more detailed one. One important task will be to resample input data, which generally have their own specifications, to the standard assimilation grids used for accounting.

3.2.2 Statistical generalization and the creation of the dominant land-cover type (DLCT) map

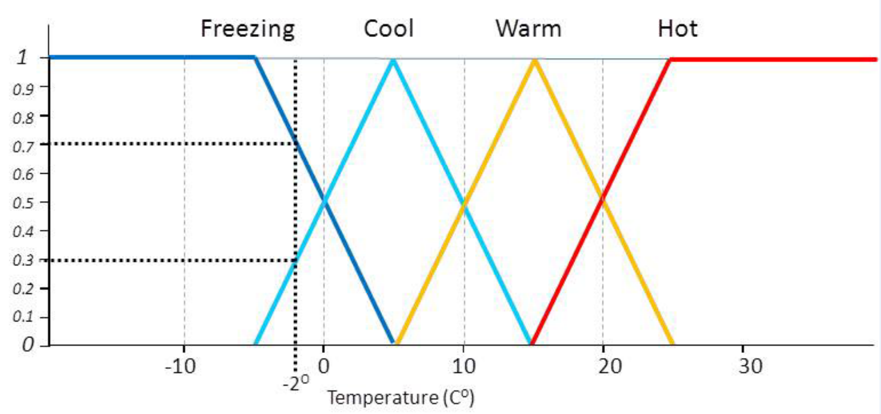
There is no unique, ideal scale for accounting. Some variables can be observed only with high resolution, even with microscopes, other objects, structures and processes may require encompassing large units. Aggregation and generalization of spatial data are important steps for creation of an account's database. Geographic information system tools are available for that, the problem being choosing the most appropriate one. As the purpose of the QSP is to support the creation of real accounts, the approach to these tools should be pragmatic, having in view the meaningfulness and reliability of the data layers produced rather than their mathematical properties. This means that visual control of maps, trial and error, and adjustments are all needed.

One problem relates to extrapolation of point data, in particular the results from networks of monitoring stations. In principle, the work of the accountant does not go that far upstream and starts from data generalized by scientists. There may, however, be a need to control area characteristics with point data. One way of doing this is statistical and uses points as samples and then compares the values obtained with total values extracted from a generalized map. Another way is to use extrapolation and interpolation techniques such as Gaussian heatmap algorithms or Kriging programs[5].

Another problem results from the usual way in which thematic maps are made that segment a territory into crisp units with clear-cut boundaries when there is in fact more continuity. The problem is the same when analysing a series of data through segmentation into discrete classes. This way of doing it is a simplification and assumes a unique value for each class even when it is clear that the two edges of the class are influenced by the neighbouring classes. This has led to the development of fuzzy logic analysis (Box 3.10).

5 Gaussian heatmaps extrapolate values measured on points to their neighbourhood as an inverse function of the distance. Kriging is an interpolation method that allows prediction of unknown values between randomly observed points.

Box 3.10 Fuzzy logic



Fuzzy sets mathematics (or fuzzy logic) was created by Lotfi Zadeh, at U.C. Berkeley in 1965 and has since been widely used in domains such as electronics, robotics, artificial intelligence, linguistics, sociology and biology. A fuzzy logic conclusion is not stated as either true or false, but as being possibly true to a certain degree. While traditional logics ("crisp sets") leads to computing values in Boolean algebra as [0,1] according to their belonging to a particular class, fuzzy logic define a membership relation between 0 and 1 where 0 is FALSE, 1 is TRUE and intermediate values "somewhat true". In this classical example, the – 2 Co temperature is recorded in crisp set analysis in the 0 to -10 class (freezing) while in fuzzy sets it reads 70% freezing and 30% cool.

Most statistical units used for accounting or areas mapped are fuzzy. Considering their theoretical composition, they are rarely pure and they exist within environments or in spatial patterns where they exchange with other units that influence their functioning. Fuzzy logic is a way to take stock of that in ecosystem accounting and to some extent to overcome some shortcomings which result from the simplifications necessary for defining statistical units and corresponding geographical objects, and for classifying them. A fuzzy logic approach should be used in accounting when heterogeneity has to be taken into account and to get a picture of landscape interactions. At this stage of development of ecosystem accounts, however, the use of fuzzy logic will remain very basic and the large body of fuzzy logic mathematics will not be used; what will be done is to convert, when necessary, crisp datasets to fuzzy ones, using smoothing tools.

Smoothing data is a common practice in image processing, sometimes called Gaussian filtering, Gaussian blurring or convolution. Gaussian refers to the most commonly used algorithm, the one that is used for ENCA-QSP accounting. The multi-scalar neighbourhood potential influence analysis methodology[6] will not be described in detail in the QSP, only its purpose, how it works, and the expected results and available tools.

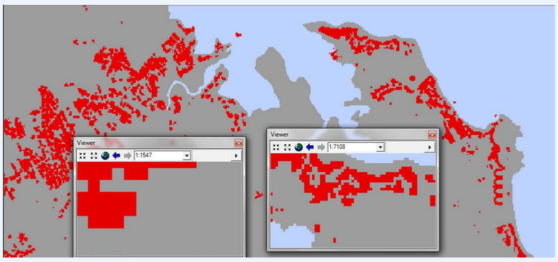
The principle of smoothing data is to take into account internal heterogeneity and external influences and to generalize data without introducing statistical bias. This last point is particularly important since not all methods used in cartography for aggregating data respect the statistical values of the mapped data. One method, which consists of giving to one aggregated cell the value of the most-represented class of higher resolution, generates arbitrary distortions that can be managed when doing generalization based on smoothing.

6 *For more on smoothing of geo-data and statistics, see http://hyantes.gforge.inria.fr/ (accessed 14 July 2014)*

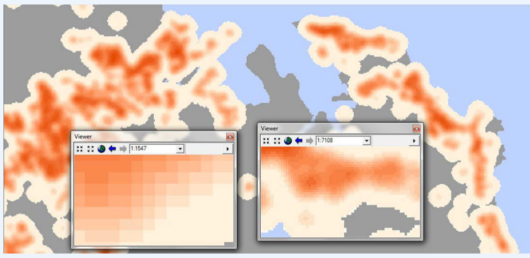
Box 3.11 Use of smoothing technique to create urban areas (land cover ecosystem unit concept)

from a high resolution database of buildings

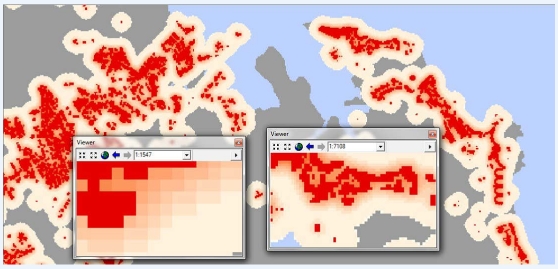
(1) Map of buildings produced by rasterisation of high resolution vector map. Pixels are of 10 m x 10 m.



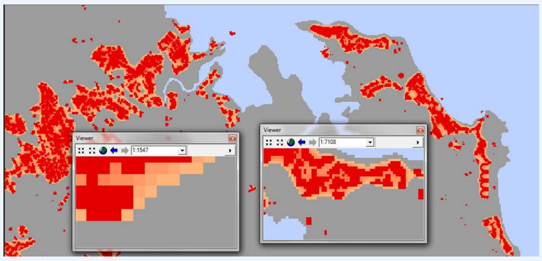
(2) Map of buildings now smoothed (Gaussian filter) with a neighbourhood radius of 100 m.



(3) Overlay of the two previous maps for selecting a smoothed value to agglomerate buildings into urban areas.



(4) Visual selection, after iterations, of an appropriate threshold value (here 25%). Note that isolated building pixels remain outside urban areas.



(data source: Statistics Mauritius; data processed with SAGA Gis)

Map smoothing can be implemented with various radiuses, commonly x5 or x10 the size of the pixel. Computation can be done on elementary pixels or on pixel statistics within larger assimilation pixels. The calculation can be illustrated by the following picture of a kernel with a x5 radius.

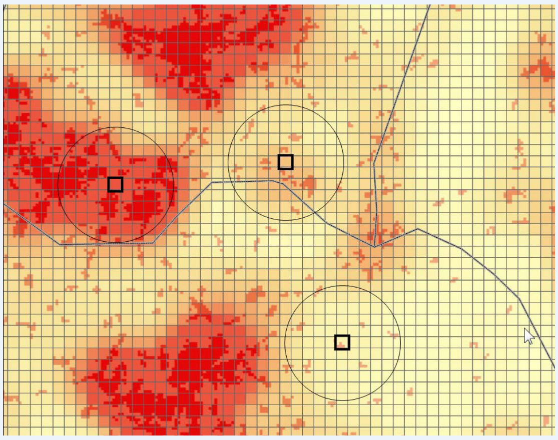
Box 3.12 Example of a kernel used by GIS programmes to calculate smoothed maps

0	0	0	0	0.0001	0.0001	0.0001	0	0	0	0
0	0	0.0001	0.0004	0.0009	0.0012	0.0009	0.0004	0.0001	0	0
0	0.0001	0.0007	0.0027	0.006	0.0078	0.006	0.0027	0.0007	0.0001	0
0	0.0004	0.0027	0.0101	0.0224	0.0292	0.0224	0.0101	0.0027	0.0004	0
0.0001	0.0009	0.006	0.0224	0.0496	0.0696	0.0496	0.0224	0.006	0.0009	0.0001
0.0001	0.0012	0.0078	0.0292	0.0696	**0.0842**	0.0696	0.0292	0.0078	0.0012	0.0001
0.0001	0.0009	0.006	0.0224	0.0496	0.0696	0.0496	0.0224	0.006	0.0009	0.0001
0	0.0004	0.0027	0.0101	0.0224	0.0292	0.0224	0.0101	0.0027	0.0004	0
0	0.0001	0.0007	0.0027	0.006	0.0078	0.006	0.0027	0.0007	0.0001	0
0	0	0.0001	0.0004	0.0009	0.0012	0.0009	0.0004	0.0001	0	0
0	0	0	0	0.0001	0.0001	0.0001	0	0	0	0
								SUM of values		**1.0**

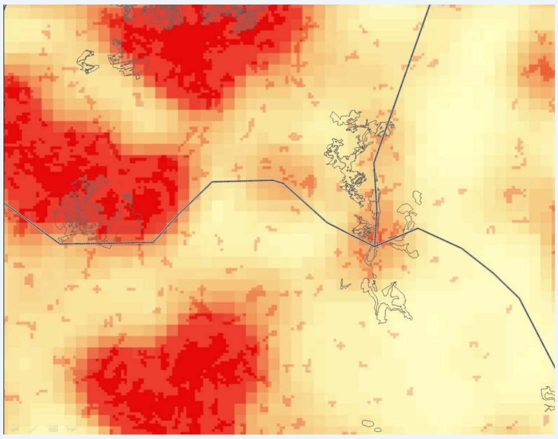
The initial value of the central cell (in grey) that was 1 is now distributed to its neighbours in inverse proportion to the square of their remoteness. The total of values scattered in this way remains 1. In subsequent iterations, the central cell will in turn accrue values from its neighbours. If it is itself surrounded by pure cells with 1 values, the final total will again be 1. If not, this total will be < 1, which will show that there is an external influence. An empty cell may get some value from neighbours. The result will have to be interpreted as the probability of finding the given type in the accounting neighbourhood. In case of urban areas, it is a measurement of their temperature over the external landscape (i.e. the potential pressure on protected areas). In the case of a forest, it will indicate a potential (the possibility of finding trees in the neighbourhood), interesting information useful for citizens, foresters or animal species for which the forest is part of the habitat.

Box 3.13 Example of use of smoothed data for assessing urban "temperature" on protected areas (source: EEA)

Urban land-cover cells at 1 ha (small, darker red) are assimilated to 1 km2 grid and smoothed (5x radius)



Designated areas for nature conservation are overlaid with the smoothed map. As expected, they do not overlay the dark red cells (actual urban cover) but many of them are on light red areas (smoothed value, high urban temperature).



Source: European Environment Agency

In Europe, smoothing methodologies have been developed mainly to find a solution to the modifiable area unit problem (MAUP) arising from the production of the first population maps by countries and municipalities. When municipalities with similar populations have very different administrative areas, the result is that population densities are of little meaning for comparison and maps may be misleading. The methodology was later used for smoothing Corine land-cover maps and has become a routine product at EEA, called CORILIS[7].

Dominant land-cover types (DLCT): one important application of smoothed land-cover datasets is the production of the headline spatially-aggregated indicators of green background and the derived landscape ecosystem potential used for accounting for landscape integrity (see below, Chapters 4 and 7). Another is the production of two maps of dominant land-cover types (DLCT), one considering only themes making more than 50 % of total cells, the other where themes making 34 % or more are combined in a specific classification. In both cases, the DLCTs are established at an aggregated level and at least one particular class is needed to record areas with no dominant character.

The steps for producing DLCTs are:

assimilation of land-cover data in the working accounting grid (rasterization or gridding tools);

smoothing with a radius of 5 to 10 times the size of a grid cell (with the Gaussian filter tool or equivalent). From empirical experience, x5 gives good results with 1 km^2 grids, while it is better use x10 for 1 ha grids; each class has to be smoothed separately;

extraction with a grid calculator tool of the cells > 50 % for each class, the others being set at zero;

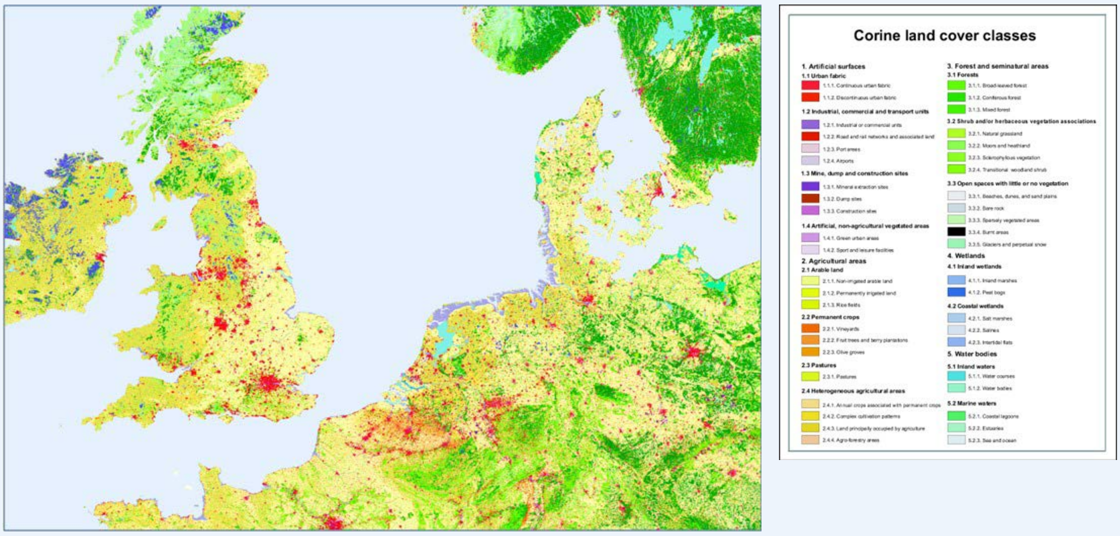
mosaic the various layers using the mosaicking tool.

7 *Lacaze M. et al. (1999). CORILIS, Lissage de Corine land cover pour l'Europe. Methodological report, Ifen-EEA 1999. Institut français de l'environnment, Orléans. And*

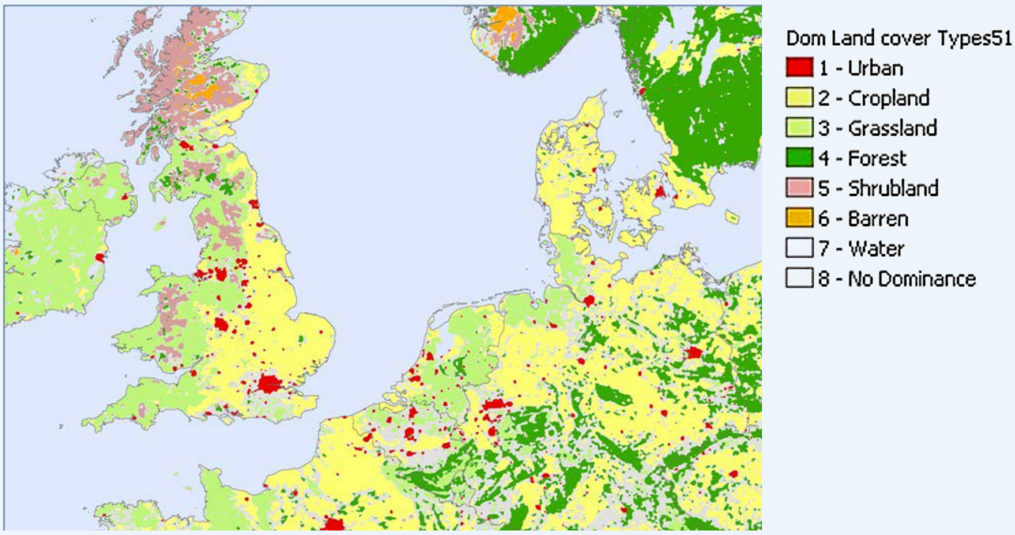
Lacaze M. and Nirascou F. (2000) Ces terres qui nous entourent..., Les données de l'environnement nº 51, IFEN, Orléans, France, 2000, downloadable at http://www.side.developpement-durable.gouv.fr/cda/portal.aspx?INSTANCE=exploitation&PORTAL_ID=medd_P0_D_ProdServ_Publications_CGDD.xml Collection : « Le point sur... », Year 2000. (accessed 4 August 2014).

Box 3.14 Land Cover and dominant land cover in Europe

Land-cover ecosystem functional units (Corine 2000)



Dominant land-cover types (more than 50% criteria)



Dominant land-cover types classification has to remain simple as it is intended to help organizing accounts, not to describe the variety of ecosystems. Typically, it will read:

UR urban and associated developed areas;
LA large-scale agriculture;
AM agriculture associations and mosaics;
GR grassland;
FO forest tree cover;
NA other natural dominant land cover;
ND no dominant land cover.

When necessary, subdivisions can be considered for classes NA and ND. In this case, a second processing has to be done for each of the two classes in order to identify the sub-dominant characteristic. For example, other natural dominant land cover can be usefully subdivided in some countries to distinguish between shrubland, bushland, heathland; sparse vegetation and bare land; permanent snow and glaciers; and wetlands.

Composite land covers, where no dominant land cover is identified at the first level, are interesting landscapes since they often correspond to a temporary situation between two dominances. For example, in the context of urban development, they may be landscapes particularly prone to change. In mountains or more natural areas in general, they reflect other transitional areas. So they can usefully be subdivided to distinguish between sub-dominant characteristics such as built-up and associated areas; agriculture; and natural and semi-natural land cover.

3.2.3 Mapping ecosystem accounting units

The concept of a socio-ecological landscape unit (SELU), one extension of the SEEA category of statistical units called ecosystem accounting units, has been introduced in Chapter 2.

Once the components are available and assimilated into the working grid, producing an SELU map and directory is rather straightforward. The datasets to be used are:

- river and sub-basin limits (compulsory);
- DLCT (compulsory);
- altitude classes (recommended);
- accessibility to groundwater (optional).

These datasets will be overlaid (raster). The raster will then be vectorized for mapping the units themselves. This is in principle easy with common GIS tools. One modality or another will be used at a later stage in various calculations. A last step will probably be necessary to eliminate, using the dissolve tool or equivalent, small units of one or two cells which may remain since they are more artefacts than analytical units.

The classification has to remain simple since SELUs are intended to help organize the accounts, not to describe the variety of ecosystems. Each SELU will finally be given an ID and a name reflecting its river basin/sub-basin location and DLCT, and possibly its altitude class or other attribute introduced in its making.

Box 3.15 Example of SELU classification based on seven DLCT and four altitude classes

UR	Urban and associated developed areas
UR.1	UR Mountain
UR.2	UR Upland
UR.3	UR Lowland
UR.4	UR Coastal zone
LA	Large scale agriculture
LA.1	LA Mountain
LA.2	LA Upland
LA.3	LA Lowland
LA.4	LA Coastal zone
AM	Agriculture associations and mosaics
AM.1	AM Mountain
AM.2	AM Upland
AM.3	AM Lowland
AM.4	AM Coastal zone
GR	Grassland dominant land cover
GR.1	GR Mountain
GR.2	GR Upland
GR.3	GR Lowland
GR.4	GR Coastal zone

FO	Forest dominant land cover
FO.1	FO Mountain
FO.2	FO Upland
FO.3	FO Lowland
FO.4	FO Coastal zone
NA	Other natural dominant land cover
NA.1	NA Mountain
NA.2	NA Upland
NA.3	NA Lowland
NA.4	NA Coastal zone
ND	No dominant land cover
ND.1	ND Mountain
ND.2	ND Upland
ND.3	ND Lowland
ND.4	ND Coastal zone

Classes ND can be detailed according to sub-dominant type such as urban, agriculture and other.

A river system unit (RSU) is defined as a single unit by river sub-basin (Chapter 2). It reflects the interconnection of the constitutive river reaches as well as their relation to land in terms of surface runoff or the roles of rivers in connecting land systems. This acknowledges that some variables will be better assessed at the scale of the river sub-basin than by individual river reaches or land-cover units. River system units are part of the standard rivers database. No proposal is made at this stage for their classification, but their Homogeneous stream reach units (HSRU) are classified according to their size and level in the Strahler graph[8].

8 *See 3.1.1, 3.07*

Marine ecosystem coastal units (MCU) have been little explored in ecosystem accounting. The SEEA-EEA acknowledges "*the delineation of marine areas taking into account not only their area but also the operation of ecosystems at varying depths as well as the sea floor is also important*"(SEEA P2, 1.29), but no definition has been proposed.

For lagoons and other landlocked sea-water bodies, their physical delineation, for example coral reefs or canals communicating to the sea, is simple to describe and implement. In many cases, there are official zonings of homogenous lagoons and these should be used, with possible subdivisions.

Boundaries of open marine coastal ecosystems are more difficult to map[9]. If such zoning exists, such as the *Satoumi* (Chapter 2), they should be used. If not, an interim solution is needed to define and map marine coastal ecosystem accounting units. Combination (intersection) of several existing zonings should be considered for producing such interim maps. They include:

bathymetry: continental shelf or maximum depth;

legal boundaries related to the extent of submerged land, typically 5–15 km from the coastline (in their absence, similar standard buffers from the coastline can be defined);

sea-bottom habitats when mapped, and marine natural protection zones when they relate to habitats (e.g. Posidonia sea grass, or fish spawning areas).

Boxes 3.16. 3.17 and 3.18 illustrate the kind of information that can be collected on marine coastal areas. They come from the US Marine Cadastre (BOEM website), a European research programme on the Baltic Sea (BALANCE), and another European research on the Mediterranean and Black Sea (PEGASO). Although standardization certainly has a long way to go, these examples show that first steps can be taken now to produce experimental maps of ecosystem accounting units for coastal seas (MCU).

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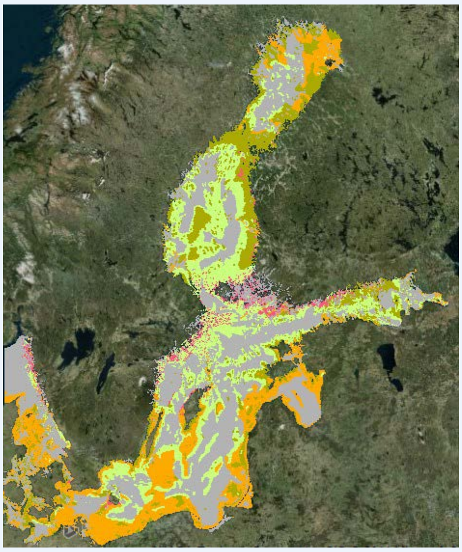
9 As noted in a presentation of the Multipurpose Marine Cadastre project, "Geology and Seafloor, Marine Habitat and Biodiversity and Human Use" layers present "significant gaps in data". http://www.centerforoceansolutions.org/Spatial-Data-and-Tools/Workshop-2009/7-MultiMarineCadastre.pdf (accessed 14 July 2014).

Box 3.17 Benthic landscape map of the Baltic Sea

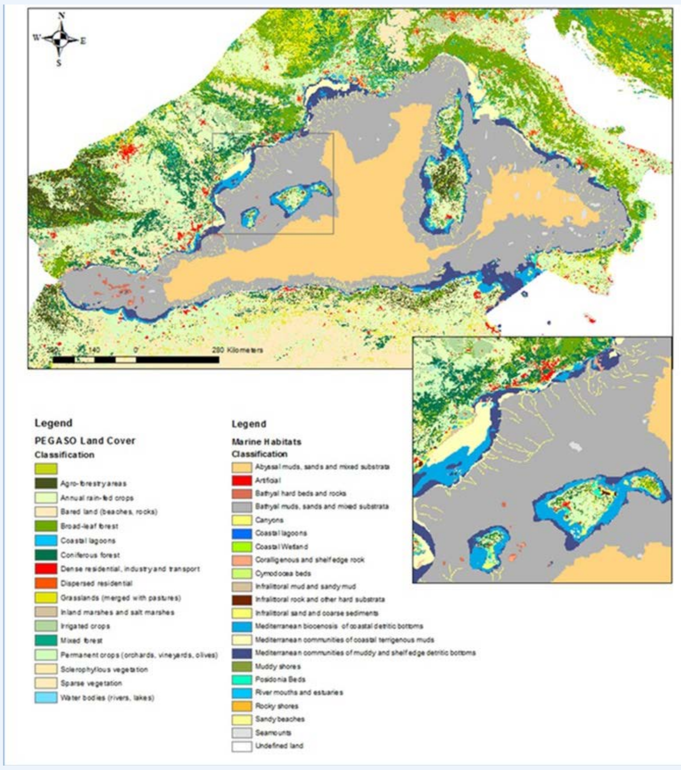


This dataset was produced by the EU-funded Baltic Sea Management – Nature Conservation and Sustainable Development of the Ecosystem through Spatial Planning (BALANCE) project run in the context of the HELCOM international convention on the Baltic Sea. It maps the ecologically-relevant benthic landscapes (broad-scale benthic habitats) of the Baltic Sea, identified by salinity, sediments and photic depth (as light touching the seabed). This marine benthic landscape map includes 60 broad-scale habitat types that are defined according to different combinations of bottom substrate, photic zone and salinity.

http://www.helcom.fi/baltic-sea-trends/data-maps/habitat/balance/ (accessed 29 July 2014)

Data downloaded from the HELCOM website and processed with SAGA GIS

Box 3.18 Map of land cover and of benthic ecosystems of the Western Mediterranean



This map has been produced in the context of the EU-funded PEGASO. Land-cover accounts have been produced for the inland part. The marine part is used to calculate an impact on ecosystems index.

PEGASO stands for "people for ecosystem-based governance in assessing sustainable development of ocean and coast". It is a collaborative research programme run in support of the EU integrated coastal zone management (ICZM) sustainable development policy.

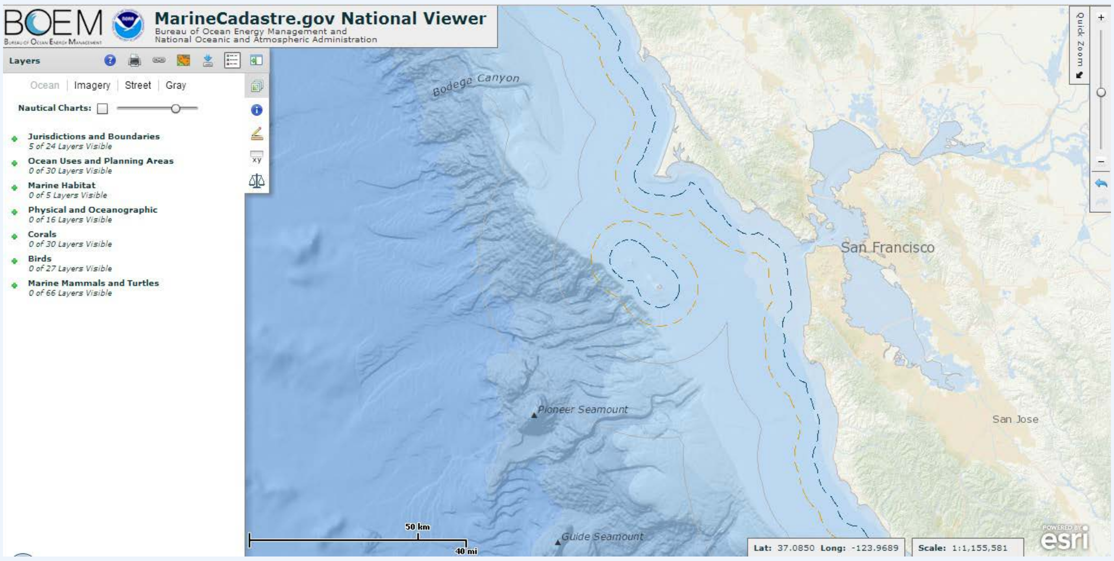
Note that sea-bottom canyons have been included in the benthic ecosystem map.

http://www.pegasoproject.eu/project-overview (accessed 14 July 2014)

Source: PEGASO final report 2014 (forthcoming)

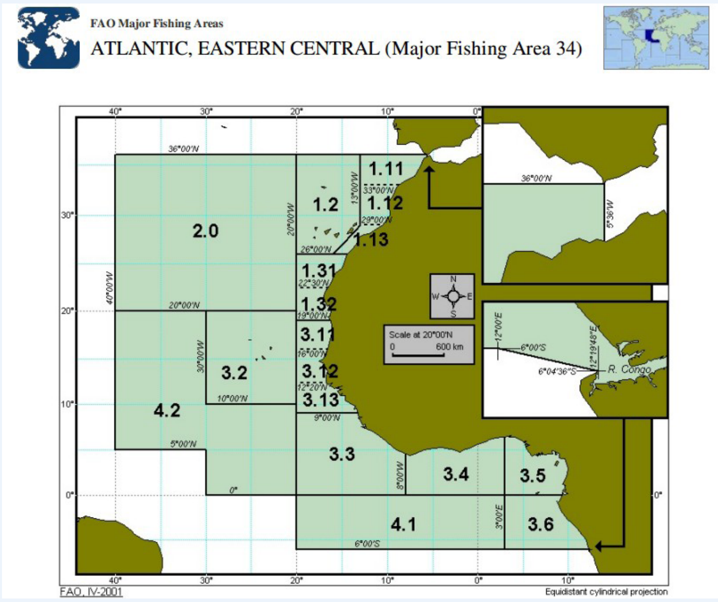
There is no agreed definition of ecosystem accounting units for the **open sea**. For reasons of consistency with the SNA rule, the SEEA recommends reference to the exclusive economic zones (EEZs) as one dimension. A working solution for a Quick Start could be to overlay the EEZ on to the FAO major fishery areas that are used to report long time-series of fish catches.

Box 3.16 Illustration of variables that can be used to map marine ecosystem coastal units



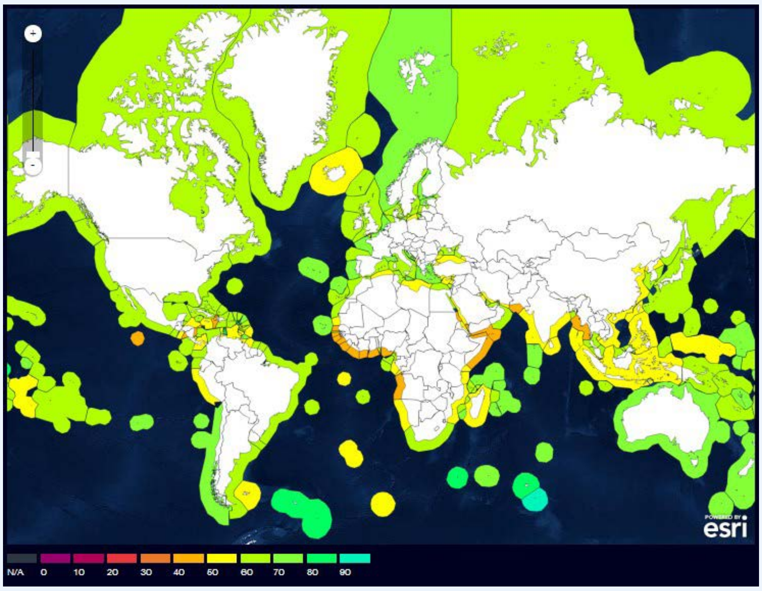
This map is produced with the viewer of the Bureau of Ocean Energy Management and the National Oceanic and Atmospheric Administration of the USA. The viewer is accessible at http://csc.noaa.gov/mmcviewer/ (accessed 29 July 2014)

Box 3.19 Extract from the FAO major fishery areas map



Source: FAO, http://www.fao.org/fishery/area/Area34/en (accessed 18 August 2014).

Box 3.20 Example of indicators by EEZ: the Ocean Health Index



Source: Ocean Health Index, http://www.oceanhealthindex.org/Countries/ (accessed 18 August 2014).

Atmosphere: there is no clear definition of atmosphere units and the solution is to follow the IPCC approach where atmospheric exchanges with land and oceans are referred to them. SEEA Part 2 adopts the same approach: "*the boundaries of a country's atmosphere should align with the terrestrial and marine boundaries used in the ecosystem accounts. Thus, in principle, it would consist of all air volumes directly above that stated scope of the accounts, potentially out to the limit of the EEZ. Within this boundary it may be useful to delineate the atmosphere into smaller units, for example 'airsheds' associated with individual cities*" (para. 2.80).

4. THE LAND COVER ACCOUNT

4.1 LAND-COVER MAPS, STOCKS AND CHANGES

4.1.1 Specific role(s) of land-cover accounts in the ENCA framework

Land cover is an observable image of the many processes taking place on the land surface. It reflects land occupation by various natural, modified or artificial systems, and, to some extent, the way land is used by such systems. Land-cover cartographic and statistical information therefore plays a central role in the description and quantification of the interactions between the economy and nature by providing:

- **Statistical units**: observation of the bio-physical characteristics of land cover provides the basic variables which describe ecosystem composition and structure.
- **Data integration**: because land cover can be observed in many ways, including by satellite or airborne remote sensing, area sampling, and censuses and administrative data, it provides the foundation of more comprehensive descriptions combining land cover and land use, and land cover and biological data.
- **Localization**: land-cover data are generally geo-referenced with high accuracy for use in geographical systems together with other data. Land-cover data with lower spatial resolution are often used as a proxy or tool to model spatial distribution of less accurate data. An example is the reallocation of statistics to a regular grid, based on the assumed correlation between an observed phenomenon and a particular land-cover class (e.g. population and urban fabric, tree harvest and forested lands).
- **Change monitoring**: land-cover change is basic information about what has actually happened rather than about emerging issues, but it gives a fair and robust description of major processes such as urban development, extension of agriculture over marginal land, and change in forest tree-cover. The abundance of images provided by of Earth observation satellites, and progress in open dissemination and access to image-processing tools, make land-cover change or flow (in the sense of "other flows" in the System of National Accounts (SNA 2008), which describe the "other change in volume" of non-financial assets) one of the bases of ecosystem accounts.

If enough data and maps exist in various organizations in charge of cadastre, transport, agriculture, forestry, water management, and environment and in research centres, they can be used in a Quick Start of ecosystem natural capital accounting. Indications are given of possible methods of combining such maps into a first land-cover map. This can usefully be done for defining the statistical units (SELUs) needed to start accounting, as explained in Chapter 2. However, it might be more difficult to monitor land-cover change in that way. Even though thematic maps are updated, the frequency of these updates, the dates and the methodologies used may vary from one domain to another, making a synthesis and the production of reliable land-cover accounts difficult.

More broadly, the heterogeneity of dates poses the challenge of choosing a base or reference year for accounting. Since all ecosystem accounts are connected to some extent to land cover, the baseline land-cover map will play a very important role in structuring the whole information system.

When it is necessary to produce new land-cover maps of stocks and change for accounting, this will be an investment not only for accounting but also for the national geographical system as a whole, requiring the involvement of the national mapping agency and other stakeholders. The discussion of land-cover mapping in this chapter will therefore go beyond the strict requirements of a Quick Start of ecosystem accounting and address the issue in a broader context.

Box 4.01 About the land cover classification system (LCCS)

The purpose of LCML is to define a common reference structure for the comparison and integration of data for any generic land-cover legends or nomenclatures. In simple terms, the LCCS conceptual model and software package allow definition, in a strict logical way and without ambiguities, of classifications at various levels of detail, keeping the essential properties of interoperability of databases and comparability of very different geographical objects.

The LCCS approach does not contain any prescription regarding the contents of the classification. The LCCS3 software package developed by FAO to support the implementation of land-cover classifications allows integration into class definitions of all the variables that the user may need to know, including land-use aspects and the spatial patterns under which the basic land-cover objects are combined in the real world. Some land-cover classifications, based mainly on bio-physical variables, in particular on vegetation characteristics, are sometimes qualified as LCCS classifications when they reflect only one possible way of using the LCCS rules. Other ways of implementing a LCCS-compatible classification exist, such as the approach used for the SEEA and followed by ENCA-QSP.

Since the aggregated land-cover classes used for the QSP are rather simple, it is likely that they will not change significantly in the near future. More detailed levels will probably be needed because of ongoing standardization activities, which may have some (marginal) consequences on the way classes are defined. In particular, the SEEA land-cover classifications are addressed in the FAO Global Land Cover-SHARE* approach to improving the information accuracy of global land-cover databases. The GLC-SHARE integrates the best land-cover data available at the sub-national, national, regional and global levels (including CORINE land cover for Europe) into one single harmonized database. It uses international standards: ISO TC211-19144-2:2013 LMCL, and refers explicitly to the SEEA process.

The LCCS3 v. 1.7.0 software package can be downloaded from http://www.geovis.net/Home.htm. The help section contains a tutorial.

* Cumani R. and Latham J., 2013, FAO and Land Cover Mapping: methodology, tools and standards and GLC-SHARE database, International Symposium on Land Cover Mapping for the African Continent June 25-27, 2013, UNEP HQ and RCMRD, Nairobi, Kenya. http://www.glcn.org/downs/pub/ppts/Kenya_lcAfrica/FAO_GLCSHARE_LC_Africa_Cumani-Latham.pdf (accessed 14 July 2014).

The LCEU classification has benefited from recent progress of the FAO land cover classification system (LCCS) and its Version 3 which has been established as an application of the geomatics[2] rules adopted at the international level by ISO TC211 on the basis of the land cover meta language (LCML) developed by FAO.

The principle of the LCEU classification is to recommend a top level of 14 classes (plus the sea) as a common level for SEEA-EEA tests. It is used for ENCA-QSP. This aggregated level can then be subdivided, depending on specific needs, while maintaining overall consistency by following the LCCS rules. When other classification systems exist and are well developed, such as CORINE Land Cover in Europe or the land use classification system used by the Brazilian Institute of Geography and Statistics (IBGE), they supply the necessary detail for accounting. For future comparisons and in a broader context than ENCA-QSP, correspondence between these systems and the LCCS rules can be checked, as has been done for CORINE.

The FAO LCCS3 allows the description of any land cover at any scale by combining basic biophysical objects: grass, shrub, tree, rock, sand, snow, ice, water, etc. Basic objects can be qualified according to their characteristics (e.g. type or size of tree) and properties (e.g. natural grass or cultivated crop). They can also be combined according to their spatial arrangement in the real world where they exist as geographical units, which can be observed, mapped and analysed as land systems. This is achieved in LCCS by combining objects according to rules defining vertical and horizontal patterns.

1 *The developments of land-cover classification and land-cover flows have benefited from the support given by the European Environment Agency through its European Topic Centre on Spatial Information and Assessment. The studies carried out by Gabriel Jaffrain (the European Topic Centre for Spatial information and Analysis (ETC/SIA) and the French National Institute of Geographic and Forest Information (IGN FI)) on the applications of CORINE land cover outside Europe, the translation between various land-cover legends used at the international scale, and the advice given in this chapter, have been very valuable. In previous years, discussions on land-cover/land-use classification carried out by the European Environment Agency and FAO in the context of the SEEA revision have contributed to the clarification of most issues and allowed the proposal of this framework.*

2 *Geomatics is a relatively new science concerned with the analysis, acquisition, management and visualization of geographic data with the aim of gaining knowledge and better understanding of the built and natural environments. (source: http://www.tudelft.nl/en/study/master-of-science/master-programmes/geomatics/)*

The LCEU classification is derived from the classification of land-cover types presented in the SEEA-CF[3]. The main difference is that, since the SEEA-CF covers assets and the supply and use of the resources that they deliver, the focus is on the objects that make up the land-cover classes. In SEEA Part 2 on experimental ecosystem accounting, the focus is on the ecosystems of which land cover is an image, meaning that the existence of complex systems has to be recognized in the classification.

In order to provide the best bridge between the two land-cover classifications, FAO and the European Environment Agency have further developed the SEEA-CF classification[4] (Box 4.02). In that way, the land-cover classification for ecosystem accounting can be defined in terms of additional horizontal spatial patterns needed to identify typical mosaic landscapes. This standardization of the method will guide the addition of details when needed. It will also facilitate translation between LCEUs and other classifications such as the ones used in the FAO land-cover maps or CORINE Land Cover.

The LCEU classification produced on this basis has 14 classes (plus sea):

Class	Label
01	Urban and associated developed areas
02	Homogeneous herbaceous cropland
03	Agriculture plantations, permanent crops
04	Agriculture associations and mosaics
05	Pastures and natural grassland
06	Forest tree cover
07	Shrubland, bushland, heathland
08	Sparsely vegetated areas
09	Natural vegetation associations and mosaics
10	Barren land
11	Permanent snow and glaciers
12	Open wetlands
13	Inland water bodies
14	Coastal water bodies and inter-tidal areas
	Sea (interface with land)

The composition of LCEU classes in terms of land-cover types is shown in Box 4.02. For clarity, the look-up table of land-cover ecosystem units and types is established at three hierarchical levels; this is not to be interpreted as a recommendation but as an illustration. The LCEU Level 1 classes can be subdivided differently, or accounts can simply be implemented at Level 1.

3 *SEEA CF, Chapter V Asset accounts, Land cover classes, paragraphs 5.257 to 5.262*

4 *Di Gregorio, A., Jaffrain, G. and Weber, J.-L. Land cover classification for ecosystem accounting, paper prepared by Antonio di Gregorio (FAO), Gabriel Jaffrain (IGN FI) and Jean-Louis Weber (EEA), Expert Meeting on Ecosystem Accounts, 5–7 December 2011, London, UK. http://unstats.un.org/unsd/envaccounting/seeaLES/egm/lod.htm (accessed 14 July 2014)*

Box 4.02 Classification of LCEU and correspondence to land-cover types

LCEU: Land Cover Ecosystem functional classes			LCEU contents: main and other land cover type	
01 Urban and associated developed areas			LCT.1	
	011	Urban fabric and associated developed areas	LCT.01.b	
	012	Dispersed human settlements	LCT.01.a	
02 Homogeneous herbaceous cropland			LCT.02.c and LCT.02.d	continuums of LCT.02.a and LCT.02.b
	021	Rainfed homogeneous herbaceous cropland	LCT.02.c	continuums of LCT.02.a
			LCT.02.c	
			continuums of LCT.02.a	
	022	Irrigated or aquatic homogeneous herbaceous cropland	LCT.02.d	continuums of LCT.02.b
			LCT.02.d	
			continuums of LCT.02.b	
03 Agriculture plantations, permanent crops			LCT.03.b	continuums of LCT.03.a
	031	Agriculture plantations, permanent crops, rainfed	part of LCT.03.b	part of continuums of LCT.03.a
			part of LCT.03.b	
			part of continuums of LCT.03.a	
	032	Agriculture plantations, permanent crops, irrigated	part of LCT.03.b	part of continuums of LCT.03.a
			part of LCT.03.b	
			part of continuums of LCT.03.a	
04 Agriculture associations and mosaics			discontinuous LCT.02.a, LCT.02.b, LCT.03.a, LCT.05.b	LCT.4
	041	Multiples crops and small size pastures	part of LCT.4	
	042	Layered crops	part of LCT.4	
	043	Mosaics of small agriculture and natural plots	discontinuous LCT.02.a, LCT.02.b, LCT.03.a, LCT.05.a, and natural classes	
05 Pastures and natural grassland			part of LCT.5	
	051	Pastures	continuums of LCT.05.b	
	052	Natural grassland	LCT.05.a	

LCEU: Land Cover Ecosystem functional classes			LCEU contents: main and other land cover type	
06 Forest tree cover			part of LCT.06.b & LCT.06.c	LCT.7
	061	Forest broadleaves tree cover	part of LCT.06.b & LCT.06.c	
	062	Forest deciduous tree cover	part of LCT.06.b & LCT.06.c	
	063	Forest mixed tree cover	part of LCT.06.b & LCT.06.c	
	064	Mangroves	LCT.7	
07 Shrubland, bushland, heathland			LCT.8	
08 Sparsely vegetated areas			LCT.10	
09 Natural vegetation associations and mosaics			discontinuous LCT.05.a, LCT.6, LCT.8	
10 Barren land			LCT.11	
11 Permanent snow and glaciers			LCT.12	
12 Open wetlands			LCT.9	
13 Inland water bodies			LCT.13	
	131	Rivers and canals	LCT.13 part	
	132	Lakes and reservoirs	LCT.13 part	
14 Coastal water bodies and inter-tidal areas			LCT.14	
	141	Estuaries	LCT.14.a part	
	142	Lagoons	LCT.14.a part	
	143	Coastal flats (beaches and mudflats)	LCT.14.b part	
	144	Coral reefs	LCT.14.b part	
Sea (interface with land)			-	-

Land Cover Types detailed classification	
LCT.1	Artificial surfaces (including urban and associated areas)
LCT.01.a	Artificial surfaces from 10 to 50 %
LCT.01.b	Artificial surfaces from 51 to 100 %
LCT.2	Herbaceous crops
LCT.02.a	Small size fields of herbaceous crops rainfed
LCT.02.b	Small size fields of herbaceous crops irrigated or aquatic (rice)
LCT.02.c	Medium to large fields of herbaceous crops rainfed
LCT.02.d	Medium to large fields of herbaceous crops irrigated or aquatic (rice)
LCT.3	Woody crops
LCT.03.a	Small size fields of woody crops
LCT.03.b	Medium to large fields of woody crops
LCT.4	Multiple or layered crops
LCT.5	Grassland
LCT.05.a	Natural grassland
LCT.05.b	Improved grassland
LCT.6	Tree covered area
LCT.06.a	Tree covered area from 10 to 30-40 %
LCT.06.b	Tree covered area from 30-40 to 70 %
LCT.06.c	Tree covered area from 70 to 100 %
LCT.7	Mangroves
LCT.8	Shrub covered area
LCT.08.a	Shrub covered area from 10 to 60 % (open)
LCT.08.b	Shrub covered area from 60 to 100 % (closed)
LCT.9	Shrubs and/or herbaceous vegetation aquatic or regularly flooded
LCT.09.a	From 2 to 4 months
LCT.09.b	More than 4 months
LCT.10	Sparsely natural vegetated areas
LCT.11	Terrestrial barren land
LCT.11.a	Loose and shifting sand and/or dunes
LCT.11.b	Bare soil, gravels and rocks
LCT.12	Permanent snow and glaciers
LCT.13	Inland water bodies
LCT.14	Coastal water bodies and inter-tidal areas
LCT.14.a	Coastal water bodies (lagoons and/or estuaries)
LCT.14.b	Inter-tidal areas (coastal flats and coral reefs)

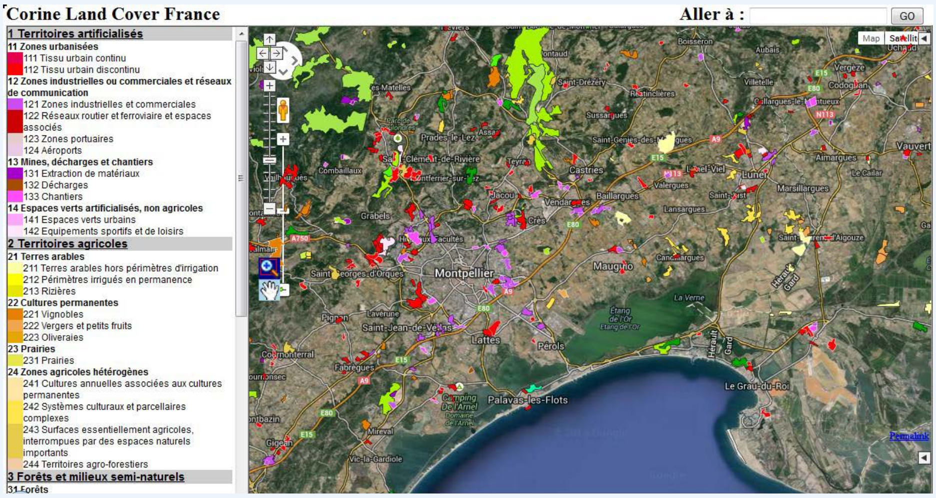
4.1.3 Land-cover mapping

In principle, the accountant will have to use land-cover maps produced nationally or internationally by mapping agencies, space agencies or related scientific programmes. However, since not all such maps are fit for accounting, requests to land-cover experts for data have to be very explicit. This may be even more important when no such data exist and a land-cover map or maps need to be produced.

An essential point is that, for accounting, **change matters as much as stocks**.

A general rule is that, in most cases, **change cannot simply be computed as the difference between two land-cover maps** at different dates. Land-cover maps have an accuracy that ranges from 60 % (low resolution automatic classifications) to 90 % or more – never 100 %. This may be acceptable for statistical purposes, but locally there are uncertainties about quality, creating noise. Errors may affect different pixels of maps produced for different dates, and the result of subtracting one map from another will add uncertainties that can then be larger than the change itself. To avoid this, it is necessary to have specific direct monitoring of change.

Box 4.03 Illustration of land-cover change 1990–2000 and 2000–2006, Montpellier region (France)

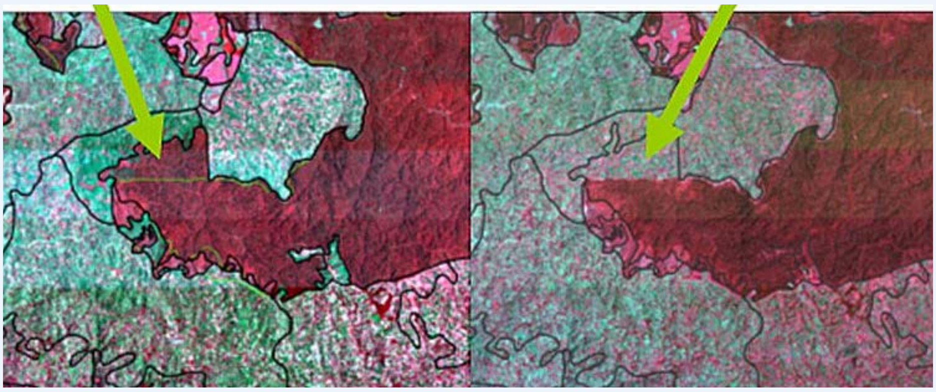


Land-cover changes 1990-2000 and 2000-2006 are grouped in this view. Change detection has been done visually by comparing maps and satellite images. It shows reforestation in the mountains, and mostly development of residentail (red) and economic areas (purple) in the plain. Some extension of arable land can be seen in yellow (east of the area).

Source: Ifen interactive CORINE Land Cover viewer at the MEDD: http://www.statistiques.developpement-durable.gouv.fr/donnees-ligne/li/1825.html (accessed 4 August 2014)

Box 4.04 Example of visual detection of land-cover change (deforestation in Kenya)

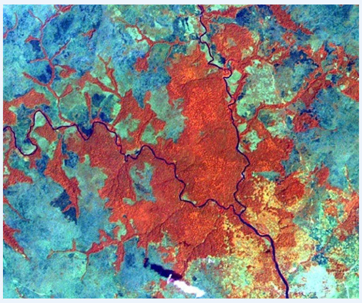
It is possible to monitor changes in land cover using remote-sensing products (see example below, Kenya, Landsat 1990/2000) where the detection of changes can be highlighted using time series of satellite images. In the right picture, the initial land-cover map (polygons) is overlaid on the new satellite image to detect change.



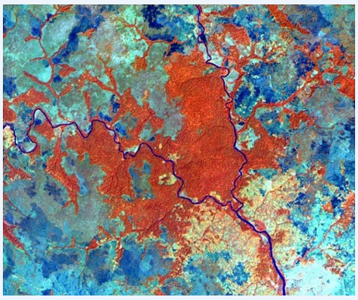
Source: FAO-GLCN http://www.glcn.org/databases/ke_change_en.jsp (accessed 14 July 2014)

Box 4.05 Example of detection of binary change forest-non forest from satellite images

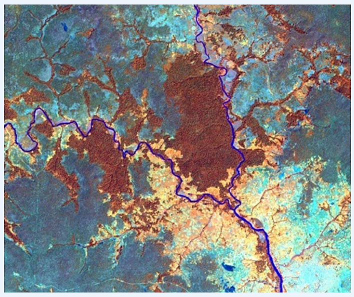
1990 (Landsat TM, 30 m resolution)

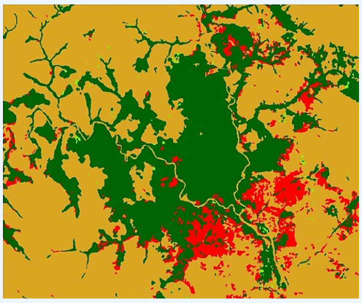


2000 (SPOT4, 20 m resolution)

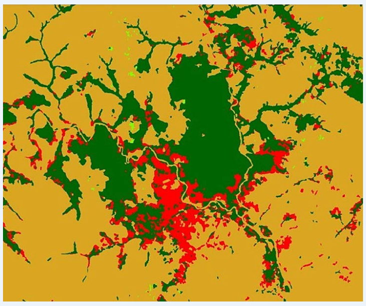


2010 (SPOT5, 10 m resolution)





Deforestation occurred between years 1990 and 2000 (red)

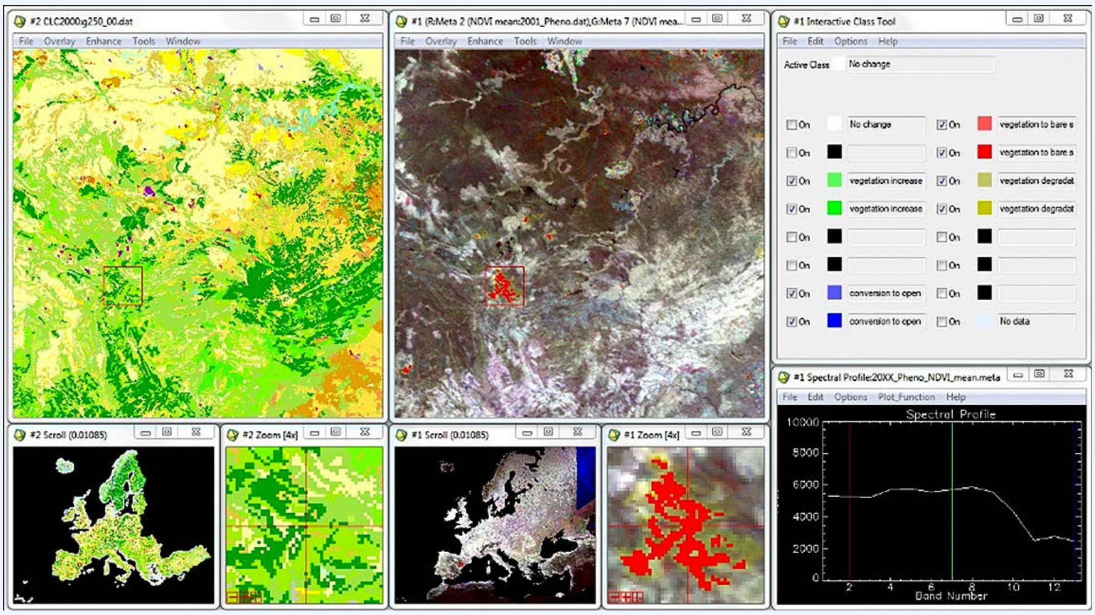


Deforestation occurred between years 2000 and 2010 (red)

The Spatial Observatory of Tropical Forest (SPOT) aims to make available the whole archive of SPOT imagery over the Congo Basin region to support REDD+ implementation and produce an analysis of historic deforestation (binary forest/non-forest classification and associated change maps, biophysical processing methodology) over three pivot dates (1990, 2000 and 2010) http://bassinducongo.reddspot.org (accessed 14 July 2014). Extract: Mambere Kadei Prefecture – Central African Republic

Research on automatic detection of change is continuing. The approach based on the Harmonic ANalysis of Time Series (HANTS) methodology (para. 4.36) aims at detecting hotspots of change. Its interest at this stage is in achieving a systematic screening and providing a first indication of the kind of change observed. In a second step, the photo-interpreter will be in a position to validate and give a more precise qualification of the change.

Box 4.06 Use of the HANTS methodology to detect hotspots of land-cover change



The screen shows the identification of a burnt forest in Spain using the HANTS methodology. The automatic step was followed by a visual interpretation of the change.

Source: Gerbert Roering and Mathis Danes, Alterra, 2013.

Figure 4.01 Monitoring of burnt areas by IKI, the Russian Space Research Institute

Source: Bartalev, S. and Loupian, E. 2012. Moderate- and high-resolution Earth Observation data based forest and agriculture monitoring in Russia using VEGA Web-Service, ESA Sentinel 2 Preparatory Symposium.
http://www.congrexprojects.com/docs/12c04_doc/1-sentinel2_symposium_bartalev.pdf?sfvrsn=2 and http://pro-vega.ru/eng/ (accessed 14 July 2014)

Other research is being carried out in Russia, based (among others) on multi-annual coverage of satellite images and the use of the LAGMA algorithm[5] (see 4.35). It allows land-cover change, such as that caused by forest fires, to be followed over several years.

As good practice, attention should be paid to the quality of change detection. A methodology – data input and classification method – which might deliver reasonably accurate maps to be used, for example, to produce DLCT and SELUs (Chapter 3) and give a coarse characterization of a region, may not be appropriate for monitoring land-cover change. It is therefore important to know the main methodological gaps or traps that need be avoided.

Several basic approaches are possible for mapping land-cover stocks and producing LCEU maps following the aggregated classification presented in section 4.1.2: visual photo-interpretation, related object-oriented automatic classification, conventional and new methodologies of automatic pixel classification, and generalization of administrative data. Problems related to the use of low-resolution satellite images need to be addressed.

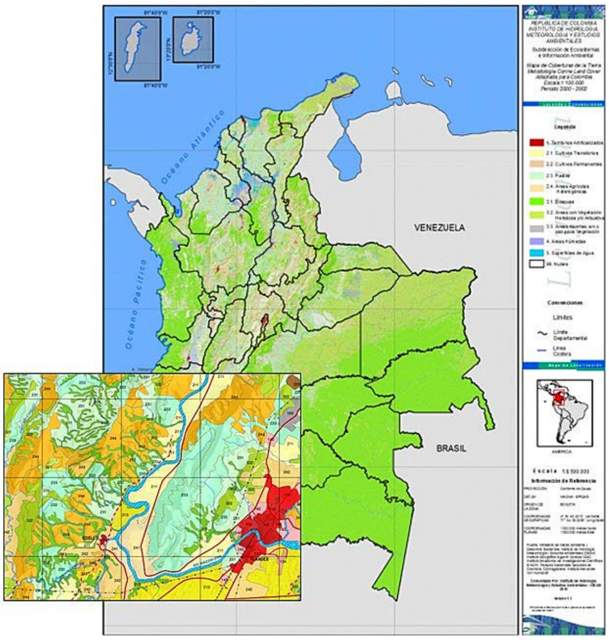
a. *Visual photo-interpretation of satellite images*

Visual photo-interpretation of satellite images is appropriate for multi-thematic land-cover classifications such as the ones needed for ecosystem accounting where the geographical objects will in most cases be landscape-like rather than pure entities that can easily be correlated with a given radiometric pixel value. The photo-interpreter is in a position to observe and delineate such landscape objects in terms of their shape, colour, texture, pattern and overall contrast in the picture, although the individual pixels may be of different colours or shades of grey. In addition, the photo-interpreter is able at any moment to check ancillary data (other maps or aerial photos) to validate the classification.

The visual photo-interpretation methodology was first developed by mapping agencies using aerial photographs and then transferred to satellite image classification. It is used in FAO-steered land-cover projects, as part of the object-oriented classification procedure, such as AFRICOVER and ASIACOVER, in the EU CORINE land cover, and in other applications such as MEDGEOBASE (Tunisia and Morocco), BDOT (Burkina Faso), and Colombia.

5 LAGMA (locally adaptive global mapping algorithm) has been developed by the Russian Academy of Sciences' Space Research Institute

Figure 4.02: Example of land-cover map produced by visual photo-interpretation – Colombia



Source: SIAC, Sistema d'Informacion Ambiental de Colombia, https://www.siac.gov.co/documentos/DOC_Portal/DOC_Suelo/20121202_Mapa_Coberturas_Tierra_Metodo_CLCC_periodo_2000-2002.pdf (accessed 14 July 2014).

This section does not aim to describe visual photo-interpretation methodology in detail: references to best practice are as follows:

FAO/Global Land Cover Network (GLCN):

- various manuals at http://www.glcn.org/pub_5_en.jsp;
- software packages at http://www.glcn.org/sof_5_en.jsp;
- Land Cover Classification System (LCCS) Version 2 (and forthcoming Version 3, LCML) which allows development of a land-cover classification according to international standards;
- GeoVIS, which features a large number of functions designed specifically to perform visual interpretation of remotely-sensed images efficiently (to be used only in FAO-related projects);
- MApping Device–Change Analysis Tool (MAD-CAT) and other tools (to be used only in FAO-related projects).

European Environment Agency: CORINE land-cover guidelines

- CORINE Land cover - Part 1: Methodology
- http://www.eea.europa.eu/publications/COR0-part1;
- CORINE Land cover - Part 2: Nomenclature
- http://www.eea.europa.eu/publications/COR0-part2;
- CORINE land cover technical guide - Addendum 2000 http://www.eea.europa.eu/publications/tech40add;
- CLC2006 technical guidelines (land cover update) http://www.eea.europa.eu/publications/technical_report_2007_17.

Columbia, IDEAM: National land cover legend: CORINE Land Cover methodology adapted to Colombia [6] http://documentacion.ideam.gov.co/openbiblio/Bvirtual/021521/LIBROCORINEFINAL.pdf

Burina Faso, Deuxième Programme National de Gestion des Terroirs/Base de données d'occupation des terres (BDOT): Evolution de l'occupation des terres entre 1992 et 2002 au Burkina Faso. http://www.fidafrique.net/IMG/pdf/BDOT_Analyse_Comptes_Langage_accessible__Janvier_2007_-2.pdf

Attempts to automate photo-interpretation have been made under the name of **object-oriented classification**. This is done in two steps: segmentation of the image into consistent areas, and classification of these areas. In that way patchy zones can be mapped as entities and the result of object-oriented classification is therefore very similar to that of a human photo-interpreter. Once calibrated, production is much faster. However, there is some instability in the segmentation of the image process, both between satellite images of different zones and between images of the same areas at different dates. For ecosystem accounting, where comparisons in space and time really

6 *IDEAM, IGAC y CORMAGDALENA. 2008. Mapa de Cobertura de la Tierra Cuenca Magdalena-Cauca: Metodología CORINE Land Cover adaptada para Colombia a escala 1:100.000. Instituto de Hidrología, Meteorología y Estudios Ambientales, Instituto Geográfico Agustín Codazzi y Corporación Autónoma Regional del río Grande de La Magdalena. Bogotá, D.C., 200p. + 164 hojas cartográficas.*

matter, this means that great care is needed when using object-oriented classification software. The FAO, which has worked in this way, uses object-oriented software packages such as GeoVIS and MadCAT[7] to support the work of photo-interpreters. The approach followed at IBGE integrates the methodology into a broader process and is presented in Section 4.1.2, e., paras. 4.45 and 4.46.

b. Use of automatic pixel classification for stocks of land cover

Automatic pixel classification, supervised with field data or unsupervised, is popular for processing satellite images since it appears to be a cheap solution. Image-processing software packages, and several generalist GIS programs, use automatic classification algorithms. The principle is to establish a correlation between a given pixel's radiometry and a land-cover type. When working on multi-thematic land-cover information with more than a very small number of classes, the difficulty of automatic pixel classifications is that the choice of a threshold for a given class has consequences for the definition of other classes. This is particularly true for pixels that are part of complex landscapes. Even if iterations and supervision lead to acceptable overall confidence (calculated statistically), the final result has more of a statistical than a cartographic meaning. It has to be used with extreme care for accounting at the level of SELUs, since pixel values are very uncertain. In all cases, automatic pixel classification requires rigorous visual quality assurance and control.

To some extent, automatic pixel classification maps can be used initially to sketch SELUs. As dominant land-cover types emerge from data aggregated in a small number of classes (Chapter 3, para. 3.47), existing datasets could be used for a preliminary test. They have in every case to be checked for possible bias such as confusion between artificial areas and bare soil. In any case change detection by simple subtraction between conventional automatic multi-thematic pixel classifications at two dates is not an option.

Several approaches allow improved results to be derived from automatic pixel classification: object-oriented classification, class-by-class detection, improved supervision, and analysis of time-series.

Object-oriented classification has been discussed with visual classification methods, since it is to some extent a modelling of these and is often used in conjunction with them (para. 4.29).

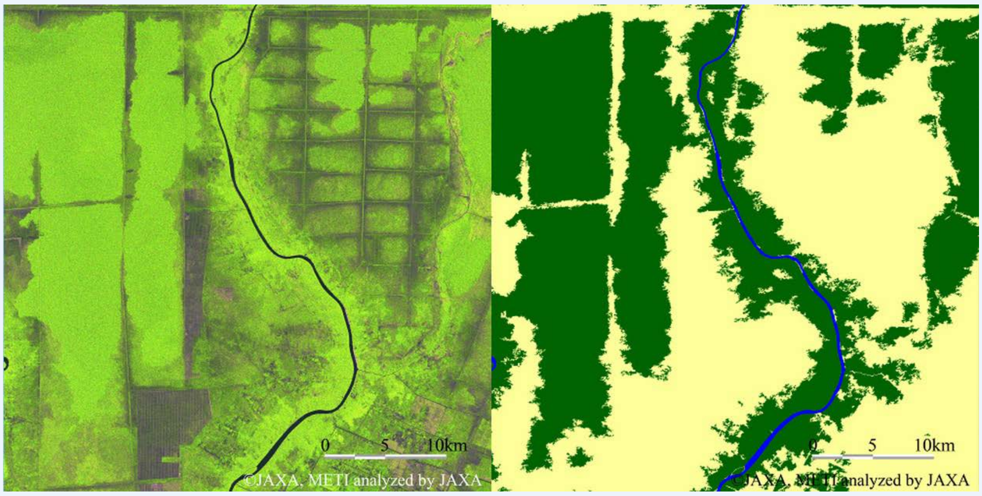
Class-by-class (binary) automatic detection is more reliable than multi-class land-cover classification. It can be implemented directly on the satellite image or after derivation of variables such as a vegetation index. It can also be applied using a mask provided by a pre-existing (validated) map. Good results have been achieved for forests, lakes and artificial areas. The binary classification indicates the existence [0,1] or the density of the theme pixel by pixel. Several examples of pixel-by-pixel classification are given below, with links, when available, to download the products:

- A: JAXA's forest/non-forest map, a view of Kalimantan;
- B: MODIS Various Continuous Fields/Forest, (percentage tree cover);
- C: Global Forest Cover (percentage tree cover, Landsat);
- D: high-resolution land cover/soil sealing;
- The "biophysical processing" methodology used for the Basin of Congo REDD+ support programme (Box 4.05) is of this type.

7 *GeoVIS is a vector-based editing system specifically designed for thematic interpretation. MAD-CAT is software mainly devoted to optimazing the production of vector polygon based maps. See http://www.geovis.net/Home.htm (accessed 16 August 2014)*

Box 4.07: Example of pixel-by-pixel classification (A)

JAXA's forest/non-forest map, a view of Kalimantan



The Japan Aerospace Exploration Agency (JAXA) has generated the world's first 10 m resolution images and maps of global forest and non-forest area distribution (in 2007 and 2009) using the Phased Array type L-band Synthetic Aperture Radar (PALSAR) aboard the advanced land observing satellite (ALOS) DAICHI.
http://www.eorc.jaxa.jp/ALOS/en/guide/forestmap_oct2010.htm (accessed 14 July 2014)

The forest/non-forest maps 2007 to 2010 at 50 m resolution can be downloaded for free for non-commercial use. It is an interesting product for tropical countries where clouds are a problem (ignored by the radar sensor).
http://www.eorc.jaxa.jp/ALOS/en/palsar_fnf/fnf_index.htm (accessed 14 July 2014)

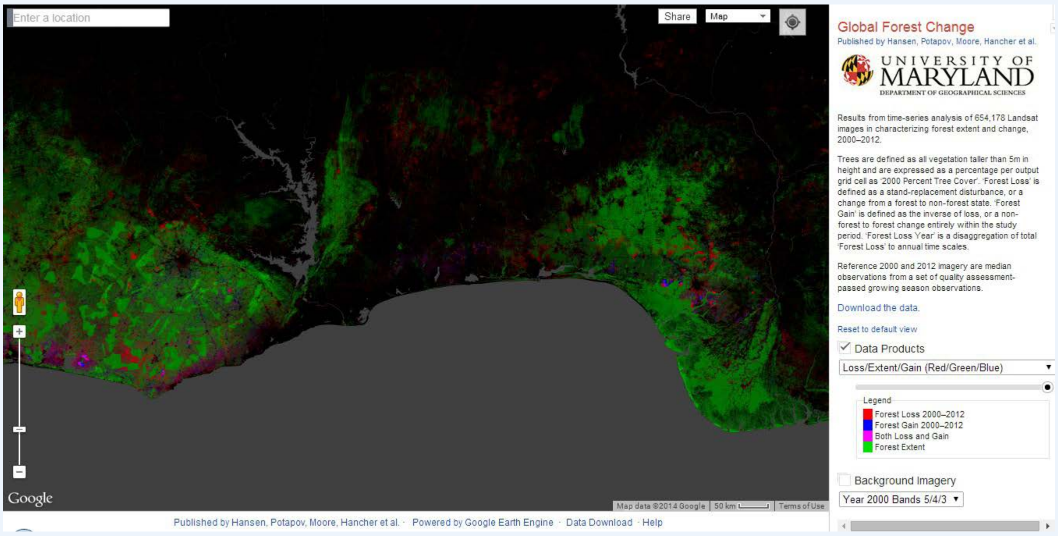
Box 4.08: Example of pixel-by-pixel classification (B)

MODIS Various Continuous Fields/ VCF Forest

Vegetation continuous fields (VCF) are proportional estimates of cover, developed from global training data derived using high-resolution imagery. The training data and phenological metrics are used with a regression tree to derive percentage cover globally.
The version currently available for downloads only contains a percentage tree-cover layer for 2000–2010. Other layers, the percentage herbaceous cover layer and the percentage bare cover layer, should become available in the near future. This product was generated from monthly composites of 250 m resolution MODIS data.
MODIS VCF is also known within the MODIS land science team as product "MOD44B". Data can be downloaded from: http://glcf.umd.edu/data/vcf/
(accessed 14 July 2014)

Box 4.09: Example of pixel-by-pixel classification (C)

Global Forest Cover (percentage tree cover)



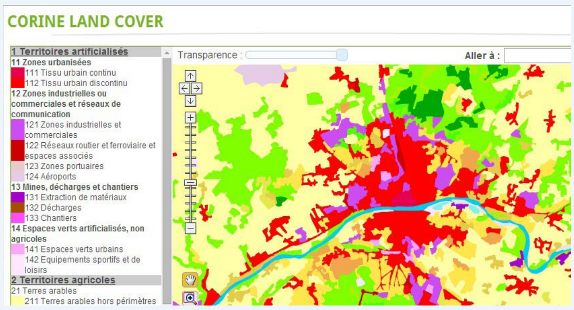
http://earthenginepartners.appspot.com/google.com/science-2013-global-forest (accessed 14 July 2014)

Results from time-series analysis of 654,178 Landsat images characterizing forest extent and change, 2000–2012.
Trees are defined as all vegetation higher than 5 m and are expressed as a percentage per output grid cell as 2000 Percent Tree Cover. Forest loss is defined as a stand-replacement disturbance, or a change from forest to non-forest state. Forest gain is defined as the inverse of loss, or non-forest to forest change entirely within the study period. Reference 2000 and 2012 imagery are median observations from a set of quality-assessed growing season observations.
NASA Goddard, based on data from Hansen *et al.*, 2013.
http://www.nasa.gov/content/goddard/nasa-usgs-landsat-data-yield-best-view-to-date-of-global-forest-losses-gains/ (accessed 14 July 2014)

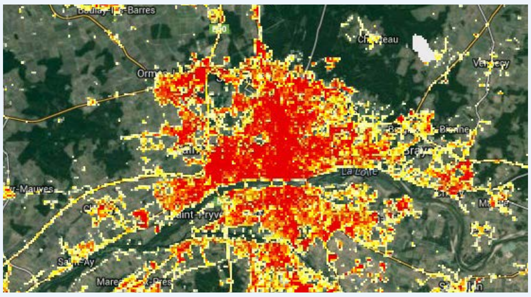
Box 4.10: Example of pixel-by-pixel classification (D)

High-resolution layer on soil sealing, Europe

CORINE Land Cover, 2006 Region of Orleans, France



The high-resolution layer on soil sealing is a product derived from the satellite images used for CORINE land cover.

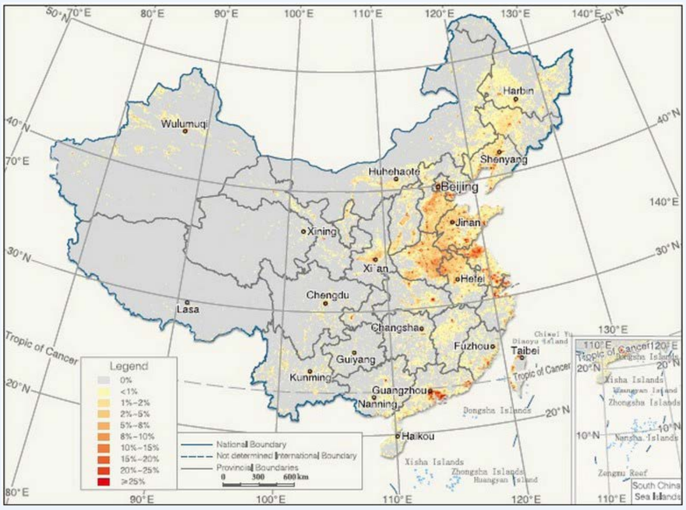


CORINE Land Cover interactive viewer at the MEDD: http://clc.developpement-durable.gouv.fr/ (accessed 24 august 2014)

This is an automatic classification produced by the COPERNICUS/GIO Land project coordinated by the European Environment Aagency. There is a very good match with the CORINE artificial classes. Within urban areas, this layer gives additional information on density.

Box 4.11: Example of pixel-by-pixel classification (D)

Dataset of global urban and rural resident land cover distribution and changes



To support global change studies and international cooperation in the Global Earth Observation System of Systems (GEOSS), the National Remote Sensing Center of China (NRSCC), has produced various datasets, including the global urban and rural resident land cover distribution and changes. The classification is based on Landsat-TM and ETM+ as well as CCD of China Satellites for Environment and Disaster Mitigation.
Data can be downloaded from the NRSCC website http://www.chinageoss.org/gee/2013/en/index.html (accessed 14 July 2014)

Figure 4.03: TerraNorte, the Vegetation cover of Russia

Sources: Russian Spatial Research Institute (IKI) http://www.iki.rssi.ru/eng/2011investig.htm and http://pro-vega.ru/eng/ (accessed 14 July 2014)

Contextual adaptive supervision – LAGMA[8]: one of the problems with automatic classification of pixels is that radiometric values are generally defined as average values for a rather large area, region or even country. Since there is variability of spatial patterns (e.g. variation of forest density), the average value may be misleading in many places and lead to confusion. One solution proposed is the LAGMA methodology, used to produce the TerraNorte map of land cover of the whole Russia by the Russian Space Research Institute (IKI). The principle is to use a locally-adaptive algorithm to recalibrate the threshold values over space in a continuous way. As with Harmonic ANalysis of Time Series (HANTS) below, multi-annual satellite images (weekly coverage) are used to correct for cloud cover and monitor the phenological cycle. This research is an example of a possible future way of streamlining the land-cover production process.

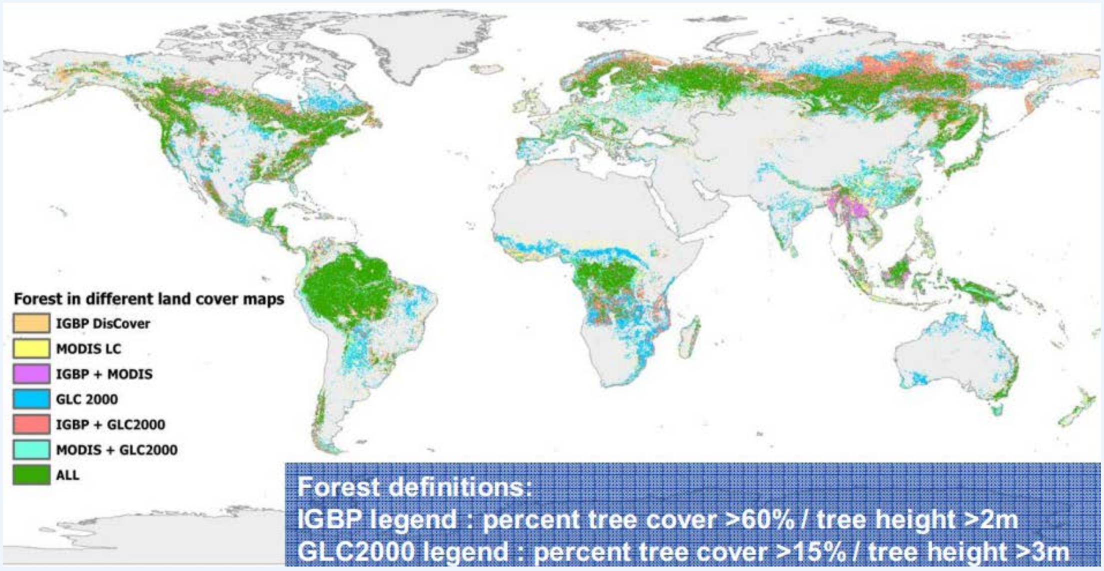
Harmonic ANalysis of Time Series (HANTS): like the approach for TerraNorte, the HANTS methodology makes use of the multi-annual deliveries of satellite

8 *LAGMA: Locally Adaptive Global Mapping Algorithm*

images, usually weekly to bi-weekly for medium- and high-resolution spatial resolution satellites. The methodology allows phenological cycles to be followed and therefore a much better analysis of vegetation types than classifications based on just one image a year. As mentioned above, anomalies (hotspots) reveal land-cover changes and can be a valuable input to analysis by photo-interpreters.

Box 4.12 Problems in the use of low-resolution images for land-cover mapping

Low-resolution satellite images are abundant but their use for land-cover accounting has to be considered with care, in particular for detecting change. Land-cover mapping with low-resolution satellite images consists in general of using automatic classification to identify different classes on the basis of their reflectance. At low resolution, elementary pixels will reflect a compound of elementary types that are difficult to disentangle – except for very homogeneous large areas. There is a difference between assimilating data collected with high resolution into a 1 km2 grid where each cell contains a statistic of land-cover types, and using satellite images with 1 km pixel resolution with an uncertain radiometry. The quality issue is critical in the case of complex landscapes. Enhanced methodologies have been tested using the repetitiveness potential of low-resolution satellites but problems remain, particularly when trying to assess land-cover change at the pixel level. The outcome of low-resolution land-cover mapping has to be understood as a statistic – and can be used as such – but is a poor pixel-by-pixel measurement, although results are often presented as printed maps. Also, the results of trying to detect change by comparing two such maps are very uncertain, even misleading. Low-resolution satellite images therefore cannot be used for land-cover accounting.
Forest land in different global land-cover data sets



Source: Di Gregorio, FAO – GLCN, LPIS Workshop, Tallinn 2009 S7_LCML_Di_Gregorio_FAO.pdf

This statement does not apply to low-resolution satellite images in general, only to the problem resulting from pixels of unknown heterogeneity when mapping land cover. For monitoring one variable only, e.g. rain or vegetation indices, low spatial resolution compensates for this limitation by the frequency of the observations, daily or more often.

Medium resolution: from empirical experience, the minimum resolution that can be used for land-cover mapping for accounting is that of the medium-resolution satellites, MODIS and MERIS being the most popular. Even in this case, one has to check how medium resolution fits the purpose of accounting in a given region. Examples of excellent maps can be found in large countries with continuous broad-pattern landscapes (as in the Russian and Brazilian examples above). For a quick start of an ENCA test, it may be advisable to use such maps – duly controlled – to produce SELUs (Chapter 3), when no more accurate land-cover map is available. Particular attention should be paid to the correct mapping of urban areas – often confused with bare soils in automatic classifications. For detection of land-cover change, automatic methodologies based on pixel-by-pixel subtractions of classified maps should in principle be avoided as it multiplies the errors. The solution is to have independent monitoring of change, based on analysis of satellite images.

c. *Cartographic sources of land-cover information*

Land-cover monitoring is done in various mapping activities at the national or regional level, in relation to cadastre urban planning, agriculture and forestry, transport, environment protection, etc. Such data can be used as a source of land-cover information for ecosystem accounting. The development of large national, regional and global geographical databases has steered standardization in order to allow interoperability in the use of various datasets on the same platform. The ISO geomatics standards, such as ISO TC 211-19144-2:2013 for land cover meta language (LCML) to which the SEEA land-cover classifications refers, are examples of such achievements.

In Europe, the INSPIRE Directive[9] of 2007 established an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities that may have an impact on the environment. Its purpose is to ensure that the spatial data infrastructures of Member States are compatible and usable in a Community and transboundary context. The Directive requires that common implementing rules are adopted in a number of specific areas: metadata, data specifications, network services, data and service sharing, and monitoring and reporting. In this context, the integration of land-cover data, produced top-down for programmes such as CORINE Land Cover and bottom-up by generalization of maps produced by the various mapping agencies, has resulted in a process which aims to create a unified framework for land monitoring. In particular the EAGLE[10] project proposes the definition of a translation matrix and an object-oriented model to allow the future bottom-up production of EU-consistent land-cover maps from large-scale national data[11] when countries are willing to do so.

d. *Use of statistics to support land-cover accounting*

Land cover, and of course land use, can be monitored by statistical surveys of different types: surveys of businesses, institutions and households, cadastre data and area sampling. Statistics can supplement land-cover data with land-use variables, can provide an efficient way to quality-assess the land-cover and change database, but can rarely replace land-cover mapping. The following chapters show that statistics of various types are important sources for ecosystem capital accounting and how they can be downscaled to the land-cover level.

Regular statistical surveys, for example by municipalities or wards, are useful in that they deliver detailed data. This is the case for agriculture censuses that are a rich source of information. Population censuses and some forest surveys are of the same type.

Cadastre data are used in several countries as a source of information on land and for land accounting. The digitization of cadastre data and geo-referencing of maps makes this a source of growing interest. Regular land-use statistics are compiled from cadastre data by the German Federal Statistical[12] office but no detailed map has so far been produced. In Queensland, Australia, land parcels extracted from the cadastre (i.e. boundaries of the land title of farms) have been used for defining LCEUs with the aim of getting a closer connection with statistical attributes such as land use and land value[13]. Although the use of cadastre data is very valuable, the national procedures used to update the cadastre database require checking. In several countries, annual updating is not systematic and is only done when a transaction on a given estate takes place.

Surveys of land cover by sampling give generally very good statistical results that can be used to check the statistical quality of maps. Generally surveys by sampling do not allow the production of maps other than some broad statistics at the regional level. The problem is that the results are meaningful either for each individual sampling point or segment, or statistically for a minimum number of observations, empirically for a cluster of around 300 in the case of sampling on a regular grid. In this case, densely represented classes, such as large-scale agriculture areas, can produce good results even for small regions. However, smaller land-cover types, which are generally important when assessing landscape diversity, have valid results only for broader areas, limiting mapping possibilities to only average values. Attempts to overcome this problem have been made by stratifying samples against land cover. Difficulties may arise when the objects monitored are not exactly the same, with sampling focussing on basic objects while mapping defines zones that are more or less heterogeneous. Observations by sampling are more attributes of the LCEUs and/or useful information to control their classification than alternative ways of mapping them.

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9 *http://inspire.ec.europa.eu/ (accessed 14 July 2014).*

10 *EAGLE - Eionet Action Group on Land monitoring in Europe. http://sia.eionet.europa.eu/EAGLE (accessed 14 July 2014)*

11 *http://www.earsel.org/symposia/2013-symposium-Matera/pdf_proceedings/EARSeL-Symposium-2013_10_2%20_Arnold.pdf (accessed 4 August 2014)*

12 *https://www.destatis.de/EN/FactsFigures/NationalEconomyEnvironment/Environment/EnvironmentalEconomicAccounting/LandUse/LandUse.html (access 14 July 2014).*

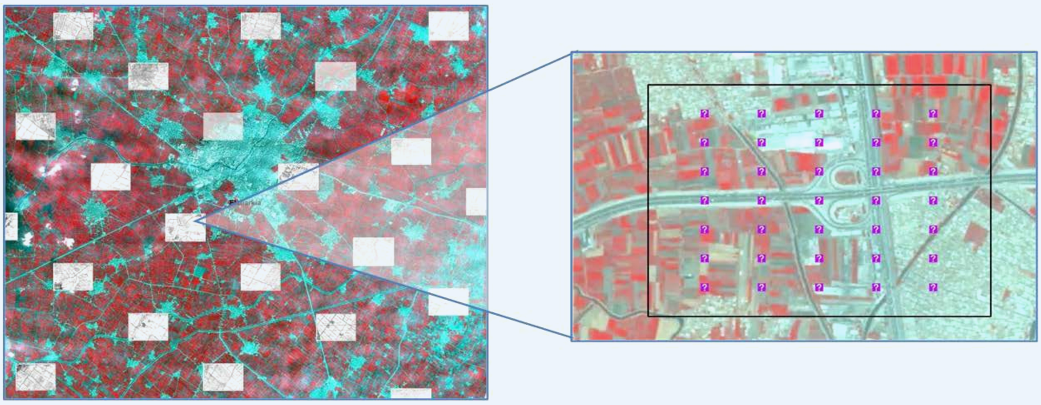
13 *See Vardon, M. (Australian Bureau of Statistics). The building blocks for accounts: basic units and lessons. Ecosystem Accounting Workshop, WAVES Partners Meeting Washington DC, 12 April 2012 http://www.wavespartnership.org/sites/waves/files/images/WAVES_SEEA%20EEA%20Workshop.pdf (accessed 14 July 2014)*

Box 4.13 Arable land monitoring and assessment of Egypt,

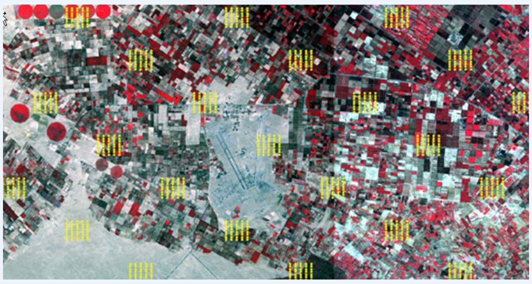
Combining sampling and analysis of satellite images and cadastral maps

Primary sampling: sampling distribution of cadastral maps

Secondary sampling units for field data collection



Assessment of primary sampling units change with satellite images Landsat 1985 and SPOT 2005



Re-classification of changes into land cover flows and compilation of accounts.

		Land cover class in 2005				
		1	2	3	4	5
Land cover class in 1985	1	Ø	LCFOTH	LCFOTH	LCFOTH	LCFOTH
	2	LCFURB	Ø	LCFNAT	LCFOTH	LCFWAT
	3	LCFURB	LCFAGR	Ø	LCFOTH	LCFWAT
	4	LCFURB	LCFAGR	LCFOTH	Ø	LCFWAT
	5	LCFURB	LCFAGR	LCFOTH	LCFOTH	Ø
LCFURB: Urbanisation						
LCFAGR: Agriculture extension						
LCFWAT: Water bodies management						
LCFNAT: Afforestation, natural and semi-natural conversion						
LCFOTH: Other or unclassified changes						

Source: Arable land monitoring and assessment project (ALMA) of the Egyptian Ministry of Agriculture/Soil Water Environment Research Institute (SWERI) and IGN-FI. 2007. http://www.ignfi.com/en/content/arable-land-monitoring-and-assessment-project-egypt-0 (accessed 14 July 2014)

Figure 4.04 Map of Brazil's land cover and land use, 2010

Source Domingues E. and Moreira M. Z. LANCOVER/LANDUSE CHANGES: Brasil 2000–2010, National Seminar of SEEA Implementation, September 2013, IBGE, Diretoria de Geociências, Rio de Janeiro, Brazil.
downloaded from http://unstats.un.org/unsd/envaccounting/workshops/Rio2013/R-N-Brazil.pdf (accessed 14 July 2014).

e. Integrated approaches to land-cover mapping

The land-cover map should not be considered as a stand-alone product but as a key feature within the information system needed for accounting. Since it will be integrated into the ecosystem assessment model at a later stage, it is important that its construction is based on the best mapping methodologies and also takes account of other information on environmental and socio-economic domains. One example is the work carried out at IBGE.

The land-cover/land-use maps produced by IBGE start from image segmentation into objects that are first automatically classified according to pixel radiometry. Changes are also detected in relation to pixel radiometry. Information from other sources is also incorporated, which is made easier by the object structure of the map and incorporation of the data in a 1 km^2 grid for accounting. This additional information relates to the forest monitoring of Amazonia (PRODES and TERRACLASS carried out by the Brazilian National Institute for Spatial Research (INPE) and the Brazilian public enterprise for agricultural research (EMBRAPA), vegetation and environmental maps, socio-economic statistical surveys, other data from satellite monitoring, and hydrological features[14]. the Brazilian Institute of Geography and Statistics has also compiled data and produced comprehensive maps of land use for 1996 and 2006 based on satellite images and on the statistics of the census of agriculture, adding other cadastral information such as areas under mining, cadastre areas of plant extraction, and data from population censuses.[15]

f. Example of a possible Quick Start methodology for land-cover mapping

In the absence of existing fit-for-purpose land-cover maps/data for accounting, it is possible to start with existing datasets in a simple way to implement the ENCA-Quick Start Package. The principle is to work class by class, and select datasets that can be translated into the LCEU classification. Commonly, maps of constructions and/or urban areas, roads, forests, agriculture, lakes, rivers, biotopes/habitats (wetlands of various types, grasslands, etc.) may be found from various agencies. Often, these maps will be on too detailed a scale regarding the definition of LCEUs. For example, detailed maps of fields will exclude lanes or small roads, fences and hedges, small ponds and small woods and sometimes isolated farms or barns that are part of the LCEU homogeneous cropland units. Also,

14 More on the IBGE methodology of land cover/land use classification in the Manual http://www.ibge.gov.br/english/geociencias/recursosnaturais/usodaterra/manual_usodaterra.shtm (accessed 14 July 2014).

15 The third version of the IBGE Land Use Technical Manual (Manual Técnico de Uso da Terra, 2013) can be downloaded in Portuguese from http://www.ibge.gov.br/home/geociencias/recursosnaturais/usodaterra/manual_usodaterra.shtm (accessed 14 July 2014).

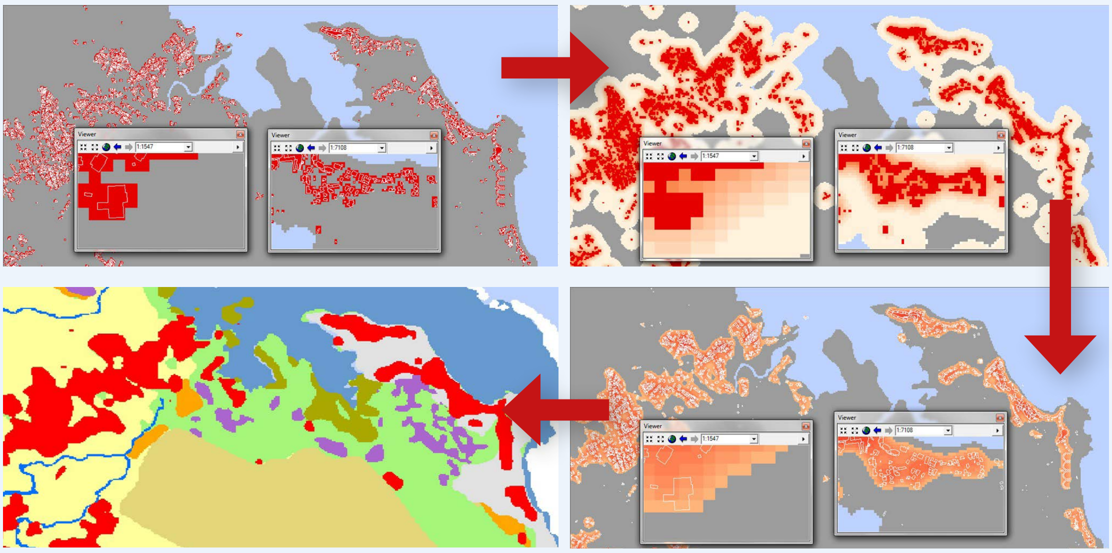
Box 4.14 Producing a land-cover map from various geographical datasets

The steps for producing a land-cover map from various geographical datasets are:

- rasterize the various vector geographical datasets; the resolution will depend on the scale of the input data; high resolution is the best choice. Use a high-resolution raster layer if available (e.g. for forests);
- smooth the raster data using a Gaussian filter (or blurring or smoothing) GIS tool;
- select an appropriate threshold for each class; the choice has to be made visually, class by class; it may be useful to produce two variants for the urban layers: dense/homogenous and dispersed;
- combine the various layers. The GIS mosaic tool will produce a pile of layers, which require definition of a priority order. The rationale is to keep track of landscape diversity and integrity and thus give priority to small areas. Mosaicking will therefore start with the largest themes. Doing this also minimizes the relative error for each class. Also, urban cover generating the highest environmental stress on ecosystems should be put on top;
- map the mosaic classes: some pixels will not be classified in the previous steps because of their mixed content. In the LCEU classification, two classes can be used: 04 Agriculture associations and mosaics, and 09 Natural vegetation associations and mosaics. These need to be separated. It is difficult to give a precise threshold value but as an empirical rule 04 should be chosen when the agriculture theme makes up more than 50 % of the threshold used for the 02 class (homogenous crops). If this condition is not met, the mosaic will be assumed to be of natural type 09;
- dissolve the isolated pixels or very small spots into adjacent areas with an automatic tool.

Box 4.15 Example of application of a Quick Start methodology in Mauritius

Rasterization of the buildings map (10 m pixels) — Smoothing of the raster file (radius: 10 x pixel size)



Final LCEU map after processing and mosaicking all layers — Visual selection of a threshold value for urban areas (here 25 %)

Source Experimental Ecosystem Natural Capital Accounts Mauritius Case Study, op. cit.

for mosaic landscapes, the accounting units have to be defined from a combination of the more characteristic of these detailed inputs, taking account of the scale of the map. The solution is to smooth[16] detailed data and define appropriate class-by-class thresholds to map LCEUs. The main steps are summarized in Box 4.14.

An illustration is given from the Mauritius case study[17]. A similar procedure has been used for some classes in the IBGE project of land-cover/land-use maps described in paras. 4.44, 4.45 (Figure 4.04).

16 *See Chapter 3, 3.2.2.*

17 *Weber, J.-L. 2014. Experimental Ecosystems Natural Capital Accounts, Mauritius Case Study, Methodology and preliminary results 2000 – 2010. Indian Ocean Commission, Mauritius.* http://commissionoceanindien.org/fileadmin/resources/Islands/ENCA_Mauritius.pdf *(accessed 5 August 2014)*

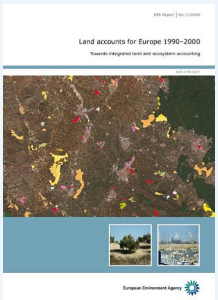
Other sources such as the NASA Global Forest Cover presented previously (Box 4.09) can be used in the same way in the process of quick production of a land-cover map.

The methodology described above to produce an LCEU map is rather simple to implement. This first map of the land-cover stock can be used in several parts of the accounting process, starting with SELU definition and as a reference layer for future classification. Indeed, since the input data are of high quality, this map is a very valuable input for classification and validation, in particular in the case of visual photo-interpretation. One limitation, however, is that because of multiple sources, the various inputs do not have a consistent update cycle. In addition, some of the maps may improve with time, making comparisons difficult. It is therefore risky to try to update the complete land-cover map, which means that a consistent monitoring of land-cover change (typically from 1990 to the present) will have to be undertaken after the Quick Start process.

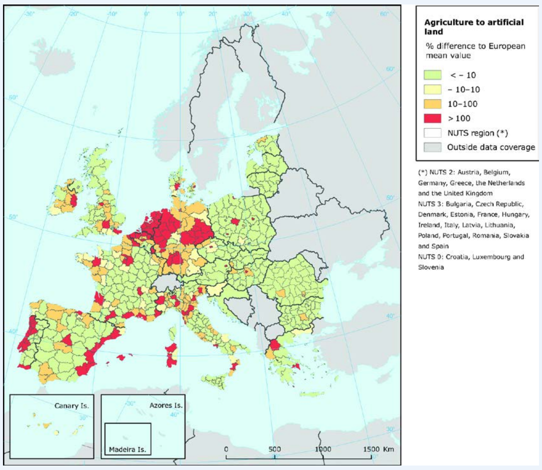
4.2 THE LAND-COVER ACCOUNTING FRAMEWORK

First land-cover accounts were published by the European Environment Agency in 2006 for 1990–2000, covering 26 countries. The sub-title of the report *Towards Integrated Land and Ecosystem Accounting* (LEAC) indicated clearly that land-cover accounts were considered as the first step in this endeavour. Land-cover accounts have been produced from CORINE land cover and updated with CORINE itself for 2006. The 2012 update is being carried out for more than 30 countries in 2014/2015.

Box 4.16 Land accounts for Europe 1990–2000 and 2006



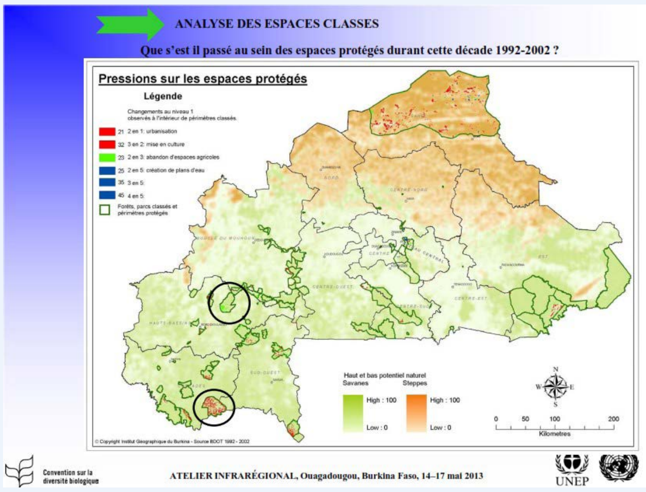
Land accounts for Europe 1990–2000, Towards integrated land and ecosystem accounting, EEA Report No 11/2006 (EN), (Drafted by Haines-Young, R. and Weber, J.-L.)
http://www.eea.europa.eu/publications/eea_report_2006_11
(accessed 14 July 2014)
Land cover accounts 1990–2000 and the 2006 update can be produced in line with the European Environment Agency viewer accessible at its website: http://www.eea.europa.eu/data-and-maps/data/data-viewers/land-accounts (accessed 14 July 2014)



Loss of land from agriculture to artificial surfaces by NUTS regions
This maps shows the deviation from average of the urban sprawl (1990-2000)

The EEA report presents an assessment of land-cover change in Europe as well as the methodology for accounting, the detailed classifications used and methodological developments such as smoothing, calculation of urban temperatures, green background landscape indices and dominant landscape types.

Box 4.17 Application of Land-cover change accounts to Protected Areas of Burkina Faso (BDOT)



The map background shows the relative importance of savannahs (pale green) and steppes (pale brown), calculated with smoothed land-cover values. In the perimeters of protected areas, overlaid colours indicate land-cover flows: red for urban development, bright green for withdrawal of farming and blue for creation of water bodies.

Sources: Adama; Jaffrain and Adama, op. cit.

In the context of the Base de Données de l'Occupation des Terres (BDOT)[18] project, the LEAC methodology has been successfully implemented in Burkina Faso, 1992–2002, with marginal adjustments of the classifications of stocks and flows[19].

4.2.1 Stocks, changes and flows of consumption and formation

The ENCA-QSP broadly follows the LEAC methodology for land-cover accounting. A particular aspect is to group the one-to-one land-cover changes between two dates into processes called land-cover flows. A similar approach has been tested by IBGE with slightly different groupings. Box 4.20 presents a comparison of the two presentations.

The stocks of land cover correspond to the surfaces of the land-cover map. These stocks are assets, or capital components, of different types. The total surface of a country only changes in a very limited way – as a result of coastal erosion – but the various covers can vary, appear or disappear.

The flows of land cover are consumption and formation. The wording uses the terminology used by SNA for consumption and formation of fixed capital. The word flow corresponds to the concept of other flows used for describing "*other change in the volume of assets*" (SNA 2008, para. 3.102). In ENCA-QSP, land-cover change is not a mere change in appearance but the combined result of human activities (land use) and natural processes on an element of the natural capital.

Flows of observable land cover do not capture all land-cover modifications due to intensive use, climate change, etc., for example when there is no change of land-cover class. Such changes will instead be described in other ENCA tables on carbon/biomass, water and landscape diversity.

18 BDOT – land-cover database

19 A complete presentation (in French) of the BDOT land cover map and accounts can be downloaded from the Convention on Biological Diversity (CBD) website: Comptabilité environnementale et utilisation des terres au Burkina Faso, by Adama, O. http://www.cbd.int/doc/meetings/im/rwim-wafr-01/other/rwim-wafr-01-adama-oumar-fr.pdf (accessed 14 July 2014).

A similar presentation in English is downloadable from the European Environment Agency website: Land cover accounts in Burkina Faso. Jaffrain G. and Adama, O. European Environment Agency, 2007 (EN) http://projects.eionet.europa.eu/leac/library/cube/land_cover/presentation_leac_burkina_faso_ppt (accessed 14 July 2014).

The flows of land cover are not simply increases or decreases of stock. They result from changes in land use and have to reflect that explicitly – which is done with the classification of land-cover flows. The land-cover flow classifications will also be used in the account of Functional Services supplied by landscape integrity and biodiversity (Chapter 7).

The land-cover matrix of transition from one date to another shows, in the case of the aggregated LCEU classification, that there are ((14 x 14)-14) = 182 possible elementary changes. When using a more detailed land-cover classification, the theoretical number of possible changes can be very large and the classification of little usefulness. With the EU CORINE land cover (44 classes) the total number of possible changes is 1,892, for Burkina Faso's BDOT (36 classes) 1,260, and FAO LCCS- based application as in Senegal (50 classes) 2,450.

The land-cover flow classification is produced from analysis of the transition matrix. Changes are grouped according to processes. In Boxes 4.18 and 4.19, colours are used to map the land-cover flow classes (coded lf xx) over the matrix (not elsewhere classified (n.e.c.)). It is important that the standard computation matrix produced by the GIS is modified slightly to produce the correct accounting matrix. In the standard computation matrix, the diagonal is devoted to no change, with the consequence that this amount varies according to the level of detail of the land-cover classifications used, increasing when aggregating. In the accounting matrix (Box 4.19), actual no change is separated from changes which are internal to a given class. Technically, the solution is to extract no change (lf0) from the diagonal and record it as an additional item in rows and columns.

Box 4.18 Aggregated land cover flows (provisional) classification (lf)

Land cover flows	
lf1	Artificial development
lf2	Agriculture development
lf3	Internal conversions, rotations
lf4	Management and alteration of forested land
lf5	Restoration and development of habitats
lf6	Changes of land-cover due to natural and multiple causes
lf7	Other land cover changes n.e.c. and reclassification
lf0	No observed land-cover change

n.e.c: non-elsewhere classified

Box 4.19 Derivation of land-cover flows from the change (transition) matrix between two dates

Year T1 / Year T0		Urban and associated developed areas	Homogeneous herbaceous cropland	Agriculture plantations, permanent crops	Agriculture associations and mosaics	Pastures and natural grassland	Forest tree cover	Shrubland, bushland, heathland	Sparsely vegetated areas	Natural vegetation associations and mosaics	Barren land	Permanent snow and glaciers	Open wetlands	Inland water bodies	Coastal water bodies and inter-tidal areas	Sea (interface with land)	Total Consumption of land cover	No Change	TOTAL t1
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15		99	
Urban and associated developed areas	01	lf3	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf7	lf1	lf6	lf6		lf0	
Homogeneous herbaceous cropland	02	lf1	lf3	lf3	lf5	lf5	lf5	lf5	lf5	lf5	lf6	lf7	lf5	lf1	lf6	lf6		lf0	
Agriculture plantations, permanent crops	03	lf1	lf3	lf3	lf5	lf5	lf5	lf5	lf6	lf5	lf6	lf7	lf5	lf1	lf6	lf6		lf0	
Agriculture associations and mosaics	04	lf1	lf2	lf2	lf3	lf5	lf5	lf5	lf6	lf5	lf6	lf7	lf5	lf1	lf6	lf6		lf0	
Pastures and natural grassland	05	lf1	lf2	lf2	lf2	lf3	lf5	lf5	lf6	lf5	lf6	lf7	lf5	lf1	lf6	lf6		lf0	
Forest tree cover	06	lf1	lf2	lf2	lf2	lf4	lf3	lf4	lf4	lf4	lf4	lf7	lf4	lf1	lf6	lf6		lf0	
Shrubland, bushland, heathland	07	lf1	lf2	lf2	lf2	lf6	lf5	lf3	lf6	lf6	lf6	lf7	lf6	lf1	lf6	lf6		lf0	
Sparsely vegetated areas	08	lf1	lf2	lf2	lf2	lf2	lf5	lf6	lf3	lf6	lf6	lf7	lf6	lf1	lf6	lf6		lf0	
Natural vegetation associations and mosaics	09	lf1	lf2	lf2	lf2	lf2	lf5	lf6	lf6	lf3	lf6	lf7	lf6	lf1	lf6	lf6		lf0	
Barren land	10	lf1	lf2	lf2	lf2	lf2	lf5	lf6	lf6	lf5	lf3	lf7	lf6	lf1	lf6	lf6		lf0	
Permanent snow and glaciers	11	lf1	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf3	lf6	lf6	lf6	lf6		lf0	
Open wetlands	12	lf1	lf2	lf2	lf2	lf2	lf5	lf6	lf6	lf6	lf6	lf7	lf3	lf6	lf6	lf6		lf0	
Inland water bodies	13	lf1	lf2	lf2	lf2	lf2	lf5	lf6	lf6	lf6	lf6	lf7	lf6	lf3	lf6	lf6		lf0	
Coastal water bodies and inter-tidal areas	14	lf1	lf6	lf6	lf6	lf6	lf5	lf6	lf6	lf6	lf6	lf7	lf6	lf6	lf3	lf6		lf0	
Sea (interface with land)	15	lf1	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf6	lf3		lf0	
Total Formation of land cover																			
No Change	99	lf0	lf0	lf0	lf0	lf0	lf0	lf0	lf0	lf0	lf0	lf0	lf0	lf0	lf0	lf0			
TOTAL t2																			

4.2.2 Classification of flows, aggregation issues (recording internal flows)

The classification of land-cover flows takes into account the practical possibility of interpreting the information provided by land-cover observations at two dates. Flows can generally be related to anthropogenic activities, but in some cases uncertainties result from the fact that change results from a combination of many causes, natural and human; a special category is necessary for these.

lf1 – Artificial development

Artificial development includes sprawl or extension of urban and associated areas, transport infrastructures, economic activity areas, and associated areas such as green urban areas and sports facilities, and mines, quarries and waste landfills.

Creation of water bodies that change land cover dramatically is also lf1.

The main categories of lf1 are:

- artificial development over agricultural land;
- artificial development over forests;
- artificial development of other natural land cover.

Conversions within urban areas are not included here but recorded in lf3.

lf2 - Agriculture development

Agriculture development includes conversion of forests, and natural and semi-natural land to agriculture. Conversion from small-scale agriculture, with associations of crops, mosaics and small linear features, to homogeneous cropland (farmland restructuring) is lf2.

If2 can be described according to the land-cover types consumed, for example as:

- conversion from small-scale/mosaic farmland to large-scale agriculture;
- conversion from grassland to agriculture;
- conversion from forest to agriculture;
- conversion from marginal land to agriculture.

Conversions between crops are internal to agriculture and are not included here but recorded in lf3.

lf3 – Internal conversions and rotations

Internal conversions and rotations (lf3) are changes which can be observed within land-cover classes: artificial, urban, forest and other types. They require observation of detailed land-cover classes.

Internal conversions can be detailed according to specific changes in the areas:

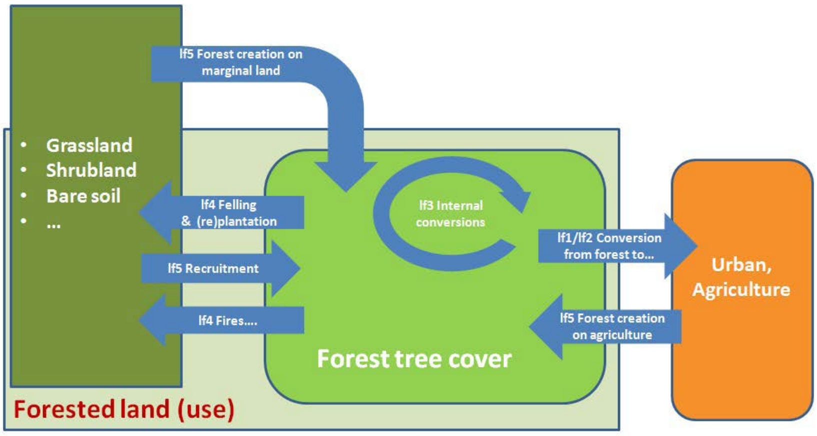
- internal conversion of artificial surfaces: reclamation of brown-field sites, development of green urban areas, or conversion of dwellings to offices or industrial buildings into apartments;
- internal conversion between agriculture crop types: extension of irrigation systems, conversion between herbaceous and shrub/tree permanent crops. Crop rotations can be recorded as lf3; Conversions between homogeneous cropland and agricultural mosaics or pasture/grassland are not recorded in lf3 but in lf2 (intensification of use) or lf5 (extensification);
- internal conversion between forest types: conversions between evergreen and deciduous, shifts between mono-specific and homogeneous stands;
- internal conversions of natural and semi-natural land types which can be observed at a detailed level.

If3 will appear in land-cover accounts when detailed data are aggregated into broader classes, in which case they are recorded in the diagonal of the change matrix. In accounts directly generated from the LCEU 15 classes, lf3 will only be used in a first step to record changes between herbaceous and woody agricultural cropland. However, lf3 can also be introduced into the accounting tables on the basis of additional statistical information, in which case accounts are balanced with a reduction of no observed change (lf0) equal to the introduced lf3. For these reasons, ENCA presents two different change matrices: the computational matrix which results from the processing of two land-cover maps, and the accounting matrix where actual no changes are recorded not in the diagonal (reserved for lf3 aggregations) but in rows and columns.

lf4 Management and alteration of forested land

Forest management refers to long time-spans with a succession of steps. Depending on the frequency of accounting, all steps are described (annual accounts) or intermediate steps are consolidated. Also, forests are socio-ecological systems that include areas with forest-tree cover (LCF06) and other areas that are managed by foresters and are considered as part of forests in a land-use sense. This distinction is reflected in land-cover accounts. Processes involving forests are recorded in all land-cover aggregated flows.

Figure 4.05 Land-cover accounts and forests



If4 includes the effects of regular forest management, in particular tree felling whether or not followed by replanting. It is observed as a shift from tree cover to various classes of used (artificial and agriculture) or non-used land cover (bare soil, grass, shrub, etc.), in the latter case temporarily considered as still part of forests in a land-use sense. Forest creation on (non-forest) marginal land and recruitment from the growth of young trees which are part of the forested land (Figure 4.05) are both recorded in the same class (lf5).

Forest management includes protection from hazards and restoration after damage. Forest tree-cover degradation by fire, wind and pests is therefore recorded in the same aggregated class as tree felling[20].

Lf5 – Restoration and development of habitats

Restoration and development of habitat groups represents flows resulting from anthropogenic processes. The main items are:

- conversion from crops to set-aside, fallow land and pasture;
- conversion from cropland to sparse and other natural vegetation in the context of shifting cultivation;
- landscape restoration (hedgerows replanting, etc.);
- withdrawal of farming;
- forest creation, afforestation of agricultural land;
- forest creation, afforestation of marginal land;
- forest recruitment.

lf6 - Changes of land cover due to natural and multiple causes

In many cases, land-cover flows cannot be clearly allocated to a particular human activity. This is the case with change driven by climate change regarding temperature, rainfall regime and hazards such as storms. For managed forests, damage is classified as lf4 (management and alteration of forested land) and development as lf5 (restoration and development of habitats). Unmanaged natural transitions are recorded in lf6. Main lf6 flows are:

- effects of climatic anomalies: droughts, seasonal regimes, etc.;
- effects of climatic and other hazards (except effects on forests): storms, floods, landslides;
- coastal erosion;
- melting of permanent snow and glacier;
- volcanic eruptions, earthquakes, tsunamis;
- indirect effects of overexploitation of natural resource (e.g. progressive degradation by overgrazing or slash-and-burn agriculture);
- natural transitions in unmanaged land.

lf7 Other land-cover changes not elsewhere classified (n.e.c.) and revaluation

This class records unlikely changes such as conversion of urban areas, and permanent snow and glaciers to agriculture or forest. Revaluation is also recorded in lf7. It corresponds to changes in classification due to errors in the initial database. As long as the initial database is not revised and upgraded, such false change is recorded as revaluation. Once revision is done, revaluation will be reclassified, generally as no observed change.

A second level of detail can be introduced in the land-cover flows classification. It has to be decided according to needs and will require a more detailed land-cover classification to implement it. Annex II gives an example as an illustration.

20 *There is a difference here from the approach of IPCC/LULUCF where fires that are independent of any anthropogenic cause are excluded. The point will be taken in the biomass/carbon account where the two types of fire will be distinguished.*

Box 4.20 Land-cover/Land-use change classification by processes – an IBGE approach

The classification IBGE uses of one-to-one change is very similar to the land-cover flows of the ENCA-QSP land-cover account. In both cases the methodology starts from systematic analysis of each single cell of the matrix of transitions between two dates. The grouping of individual changes is done in both cases according to processes similar to those described in ENCA-QSP. Broad categories of formation/expansion, consumption/retraction are acknowledged in both classifications as well as restoration/regeneration. Both contain a revaluation item for changes that are unlikely to happen and the correction of errors of interpretation. The absence of observable change at the scale of the map produced is clearly recorded in both cases as no observable change/maintenance. Change of mixed areas is addressed in the same way by identifying the main process involved.

IBGE provisional classification:	
Expansion of artificial areas	Agricultural retraction
Agricultural expansion	Retraction of agriculture in forest area
Expansion of agriculture over forest areas	Retraction of agriculture in grassland area
Expansion of agriculture over grassland areas	Retraction of livestock grazing in grassland area
Expansion of forest plantations	Retraction of planted pasture
Expansion of livestock grazing	Retraction of livestock grazing
Expansion of agriculture over forest plantations	
Expansion of water bodies over artificial areas	Regeneration of forests
Expansion of water bodies over agriculture areas	Regeneration of grassland
Expansion of water bodies over planted pasture	
Expansion of water bodies over forest areas	Revaluation
Expansion of water bodies over grassland areas	
Expansion of water bodies over bare land	Maintenance

Differences exist between the two provisional classifications. Comparing the indicative presentation of land-cover flows at level 2 (Chapter 4, Annex II) with the IBGE classification of processes shows a different focus on some themes. This is particularly the case for the creation of water bodies that is one sub-class of artificial development in the lf nomenclature but presented separately and detailed in six classes in the IBGE classification. Since it can be checked with the transition matrix presented in Box 4.19, this detail can be easily retrieved if necessary and introduced as an additional level in the lf classification. Other differences result from the fact that the land-cover/land-use map produced by IBGE is more inclusive than conventional land-cover maps. Indeed, it merges land cover with exogenous spatial information on land use that allows the recording of internal agriculture conversions in a more complete way than by only observing land cover and changes in grassland management and use for grazing. The QSP sticks at this stage to regular land-cover information, but if more advanced geographical data on land use are available, their inclusion in the land-cover account has to be considered.

4.2.3 Template

The SEEA-ENCA template for land-cover accounts at the aggregated level is presented in Accounting table 4-I.

Accounting table 4-I Template for land-cover accounts at the aggregated level

Land Cover Ecosystem Classes (LCEU)		01	02	03	04	05	06	07	08	09	10	11	12	13	14	Sea (interface with land)	Total
Land cover stocks and flows		Urban and associated developed areas	Homogeneous herbaceous cropland	Agriculture plantations, permanent crops	Agriculture associations and mosaics	Pastures and natural grassland	Forest tree cover	Shrubland, bushland, heathland	Sparsely vegetated areas	Natural vegetation associations and mosaics	Barren land	Permanent snow and glaciers	Open wetlands	Inland water bodies	Coastal water bodies and inter-tidal areas		
Opening stock																	
F_lf1	Artificial development																
F_lf2	Agriculture development																
F_lf3	Internal conversions, rotations																
F_lf4	Management and alteration of forested land																
F_lf5	Restoration and development of habitats																
F_lf6	Changes of land-cover due to natural and multiple causes																
F_lf7	Other land cover changes n.e.c. and reclassification																
Total formation of land cover																	
C_lf1	Artificial development																
C_lf2	Agriculture development																
C_lf3	Internal conversions, rotations																
C_lf4	Management and alteration of forested land																
C_lf5	Restoration and development of habitats																
C_lf6	Changes of land-cover due to natural and multiple causes																
C_lf7	Other land cover changes n.e.c. and reclassification																
Total consumption of land cover																	
Net change in land cover (formation - consumption)																	
No change																	
Closing stock																	

The table can be subdivided in two ways: LCEU and/or lf classifications. Annex III gives an example of a table combining aggregated land-cover flows and detailed LCEU classification.

4.3 PRODUCING AND ANALYSING LAND-COVER ACCOUNTS

4.3.1 Computing land-cover flows from land-cover tables

Once consistent digital maps of land-cover stocks and changes are available in a raster format, extracting land-cover accounts is quite straightforward. The task consists of assigning land-cover change values to the cells of the assimilation grid (Chapter 3) chosen for integrating the ecosystem accounts. This means creating a table with grid cell IDs and attributes of land-cover and land-cover flows.

Computing the transition matrix from two land-cover tables requires a table to code all the pairs of changes occurring in each cell. This is called a flatmatrix. It can be produced with modules or tools available in several GIS packages. An example of a flatmatrix for aggregated LCEU and lf is given in Box 4.19.

Box 4.21: Flatmatrix level 1

LC_t1	LC_t2	LCFlow
01	01	NC
01	02	lf7
01	03	lf7
01	04	lf7
01	05	lf7
01	06	lf7
01	07	lf7
01	08	lf7
01	09	lf7
01	10	lf7
01	11	lf7
01	12	lf7
01	13	lf1
01	14	lf6
01	15	lf6
02	01	lf1
02	02	NC
02	03	lf3
02	04	lf5
02	05	lf5
02	06	lf5
02	07	lf5
02	08	lf5
02	09	lf5
02	10	lf6
02	11	lf7
02	12	lf5
02	13	lf1
02	14	lf6
02	15	lf6

LC_t1	LC_t2	LCFlow
03	01	lf1
03	02	lf3
03	03	NC
03	04	lf5
03	05	lf5
03	06	lf5
03	07	lf5
03	08	lf6
03	09	lf5
03	10	lf6
03	11	lf7
03	12	lf5
03	13	lf1
03	14	lf6
03	15	lf6
04	01	lf1
04	02	lf2
04	03	lf2
04	04	NC
04	05	lf5
04	06	lf5
04	07	lf5
04	08	lf6
04	09	lf5
04	10	lf6
04	11	lf7
04	12	lf5
04	13	lf1
04	14	lf6
04	15	lf6

LC_t1	LC_t2	LCFlow
05	01	lf1
05	02	lf2
05	03	lf2
05	04	lf2
05	05	NC
05	06	lf5
05	07	lf5
05	08	lf6
05	09	lf5
05	10	lf6
05	11	lf7
05	12	lf5
05	13	lf1
05	14	lf6
05	15	lf6
06	01	lf1
06	02	lf2
06	03	lf2
06	04	lf2
06	05	lf4
06	06	NC
06	07	lf4
06	08	lf4
06	09	lf4
06	10	lf4
06	11	lf7
06	12	lf4
06	13	lf1
06	14	lf6
06	15	lf6

LC_t1	LC_t2	LCFlow
07	01	lf1
07	02	lf2
07	03	lf2
07	04	lf2
07	05	lf6
07	06	lf5
07	07	NC
07	08	lf6
07	09	lf6
07	10	lf6
07	11	lf7
07	12	lf6
07	13	lf1
07	14	lf6
07	15	lf6
08	01	lf1
08	02	lf2
08	03	lf2
08	04	lf2
08	05	lf2
08	06	lf5
08	07	lf6
08	08	NC
08	09	lf6
08	10	lf6
08	11	lf7
08	12	lf6
08	13	lf1
08	14	lf6
08	15	lf6

LC_t1	LC_t2	LCFlow
09	01	lf1
09	02	lf2
09	03	lf2
09	04	lf2
09	05	lf2
09	06	lf5
09	07	lf6
09	08	lf6
09	09	NC
09	10	lf6
09	11	lf7
09	12	lf6
09	13	lf1
09	14	lf6
09	15	lf6
10	01	lf1
10	02	lf2
10	03	lf2
10	04	lf2
10	05	lf2
10	06	lf5
10	07	lf6
10	08	lf6
10	09	lf5
10	10	NC
10	11	lf7
10	12	lf6
10	13	lf1
10	14	lf6
10	15	lf6

LC_t1	LC_t2	LCFlow
11	01	lf1
11	02	lf6
11	03	lf6
11	04	lf6
11	05	lf6
11	06	lf6
11	07	lf6
11	08	lf6
11	09	lf6
11	10	lf6
11	11	NC
11	12	lf6
11	13	lf6
11	14	lf6
11	15	lf6
12	01	lf1
12	02	lf2
12	03	lf2
12	04	lf2
12	05	lf2
12	06	lf5
12	07	lf6
12	08	lf6
12	09	lf6
12	10	lf6
12	11	lf7
12	12	NC
12	13	lf6
12	14	lf6
12	15	lf6

LC_t1	LC_t2	LCFlow
13	01	lf1
13	02	lf2
13	03	lf2
13	04	lf2
13	05	lf2
13	06	lf5
13	07	lf6
13	08	lf6
13	09	lf6
13	10	lf6
13	11	lf7
13	12	lf6
13	13	NC
13	14	lf6
13	15	lf6
14	01	lf1
14	02	lf6
14	03	lf6
14	04	lf6
14	05	lf6
14	06	lf5
14	07	lf6
14	08	lf6
14	09	lf6
14	10	lf6
14	11	lf7
14	12	lf6
14	13	lf6
14	14	NC
14	15	lf6

LC_t1	LC_t2	LCFlow
15	01	lf1
15	02	lf6
15	03	lf6
15	04	lf6
15	05	lf6
15	06	lf6
15	07	lf6
15	08	lf6
15	09	lf6
15	10	lf6
15	11	lf6
15	12	lf6
15	13	lf6
15	14	lf6
15	15	NC

4.3.2 Finalising the accounts

Once the tables are in place, they can be searched in order to produce land-cover accounts according to various reporting units: administrative regions, river basins, specific geographic zones (e.g. coastal zones or mountains), protected areas, etc.

Before analysis, a validation step is needed. Different methods can be considered such as visual comparisons of maps or statistical analysis of trends to detect anomalies. If exogenous sources are available (cadastre, area sampling surveys, etc.), they may be used to assess the accuracy of results obtained at a regional level.

Additional enhancements can be introduced directly into the accounts. They may refer for example to lf3 – internal conversions and rotations. Although not mappable at the scale of the accounting grid, some surveys with data at the local level (e.g. agriculture or population censuses) may provide additional information (e.g. agriculture change in crop types or built-up densification in urban areas) that can be introduced directly into the accounts using lf3.

4.3.3 Managing the land-cover accounts database

Managing the land-cover accounts database can be done with the tools available in the organization in charge of accounting. Cloud computing is likely to be an option for the future – although there is as yet no experience.

An illustration of what land accounts might look like is given in Table 4.01[21]. It has been produced from the database and OLAP cube[22] computed from conversion of European CORINE Land Cover 1990, 2000 and 2006 and production of LEAC tables as a test of the SEEA-ENCA land-cover accounts classifications.

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21 By courtesy of the European Environment Agency European Topic Centre on Spatial Information Analysis, Internal report

22 OLAP is an acronym for online analytical processing. A cube can be considered a generalization of a three-dimensional spreadsheet; it is a shortcut for multidimensional datasets, given that data can have an arbitrary number of dimensions. An OLAP cube can be queried from a spreadsheet or a pivot table that allows the rapid production of statistical tables with a variety of presentations. Because of its versatility, the OLAP technology is used, in particular for financial analysis, and proves to be very convenient for dealing with land and ecosystem accounts.

Table 4.01 Example for land cover account 2000-2006 for three European Biogeographical Regions

Areas in km^2

	01	02	03	04	05	06	07	08	09	10	11	12	13	14		
LCEU classes / Land cover flows	Urban and associated developed areas	Homogeneous herbaceous cropland	Agriculture plantations, permanent crops	Agriculture associations & mosaics	Pastures and natural grassland	Forest tree cover	Shrubland, bushland, heathland	Sparsely vegetated areas	Natural vegetation associations & mosaics	Barren land	Permanent snow and glaciers	Open wetlands	Inland water bodies	Coastal water bodies and intertidal area	Sea	Total
Alpine biogeographical region																
Opening Stock (2000)	8354	12621	1323	19807	54419	233627	71642	83138	21160	38080	5620	23648	17436	73	1696	593034
F_lf1 Artificial development	122												1			123
F_lf2 Agriculture development		15		58	4											77
F_lf3 Internal conversions, rotations	6	2	1	8	1	38							0			56
F_lf4 Management and alteration of forested land					10		1	1	1200	1		1				1213
F_lf5 Restoration and development of habitats				3	14	334	0		33							383
F_lf6 Changes of land-cover due to natural and multiple causes					1		4	1	5	93		0	0			105
F_lf7 Other land cover changes n.e.c. and revaluation		1		1	1				0							2
Total formation of land cover	128	18	1	69	30	372	5	2	1238	94		1	1			1959
C_lf1 Artificial development		16	1	17	32	43	5	1	6			2				123
C_lf2 Agriculture development				4	59	2			9	3		0				77
C_lf3 Internal conversions, rotations	6	1	2	8	1	38							0			56
C_lf4 Management and alteration of forested land						1213										1213

	01	02	03	04	05	06	07	08	09	10	11	12	13	14		
C_lf5 Restoration and development of habitats		12	2	6	45		0	0	316	1		0	0			383
C_lf6 Changes of land-cover due to natural and multiple causes				0	1		9	1	0	5	87	0	0			105
C_lf7 Other land cover changes n.e.c. and revaluation	2															2
Total consumption of land cover	9	29	6	34	139	1296	14	2	331	8	87	2	1			1959
Net change in land cover (= Formation - Consumption)	120	-11	-5	35	-109	-924	-9	-1	907	86	-87	-2	0			
lf0 No observed land-cover change	8345	12592	1317	19773	54280	232331	71627	83136	20828	38072	5533	23645	17435	73	1696	590683
Closing stock (2006)	8473	12610	1318	19842	54310	232703	71632	83138	22066	38166	5533	23646	17437	73	1696	592642
Atlantic biogeographical region																
Opening Stock (2000)	56339	241179	5034	86298	197856	136213	43566	19104	18851	4097	44	30203	11574	2404	7055	859819
F_lf1 Artificial development	1607												51			1657
F_lf2 Agriculture development		143	2	78	19											242
F_lf3 Internal conversions, rotations	329	9	2	3	19	51	0					18				430
F_lf4 Management and alteration of forested land					38		29		2719	50		9				2845
F_lf5 Restoration and development of habitats				13	68	1986	3		307			42				2419
F_lf6 Changes of land-cover due to natural and multiple causes		10	0	12	80	13	106	7	306	77		21	4	134	1	769
F_lf7 Other land cover changes n.e.c.		38	0	9	33	5	5	2	19			1				113
Total formation of land cover	1936	200	4	115	257	2055	143	9	3351	127		90	55	134	1	8476
C_lf1 Artificial development	9	678	6	298	487	92	31	3	28	0		4	3	3	15	1657

	01	02	03	04	05	06	07	08	09	10	11	12	13	14		
C_lf2 Agriculture development				25	135	32	3	3	25	6		11	2			242
C_lf3 Internal conversions, rotations	329	3	8	3	19	51	0					18				430
C_lf4 Management and alteration of forested land						2845										2845
C_lf5 Restoration and development of habitats		90	1	110	272		20	0	1816	99		10				2419
C_lf6 Changes of land-cover due to natural and multiple causes	1	1	0	1	8	0	59	6	49	52		267	6	1	318	769
C_lf7 Other land cover changes n.e.s.	113															113
Total consumption of land cover	452	772	14	437	921	3021	112	12	1919	157		310	12	3	334	8476
Net change in land cover (= Formation - Consumption)	1484	-572	-10	-322	-664	-966	31	-3	1432	-30		-220	43	130	-333	
lf0 No observed land-cover change	55887	240407	5020	85861	196935	133192	43453	19092	16933	3941	44	29893	11562	2401	6722	851343
Closing stock (2006)	57823	240606	5025	85976	197192	135247	43597	19101	20284	4067	44	29983	11617	2534	6722	859819
Mediterranean biogeographical region																
Opening Stock (2000)	26503	233671	73198	185587	57772	213958	82959	33227	96316	7878		2710	6264	1395	4389	1025828
F_lf1 Artificial development	2011												266			2277
F_lf2 Agriculture development		474	324	659	91											1549
F_lf3 Internal conversions, rotations	481	696	1108	37	4	62	8			2		2	14	1		2413
F_lf4 Management and alteration of forested land					52		148	14	5616	474		0				6304
F_lf5 Restoration and development of habitats				254	16	1948	95	2	1563			5				3883
F_lf6 Changes of land-cover due to natural and multiple causes		1		0	135	1	417	36	622	430		4	5	0	2	1654

	01	02	03	04	05	06	07	08	09	10	11	12	13	14		
F_lf7 Other land cover changes n.e.c.		16	11	15	16	6	4	5	21	0		0				94
Total formation of land cover	2492	1186	1444	965	313	2016	672	58	7822	907		12	285	1	2	18175
C_lf1 Artificial development	10	768	230	524	179	196	180	37	133	9		3	3	0	7	2277
C_lf2 Agriculture development				334	192	228	224	94	408	47		16	6			1549
C_lf3 Internal conversions, rotations	481	1716	88	37	4	62	8			2		2	14	1		2413
C_lf4 Management and alteration of forested land						6304										6304
C_lf5 Restoration and development of habitats		526	67	272	293		19	1	1814	891			0			3883
C_lf6 Changes of land-cover due to natural and multiple causes	1	4	1	11	21		962	28	289	321		6	4	1	3	1654
C_lf7 Other land cover changes n.e.s.	94															94
Total consumption of land cover	586	3013	386	1177	689	6790	1393	160	2644	1270		27	27	3	10	18175
Net change in land cover (= Formation - Consumption)	1906	-1827	1058	-212	-376	-4774	-720	-102	5178	-364		-15	259	-1	-8	
lf0 No observed land-cover change	25917	230658	72812	184410	57083	207168	81566	33067	93672	6608		2683	6237	1392	4379	1007652
Closing stock (2006)	28409	231844	74255	185374	57396	209185	82239	33124	101494	7515		2695	6523	1394	4381	1025828

Coverage: EEA Member Countries (no data for Greece), 2000-2006 – Data source: European Environment Agency. CORINE and LEAC data in the EEA classification are accessible at http://www.eea.europa.eu/data-and-maps/data/data-viewers/land-accounts (accessed 5 August 2014) Conversion to ENCA-QSP classification done by the EEA Topic Centre on Spatial Information Analysis.

Annex I:

Detailed classification of Land-cover Types used to define the LCEU nomenclature

Code	Label
01	Artificial surfaces (including urban and associated areas)
01.a	Artificial surfaces from 10 to 50 %
01.b	Artificial surfaces from 51 to 100 %
02	Herbaceous crops
02.a	Small size fields of herbaceous crops rainfed
02.b	Small size fields of herbaceous crops irrigated or aquatic (rice)
02.c	Medium to large fields of herbaceous crops rainfed
02.d	Medium to large fields of herbaceous crops irrigated or aquatic (rice)
03	Woody crops
03.a	Small size fields of woody crops
03.b	Medium to large fields of woody crops
04	Multiple or layered crops
05	Grassland
05.a	Natural grassland
05.b	Improved grassland
06	Tree-covered area
06.a	Tree-covered area from 10 to 30–40 %
06.b	Tree-covered area from 30–40 to 70 %
06.c	Tree-covered area from 70 to 100 %
07	Mangroves
08	Shrub-covered area
08.a	Shrub-covered area from 10 to 60 % (open)
08.b	Shrub-covered area from 60 to 100 % (closed)
09	Shrubs and/or herbaceous vegetation aquatic or regularly flooded
09.a	From 2 to 4 months
09.b	More than 4 months
10	Sparsely natural vegetated areas
11	Terrestrial barren land
11.a	Loose and shifting sand and/or dunes
11.b	Bare soil, gravels and rocks
12	Permanent snow and glaciers
13	Inland water bodies
14	Coastal water bodies and inter-tidal areas
14.a	Coastal water bodies (lagoons and/or estuaries)
14.b	Inter-tidal areas (coastal flats and coral reefs)

Annex II:

Example of development of the draft land-cover flow classification

lf1	Artificial development
lf11	Artificial development over agriculture
lf12	Artificial development over forests
lf13	Artificial development of other natural land cover
lf14	Water bodies creation
lf19	Other ...
lf2	Agriculture development
lf21	Conversion from small scale/mosaic to large scale agriculture
lf22	Conversion from grassland to agriculture
lf23	Conversion from forest to agriculture
lf24	Conversion from marginal land to agriculture
lf29	Other ...
lf3	Internal conversions, rotations
lf31	Internal conversion of artificial surfaces
lf32	Internal conversion between agriculture crop types
lf33	Internal conversion between forest types
lf34	Internal conversions of natural land
lf39	Other ...
lf4	Management and alteration of forested land
lf41	Management, felling and replantation
lf42	Fires, epidemics and other
lf49	Other ...
lf5	Restoration and development of habitats
lf51	Conversion from crops to set aside, fallow land and pasture
lf52	Withdrawal of farming/ Landscape restoration
lf53	Forest creation, afforestation of agriculture
lf54	Forest creation, afforestation of marginal land
lf55	Forest recruitment
lf56	Restoration of degraded land
lf59	Other ...
lf6	Changes of land-cover due to natural and multiple causes
lf61	Climatic anomalies
lf62	Climatic and other hazards
lf69	Natural transitions n.e.s.
lf7	Other land cover changes n.e.c. and reclassification
lf0	No observed land-cover change

5. ECOSYSTEM CARBON ACCOUNTS

Carbon accounting, in the sense in which it is addressed in the ENCA-QSP, is not new in terms of general knowledge and data collection. The greenhouse gas emission inventories and the carbon budgets established by countries and companies for reporting under the UNFCCC Kyoto Protocol are accounts[1]. Not all the information collected in following IPCC Guidelines is directly usable but a large part of it is a valuable input to ecosystem accounting. The IPCC principles take into account a variety of situations and propose an incremental approach. Regarding carbon, data availability therefore varies from one place to another. Since ENCA-QSP recommends using the best available data in countries, there is no one-fits-all solution. This variety of conditions is taken into account in this chapter.

An ecosystem carbon account records an ecosystem's sustainable capacity to produce biomass, measured as biocarbon, and the way this is used by crops, harvest and tree removal, sterilized by artificial developments, and destroyed by soil erosion or forest fires. It also records the carbon that is assimilated by the atmosphere and oceans. The account records, in tonnes of carbon, the stocks available in soil, below- and above-ground vegetation, and in water (fish and vegetal species), the flow of gross primary production (GPP) of biomass by natural and cultivated vegetation, and its use by crops and timber harvests as well as by nature itself. The secondary production of animal biomass is added to the primary production.

In addition to inland ecosystems, the accounts cover seas – fisheries, sea grass and algae, plankton and net accumulation of calcium carbonate ($CaCO_3$) produced by corals and other calcifying organisms, and sea-regulating capacity. The atmosphere's climate regulation ecosystem service is also considered here. For this, the capacity of the system to sequester carbon (in biomass) or to assimilate greenhouse gases (measured in carbon dioxide (CO_2)-equivalents) up to the agreed UNFCCC target[2] of a maximum increase of temperature of 2 °C defines the limits of total carbon use without ecosystem degradation. However, the ENCA quick start package explicitly addresses only issues related to biocarbon (including emissions and sequestration), considering that the comprehensive gaseous carbon compounds account is covered in IPCC reporting.

Formally, the biocarbon account is a development of SEEA and connects accordingly to the SNA. This consistency is improved by the use of official statistics on agriculture, forestry and fisheries. It includes a link to a calculation of the total use of carbon of biological and fossil origin, which corresponds to a subset of the material flows accounts commonly used to support strategies such as resource efficiency (European Union) or green growth (OECD). At the same time, ecosystem biocarbon accounts seek the maximum consistency with IPCC reporting, in particular regarding the LULUCF sector and agriculture, forestry and other land use (AFOLU)[3]. The ecosystem perspective is very specific compared to the economic management of natural resources and the objectives of mitigating greenhouse gas emissions to the atmosphere; but the consistency of ecosystem carbon accounts with national accounts and with the climate-change programme makes them tools easy to integrate into decision-making processes.

Accounts are compiled using various data sources available within countries or at the international level. They include various kinds of monitoring data and statistics on the environment and natural resources, meteorology, and official statistics, particularly on agriculture, forestry and fisheries. Earth observation by satellite is an important data source used together with *in-situ* monitoring and statistics. National data compiled for international programmes such as IPCC-LULUCF/AFOLU, FAO SoilBase and Forest FRA2010[4] inventories and FishStat are convenient sources to start implementing ENCA-QSP, although their data need

1 *Instead, the accounts established for the same convention relate to debits and credits established according to targets or commitments.*

2 *https://unfccc.int/essential_background/items/6031.php (accessed 14 July 2014)*

3 *Agriculture, forestry and other land use (AFOLU) is a term from the 2006 IPCC Guidelines describing a category of activities that contribute to anthropogenic greenhouse gas emissions. Used in national greenhouse gas inventories, the AFOLU category combines two previously distinct sectors – LULUCF and agriculture.*

4 *The Global Forest Resource Assessment (FRA) is carried out by FAO (with countries and other organizations) every five years.*

to be downscaled to the level of the defined ecosystem accounting units.

Data collected by national and international Earth observation programmes are nowadays easy to download, for free in many cases; they can be used as a direct source for estimating variables such as land cover and intermediate data to proceed to the downscaling of national statistics. As far as possible, data sources are suggested throughout this chapter. Since data access may vary considerably, depending on national conditions, these suggestions should be considered primarily as an illustration of the kind of data to be collected and as a way to facilitate dialogue with the thematic experts who should support the accountant. However, some of these data are acceptable sources for a Quick Start and others can be tested as default values when nothing else is available.

The characteristic balancing items and indicators of ecosystem capital carbon/biomass accounts are:

Net ecosystem carbon balance (NECB) which indicates the sustainability of carbon/biomass use; in principle, NECB should be always ≥ 0[5]; in this case, there is net carbon sequestration in the ecosystem. It can be calculated either as the difference between inflows and outflows or between opening and closing stocks.

Net ecosystem accessible carbon surplus (NEACS) which measures the share of available ecosystem production of biocarbon services which meets the sustainability constraints of maintaining stocks in soils, vegetation (mostly in trees) and fisheries. In addition to biocarbon, NEACS includes an adjustment to measure the atmosphere's capacity to store carbon in the context of climate regulation. This adjustment measures the amount of fossil carbon that is accessible under the constraints defined by the UNFCCC targets.

Sustainable intensity of carbon use is measured by the ratio of NEACS to total use of ecosystem biocarbon by land and water ecosystems. For the atmosphere, the ratio is NEACS to total carbon use. This indicator provides a measure of resource use sustainability. The indicator should remain ≥ 0.

A second biocarbon indicator is calculated in the context of ecosystem health assessment. It is the ratio of total inflows of ecosystem biocarbon to total carbon requirement and measures the independence of land and water ecosystems from total bio- and fossil carbon inputs. Dependence of biomass production on artificial direct and indirect carbon inputs (fuel, chemical fertilisers, etc.) is a symptom of low ecosystem resilience. The indicator should remain ≥ 0.

Currently, there are frameworks that account for biocarbon, in particular the IPCC Guidelines for LULUCF and AFOLU, and their REDD+ extension[6] (para. 5.2.2). Human appropriation of net primary production (HANPP) is another example of a biocarbon balance compiled for calculating a headline indicator. The FAO forest statistics present tables on carbon. These frameworks have similarities with ENCA-QSP accounts as well as differences resulting from different specific purposes: the former focus on carbon balances considering the CO_2 content of the atmosphere or the ecosystem biomass resource, the latter aim at assessing ecosystem capability and degradation in a broader way.

However, the various existing carbon accounting frameworks cover a large part of the ecosystem carbon account and are valuable sources of data for accounting. They can provide data that can be re-used in ENCA-QSP, either as inputs or to cross check results obtained from different sources. As carbon monitoring is not simply the addition of observed data but entails physical modelling, there is often a need to use estimation procedures and even default values, in particular at experimental stages where not all data collection programmes are in place, which is the case for a QSP. As far as possible, this knowledge will be a privileged input for ecosystem biocarbon accounting. In addition, as well as efficiency and consistency in data collection, the best fit between these carbon accounts and ecosystem accounts will place the former into the broader context of the latter – a way to integrate approaches to mitigation, the reduction of greenhouse gas emissions to the atmosphere, and adaptation, which depends mainly on ecosystem resilience.

It is important to understand the specific targets for each accounting framework in order to be in a position to reuse data in an appropriate way. This is the purpose of section 5.2.

5 *At least on average as long as forests, which are managed in a sustainable way, have a negative NECB in the years when some parcels are logged.*

6 *reduction of emissions from deforestation and forest degradation (REDD)*

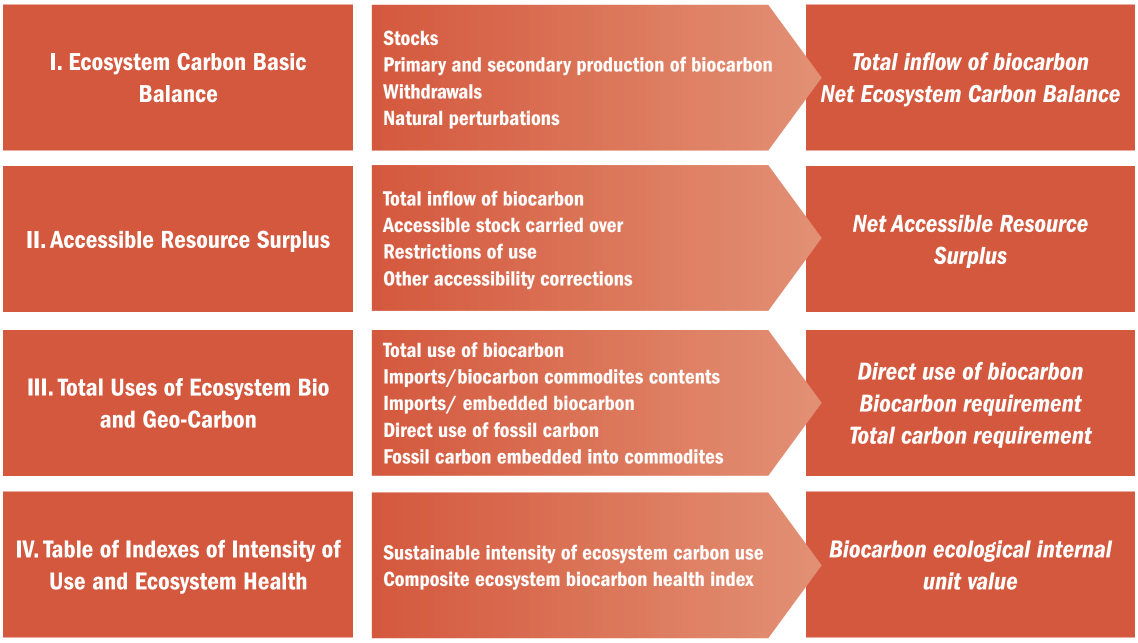
5.1 THE ECOSYSTEM CARBON ACCOUNTING FRAMEWORK

The ENCA-QSP biocarbon account is composed of four tables:

- basic balance of stocks and flows of ecosystem carbon;
- total use of carbon (domestic and imported, biocarbon and fossil carbon);
- accessible resource surplus;
- indexes of ecosystem health/distress.

This framework is consistent with water ecosystem and ecosystem infrastructure functional services accounts.

Figure 5.01 The ENCA-QSP ecosystem carbon account structure



The set of four ecosystem carbon accounts can be produced by LCEU and by SELU. LCEU classes being strongly correlated to vegetation provide the best match to IPCC land use classes. The EAU breakdown of ecosystem carbon accounts is identical to that of ecosystem water and infrastructure based functional services.

The set of aggregated accounts presented in Table 1 follows the LCEU approach. Figure 2 shows the breakdown by EAU. Aggregated and detailed accounting table templates in spreadsheet format can be downloaded from http://www.cbd.int/accounting

Table 5.01a Aggregated ecosystem carbon accounts

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SEEA-EEA & ENCA-QSP land cover ecosystem units		LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
IPCC land use classification		SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
I. Ecosystem Carbon Basic Balance													
C1	Opening Stocks												
C2.3	*NPP (Net Primary Production)*												
C2.4	*Secondary ecosystem repiration (heterotrophic)*												
C2.a	NEP (Net Ecosystem Production) = C2.3-C2.4												
C2.b	s/Total secondary biocarbon resource												
C2	**Total inflow of biocarbon (gains) = C2.a+C2.b**												
C3.a	Harvest of agriculture crops, wood & other vegetation												
C3.b	Withdrawals of secondary biocarbon												
C3	Total withdrawals of biocarbon = C3.a+C3.b												
C4	Net indirect anthropogenic losses of biocarbon & biofuel combustion												
C5	Total use of ecosystem biocarbon = C3+C4												
C6	Natural processes and disturbances												
C7	**Total outflow of biocarbon (losses)**												
C8.1	**NECB 1 [Flows] = Inflows - Outflows = C2-C7**												
C8.2	Adjustment and reappraisals												
C8.3	**NECB 2 [Stocks] = Change of biocarbon stocks**												
C9	**Closing Stocks = C1+C8.1+C8.2 or = C1+C8.3**												
II. Accessible Resource Surplus													
C2	Total inflow of biocarbon (gains) = C2.a+C2.b												
C10	Accessibility net correction												
C11	Net Ecosystem Accessible Carbon Surplus = C2 + C10												

SEEA-EEA & ENCA-QSP land cover ecosystem units		LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
IPCC land use classification		SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
III. Total Uses of Ecosystem Bio and Geo-Carbon													
C5	Total use of ecosystem biocarbon = C3+C4												
C12.1	*Imports of biocarbon/ commodities & residuals content*												
C12.2	*Exports of biocarbon/ commodities & residuals content*												
C12a	Direct use of biocarbon = C5+C12.1												
C12.3	*Virtual biocarbon embedded into imported commodities*												
C12c	Biocarbon requirement = C12a+C12.3												
C12b	Domestic consumption of biocarbon = C5+C12.1-C12.2												
C13a	Direct use of fossil carbon												
C13.3	*Virtual fossil carbon embedded into used commodities*												
C13b	Fossil carbon requirement = C13a+C13.3												
C14a	**Total Carbon Direct Use = C12a+C13a**												
C14b	**Total Carbon Requirement = C12c+C13b**												
IV. Table of indexes of intensity of use and ecosystem health													
C11	Net Ecosystem Accessible Carbon Surplus = C2 + C10												
C5	Total use of ecosystem biocarbon = C3+C4												
SCU	Sustainable intensity of carbon use = C11/C5												
CEH	Composite ecosystem biocarbon health index												
CIP	**Biocarbon ecological internal unit value = AVG(SCU+CEH)**												

Table 5.01b The typical EAU breakdown of ecosystem accounts.

Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems	Total inland ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems	Open sea	Atmosphere	TOTAL	Supply & use system
UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_ GR	MC_ CR	MC_ NC					
Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals			Seagrass	Coral reefs	Other					

In addition to ecosystems, an additional column is introduced to account for the supply and use system. This is not the whole economy as long as many human activities take place in-situ, within the ecosystem. The supply and use system column records items that cannot be assigned to any specific ecosystem. In particular it will record relationships with the rest of the world and filter or screen extraction and returns of biocarbon. In that way, not all possible relationships need to be recorded. In the case of combustion of fossil carbon, the basic balance will record only an exchange between the supply and use system and the atmosphere.

The ecosystem basic balance table columns classify inland ecosystems according to land-cover or use type. For simplicity, they are grouped here according to the IPCC/AFOLU top-level classes. In practice, they will have to refer to LCEU and probably to the subdivisions corresponding to national conditions and data availability. Water bodies, oceans and the atmosphere have been added.

At an aggregated level, the LCEU land-cover classification has a simple match with AFOLU classes (Table 5.02). As explained in Chapter 3, the LCEU classification will have to be subdivided according to national conditions. A match with the detailed classes used for IPCC reporting will have to be achieved.

Table 5.02 Correspondence between SEEA ecosystem accounting and AFOLU land classifications.

Land-cover ecosystem functional units classification		AFOLU land uses
1	Urban and associated developed areas	SL = Settlements
2	Homogeneous herbaceous cropland	CL = Cropland
3	Agriculture plantations, permanent crops	
4	Agriculture associations and mosaics	
5	Pastures and natural grassland	GL = Grassland
6	Forest tree cover	FL = Forest Land
7	Shrubland, bushland, heathland	OL = Other Land
8	Sparsely vegetated areas	
9	Natural vegetation associations and mosaics	
10	Barren land	
11	Permanent snow and glaciers	
12	Open wetlands	WL = Wetlands
13	Inland water bodies	Non explicitly covered
14	Coastal water bodies and inter-tidal areas	

The ENCA-QSP framework takes account of general SEEA guidance as well as other frameworks and reporting systems such as IPCC Guidelines (LULUCF/AFOLU) and their application to REDD+, the HANPP framework and FAO statistics, in particular FRA. As far as possible, data from these frameworks are expected to be reused, either directly when sufficient geographical breakdowns are available or after appropriate downscaling, and in any case as a way to QA/QC ecosystem capital accounts. These frameworks and their usefulness for accounting are discussed in Section 5.2.2.

Each framework has its particular legitimate purpose, and differences may appear which are not divergences but reflect diverse standpoints. For example, carbon sequestration can be understood and measured in different ways. For IPCC, which targets CO2 removal from the atmosphere as a way to mitigate greenhouse gas emissions as well as a motivation for Parties willing to meet their UNFCCC commitments, carbon sequestration is measured as accretion to a stable or permanent carbon pool. It is the difference between closing and opening stocks, taking place mostly in forests. In a symmetrical way, deforestation, which is a reduction of stocks, is assessed as a delayed emission of CO2. From an ecosystem perspective, this approach is valid but corresponds only to part of the story. Carbon sequestration is an ecosystem service that also needs to be measured as a flow. This is important to reflect the relationship of carbon sequestration to ecosystem performance regarding carbon, as well as other ecosystem services and ecosystem health in general. Carbon sequestration will therefore be measured twice: net as recommended by IPCC and gross.

The ENCA-QSP framework takes into account the available data sources at the national and international level. It is presented in aggregation with indications of the way it can be detailed to meet various needs. Despite important progress in statistics collection and Earth observation, there are still knowledge gaps. The control property of an accounting framework will be used when possible to cross-check data and acknowledge the need for adjustments in some cases.

5.1.1 Table I: The ecosystem carbon basic balance

Narrative

The ecosystem biocarbon basic account describes the stocks and flows and their relationships. The model is similar to that used in SEEA. For example it has similarities with SEEA Water that describes the interrelationship of a natural system and a supply-and-use system. Biocarbon stocks are increased by photosynthesis in vegetation, which transforms solar energy and natural inputs into biomass. This natural process consumes biomass for itself and supports the entire life chain, which is another source of consumption. The first measurement is of what is made available for other uses and accumulation, termed net ecosystem production in the literature. It could also be called gross carbon sequestration. This surplus of biomass is to a large extent extracted for human use through harvesting of crops, tree removal and by fishing. These productive activities may have leftovers that re-enter the natural process. The biocarbon extracted enters the economic system (and the supply-and-use tables of the SEEA-CF). It will return to nature as greenhouse gas, sludge or solid waste, often generated by another ecosystem, for example the urban system. In addition, anthropogenic activities may disrupt the basic biocarbon cycle by fire, erosion or changes in land use such as soil sealing or plantation of trees, as may natural disturbances. When these various flows have been subtracted from or added to net ecosystem production, a second balancing item can be calculated: the NECB. This item corresponds to the measurement of carbon sequestration in IPCC, here called net carbon sequestration[7].

In principle, we should find at this stage that opening stock + NECB = closing stock. Because available data for the many components of the accounts are of uneven quality and some of them are fragile, this equality has to be checked. The solution is to compare it with the difference of the two stocks measured independently.

The NECB can also be calculated from the observed increases and decreases of stocks. The natural growth of biocarbon stocks between two dates relates mostly to trees for which foresters know mean growth rates, which can be used for such calculations. In agriculture, stocks of woody crops (e.g. fruit trees, vines, palm trees, etc.) are either stable or changing fast, with rapid growth of new plantations or decrease by conversion to other land cover, making assessment of stocks as a function of land cover possible. *In-situ* stocks of herbaceous crops are nil or rather stable (grass) and NECB relates mostly to soil carbon in this context. In the case of soil, which on average changes slowly, assessments by soil scientists and agronomists will in particular help with measuring where there is a small increase or a small decrease. Most soil carbon loss will result from soil sealing by construction and infrastructure. In principle, NECB (stocks) calculation is more robust than NECB (flows), but more difficult to relate to flows and therefore to interpret. If the uncertainty of some variables is known, an arbitration between the two estimates can be attempted by re-sizing some upstream variables. It is likely that an adjustment item will remain at the end of the calculation.

7 *Another designation in the literature is net biome production.*

The Tables

Accounting Table I: Ecosystem carbon basic balance is the standard resource account for biocarbon, the carbon embedded in biomass and biomass products and as carbonate in the shells of water organisms. Fossil carbon is not addressed in total but only in respect to its presence and role in the ecosystem. Accounting table one is presented at a semi-detailed level. More detail is needed for accounting

Table 5.01 presents the accounting table I at its most aggregated level; details are presented in each corresponding sub-section. The codes in the first column below are the IDs of the detailed sub-table.

a. Stocks of biocarbon

Accounting Table 5-I.A: Stocks of ecosystem carbon

SEEA-EEA & ENCA-QSP land cover ecosystem units		LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
IPCC land use classification		SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
I. Ecosystem Carbon Basic Balance													
C1.11	*Trees*												
C1.12	*Shrubs*												
C1.13	*Herbaceous vegetation*												
C1.1	Biocarbon in aboveground living biomass												
C1.2	Biocarbon in litter and deadwood												
C1.3	Biocarbon in soil												
C1.41	*Biocarbon in water systems*												
C1.42	*Biocarbon in the atmosphere*												
C1.43	*Biocarbon in other ecosystem pools n.e.c..*												
C1.4	Other ecosystem biocarbon pools												
C1.5	Biocarbon in the supply and use system												
C1	Opening Stocks												

Stocks of biocarbon are made up of above-ground living biomass, litter and deadwood, carbon in soil, and other pools such as fish stocks. This breakdown is a grouping of the IPCC pools used in FAO FRA2010 forest reporting where trees roots are in soil. It corresponds to the way forest statistics are collected in practice as volume of timber over bark and other elements derived. An additional grouping can be done of carbon in soil with litter and deadwood since measurement and calculation of respiration consider these pools together. Other categories are carbon stored in the economic system and carbon in water systems. The correspondence between biocarbon classes is presented in Box 5.01.

Box 5.01 Approximate correspondence between biocarbon stocks in FAO FRA, IPCC and ENCA-QSP

FAO FRA	IPCC
Carbon in aboveground living biomass	AB = above-ground biomass
Carbon in litter and deadwood	DW = dead wood
	LI = litter
Carbon in soil	BB = below-ground biomass
	SO = soils
Additional SEEA-ENCA types	
Other biocarbon pools	
Biocarbon stocks in the economic system / wood	HWP = harvested wood products
Other biocarbon stocks in the economic system	
Biocarbon in water systems / fish stocks	
Biocarbon in water systems / other	

Estimation of biocarbon stocks by land-cover type will be done using various methodologies described in the following paragraphs. When straightforward methodologies are not available or do not exist, default values have to be found, preferably with the assistance of experts in the domain. Some of them are given as an illustration of what to search for rather than as responses to problems.

Box 5.02 Example of default value for biocarbon stocks and flows

Estimation of biocarbon stocks and flows should be done with national agencies in charge of agriculture, forestry, fishery and IPCC reporting as well as with scientific organizations in these domains. A number of methodologies and estimates are available in the scientific literature. They can be seen as orders of magnitude but their use should be submitted to national experts aware of local conditions. As an illustration, this table gives such rough estimates for the United States of America.

Table 2.4. Estimated representative values for standing biomass and net primary productivity as dry matter and the equivalent organic carbon content, for several generalized vegetative land cover types.[1]

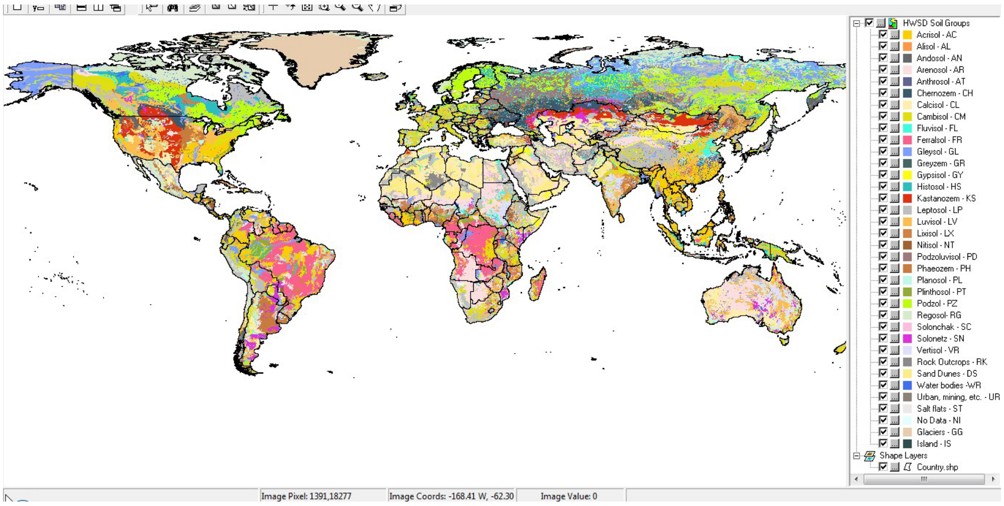
Vegetation Type (based on Olson ecosystem legend)	Aboveground Mature Biomass[2] (MT/ha)	Organic Carbon[3] (MT/ha)	Belowground Biomass[6] (MT/ha)	Organic Carbon (MT/ha)	Net Primary Productivity (MT/ha/yr)	Organic Carbon Fixed[3] (MT/ha/yr)
Forest, Coniferous	350[2]	157.5	44.00	19.80	12.00[4]	5.40
Forest, Broadleaf (UNESCO Cold-Deciduous)	350	157.50	42.00	18.90	10.00	4.50
Forest, Mixed	285[5]	128.25	43.00	19.35	11.00[7]	4.95
Woodland	110	49.50	43.00	19.35	6.00	2.70
Grassland (temperate)	30	13.50	14.00	6.30	5.00	2.25
Shrub/Scrub (UNESCO Scrub)	20	9.00	48.00	21.60	.90	.40
Tundra/Desert	0	0	9.33	4.20	.01	.005
Cropland (annual crops)	35	15.75	1.50	.67	6.50	2.92

[1]Values taken from Lieth (1975) except where noted.
[2]Data quite variable, but suggests standing biomass can equal or exceed that of temperate broadleaf forest (McGuire et al., 1992), so assumed value equal to Forest, Broadleaf.
[3]Assumed 0.45% organic carbon in dry biomass (Lieth, 1975).
[4]Estimated from McGuire et al. (1992) data and Barbour (1987).
[5]Average of values from Lieth (1975) and McGuire et al. (1992).
[6]From Jackson et al. (1996). Forest, Mixed was computed as average of Forest, Coniferous and Forest, Broadleaf; Woodland was taken as equivalent to Forest, Mixed; and Tundra/Desert was taken as average of Jackson et al. (1996) values for Tundra, Cold and Warm Desert.
[7]Taken as average of Forest, Coniferous and Forest, Broadleaf.

Source: Follett, R.F., Kimble, J.M. and Lal, R. 2001. The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect, Lewis Publishers, 457 pp. http://eco.ibcas.ac.cn/group/baiyf/pdf/gxzy/9_The_Potential_of_U.S._Grazing_Lands_to_Sequester_Carbon_and_Mitigate_the_Greenhouse_Effect.pdf (accessed 14 July 2014)

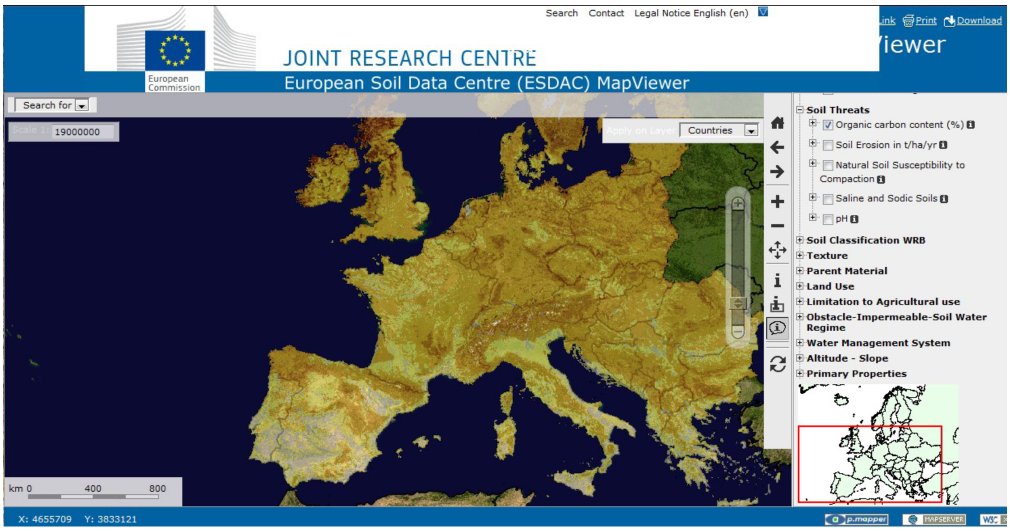
"*Soil organic carbon, the major component of soil organic matter, is extremely important in all soil processes. Organic material in the soil is essentially derived from residual plant and animal material, synthesised by microbes and decomposed under the influence of temperature, moisture and ambient soil conditions. The annual rate of loss of organic matter can vary greatly, depending on cultivation practices, the type of plant/crop cover, drainage status of the soil and weather conditions*" (JRC, European soil database, http://eusoils.jrc.ec.europa.eu/wrb/help/OCTOP80.htm). Organic carbon in soil is given mainly by national soil maps held in ministries of agriculture and forestry and related organizations (agronomic, forestry, geological survey or mapping agencies). By default, soil carbon concentration estimates can be extracted from the Harmonized World Soil Database. Values can be adjusted for forest soils using FAO FRA densities of carbon in soil.

Figure 5.02 Harmonized World Soil Database



http://www.fao.org/geonetwork/srv/en/metadata.show?id=37140 (accessed 14 July 2014)

Figure 5.03 OCTOP, Organic Carbon contents of topsoil (%) in the European Soil Database



http://eusoils.jrc.ec.europa.eu/wrb/ (accessed 14 July 2014)

Box 5.03 Steps for estimating soil carbon

Using the soil database involves the following steps:

1. download the variables on soil carbon concentration;
2. download the variables on depth (which should in principle be < 30 cm), stone content and soil density;
3. calculate the standard volume of soil to be multiplied in the next step by the carbon concentration coefficient;
4. multiply to calculate first estimates and adjust using exogenous sources (e.g. forestry or agronomic surveys) when available;
5. re-sample to the assimilation grid used for accounting (e.g. 1 ha or 1 km^2).

Forest biocarbon stocks and growth: forest surveys provide detailed data on stocks of timber measured using conventions generally accepted in the forestry community. Information can be found in the websites of national or regional organizations or at the FAO (http://www.fao.org/forestry/46203/en/). The FAO FRA global survey includes estimates of forest carbon pools (see Section 5.2.3). Because of practical difficulties of measurement and priority interests in timber production, basic data refers mostly to roundwood, the other components of the trees (stems, roots, deadwood) or soil being estimated. Tree growth can be deduced from inventories or from samplings of trees which may be available at the national level.

Forest litter, deadwood and soil are ancillary questions in forest surveys from which data can be collected and/or from IPCC LULUCF/AFOLU reporting. This information is available from FAO FRA (Box 5.04).

Box 5.04 Forest biocarbon data in FRA 2010

TABLE 2.21
Carbon stock in forest by region and subregion, 2010

Region/subregion	Carbon in biomass		Carbon in dead wood and litter		Carbon in soil		Total carbon stock	
	million tonnes	t/ha	million tonnes	t/ha	million tonnes	t/ha	million tonnes	t/ha
Eastern and Southern Africa	15 762	58.9	3 894	14.6	12 298	46.0	31 955	119.4
Northern Africa	1 747	22.2	694	8.8	2 757	35.0	5 198	66.0
Western and Central Africa	38 349	116.9	3 334	10.2	19 406	59.1	61 089	186.2
Total Africa	**55 859**	**82.8**	**7 922**	**11.7**	**34 461**	**51.1**	**98 242**	**145.7**
East Asia	8 754	34.4	1 836	7.2	17 270	67.8	27 860	109.4
South and Southeast Asia	25 204	85.6	1 051	3.6	16 466	55.9	42 722	145.1
Western and Central Asia	1 731	39.8	546	12.6	1 594	36.6	3 871	89.0
Total Asia	**35 689**	**60.2**	**3 434**	**5.8**	**35 330**	**59.6**	**74 453**	**125.7**
Europe excl. Russian Federation	12 510	63.9	3 648	18.6	18 924	96.6	35 083	179.1
Total Europe	**45 010**	**44.8**	**20 648**	**20.5**	**96 924**	**96.4**	**162 583**	**161.8**
Caribbean	516	74.4	103	14.8	416	60.0	1 035	149.2
Central America	1 763	90.4	714	36.6	1 139	58.4	3 616	185.4
North America	37 315	55.0	26 139	38.5	39 643	58.4	103 097	151.8
Total North and Central America	**39 594**	**56.1**	**26 956**	**38.2**	**41 198**	**58.4**	**107 747**	**152.7**
Total Oceania	**10 480**	**54.8**	**2 937**	**15.3**	**8 275**	**43.2**	**21 692**	**113.3**
Total South America	**102 190**	**118.2**	**9 990**	**11.6**	**75 473**	**87.3**	**187 654**	**217.1**
World	**288 821**	**71.6**	**71 888**	**17.8**	**291 662**	**72.3**	**652 371**	**161.8**

TABLE 2.25
Trends in total carbon stocks in forests, 1990–2010

	Total carbon stock (million tonnes)				Carbon stock (t/ha)			
	1990	2000	2005	2010	1990	2000	2005	2010
Carbon in biomass	299 224	293 843	291 299	288 821	71.8	71.9	71.7	71.6
Carbon in dead wood	34 068	33 172	32 968	32 904	8.2	8.1	8.1	8.2
Carbon in litter	38 855	38 748	38 825	38 984	9.3	9.5	9.6	9.7
Carbon in soil	300 425	295 073	293 232	291 662	72.1	72.2	72.2	72.3
Total carbon stock	**672 571**	**660 836**	**656 323**	**652 371**	**161.4**	**161.8**	**161.6**	**161.8**

"The world's forests store more than 650 billion tonnes of carbon, 44 % in the biomass, 11 % in dead wood and litter, and 45 % in the soil. Globally carbon stocks are decreasing as a result of the loss of forest area; however the carbon stock per hectare has remained almost constant for the period 1990–2010. According to these estimates, the world's forest is therefore a net source of emissions due to the decrease in total forest area."

http://www.fao.org/docrep/013/i1757e/i1757e02.pdf (accessed 14 July 2014)

The use of FAO FRA data for the SEEA carbon account of forests and soil was discussed at the UN London Group on Environmental Accounting meeting in 2009[8]. Like the SEEA, FAO FRA covers primary forests, other naturally-regenerated forests and planted forests[9], while greenhouse gas reporting addresses only managed forests. For accounting, the solution is therefore to use the primary forest carbon pools and the LULUCF conversion factors of the managed forests for estimating. The paper also gives an illustration of forest expansion and conversion. (Box 5.05).

8 *Muukkonen, J. 2009. Forest and soil. Issue Paper on Carbon sequestration, Statistics Finland. http://unstats.un.org/unsd/envaccounting/londongroup/meeting14/LG14_12a.pdf (accessed 14 July 2014).*

9 *At the global level, the proportions are respectively of 36 %, 57 % and 7 % that means that more than 90 % of all forests are naturally regenerated. (FRA2010).*

Box 5.05 An example of conversion factors. Finland 2009

Conversion factors:

Species	ef	dw(Mg/m3)	cc	cf(MgC/m3)
pine	1,527	0,39	0,519	0,3091
spruce	1,859	0,385	0,519	0,3715
non-coniferous	1,678	0,49	0,505	0,4152

Conversion equation: cf = ef * dw * cc

ef = expansion factor from stem volume to total tree biomass
dw = conversion factor to dry matter
cc = C-content
cf = conversion factor from stem volume to total biomass C content

Source: Muukkonen, op. cit.

Data on forest stocks or pools are reported following IPCC guidelines, where useful default values and estimation methods can be found for a quick start (http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf).

Downscaling data on stocks and stock growth obtained by modelling or as statistics then needs to be done considering the forested land for which accounts are compiled. At this stage, having LCEU details of forests types for LCEU (e.g. broadleaves/coniferous/mixed or more detailed or relevant classification breakdowns) will improve the accuracy of the estimates. Downscaled results will be of better quality if the data input is of sub-regional or local scale instead of national.

Because forest density varies, the downscaling procedure can use maps of tree density such as the MODIS VCF annual data 2000–2010 or the Global Forest Change "percent tree cover 2000"and loss and gain 2000–2012. These data sets are described in Chapter 4 as possible inputs for mapping forest cover. Although they are of high quality, they are global data sets, the local relevance of which has to be checked. They have to be used at this stage as additional information to the LCEU forest mask. Their role will be to redistribute, by pixels, the stock values obtained from forest statistics converted into stocks of tree biocarbon.

Cropland and grassland stocks of biocarbon are mostly in soils. Estimates of stocks of woody crops, perennial crops and agroforestry, are done in a way similar to forest. Currently, stocks of herbaceous vegetation are recorded in IPCC only considering change due to land conversion and related CO_2 emissions; they do not lead to net carbon (CO_2) sequestration. The default value for soil carbon change, other than resulting from land conversion, is zero; this is a reasonable proxy considering the CO_2 issue but not acceptable from an ecosystem perspective where soil carbon is a key indicator.

IPCC guidelines on cropland and grassland are at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_06_Ch6_Grassland.pdf (accessed 14 July 2014)

IPCC other land is a rather heterogeneous class which includes low biomass productivity land such as LCEU sparsely vegetated areas, barren land and permanent snow and glaciers as well as more productive shrubland, bushland, heathland and natural vegetation associations and mosaics. The use of shrubs such as *Jatropha Curcas* for biofuels may require isolation of a subcategory for accounting purposes.

Wetlands have the richest stocks of biocarbon, in the form of peat and vegetation. This category is heterogeneous and subdivisions should be used when appropriate. Note that not all wetlands in the sense of the Convention on Wetlands of International Importance, especially as Waterfowl Habitat (Ramsar Convention) are in this category. For example, temporary wet grassland is classified with grassland, and wet forests with forests.

Soil in marine coastal zones is made of layers below seagrass. "*… seagrasses use carbon to build their grassy blades. As their carbon-rich leaves die and decay, they collect on the seafloor and are buried in the soil below, trapped in sediments. It's estimated that the world's seagrass meadows capture 27.4 million tons of carbon each year! The carbon stored in sediments from coastal ecosystems, including seagrass meadows, mangrove forests, and salt marshes, is known as blue carbon.*[10]" "*With seagrass meadows disappearing at an annual rate of about 1.5 %, 299 million tonnes of carbon are also released back into the environment each year, according to research published in Nature Geoscience (DOI: 10.1038/ngeo1477). […] up to*

10 *Smithsonian National Museum of Natural History, Ocean Portal, http://ocean.si.edu/seagrass-and-seagrass-beds (accessed 14 July 2014).*

19.9 billion tonnes of carbon are currently stored within seagrass plants and the top metre of soil beneath them"[11].

Biocarbon in the ocean is not accounted in full. One part is estimated by global models and represents background data difficult to associate definitely with anthropogenic activities. Another is made up of stocks that are directly exploitable (fish stocks) or modifiable (plankton, algae and sea grass). The first type will be recorded as background data, the second as a full part of national ecosystem accounts regarding the exclusive economic zone (EEZ). In addition, the large part of these stocks which is outside national EEZ will have to be recorded in special international accounts for which rules for inclusion in ecosystem capital accounting will have to be defined. The SNA and SEEA-CF rule is that areas outside EEZ can be recorded "*in circumstances where exploitation control has been established and access rights are defined through international agreements*" (SEEA-EEA, 6.63). Regarding oceans exploitation, SEEA follows SNA that define the economy as the sum of resident units. Therefore the extraction of biocarbon by such units in international seas should be recorded in national accounts.

Regarding the atmosphere, a distinction needs to be made between local systems (which are not of importance regarding carbon storage) and the global atmosphere/climate system for which GHG concentrations are measured and increases of CO2 equivalents correlated to increases in temperature, an indicator of state. For practical reasons, IPCC calculates GHG emissions for national territories. This point is criticised in SEEA since the IPCC rule forbids comparisons of emissions with GDPs calculated on the basis of the residence of economic units. Bias results, particularly from differences in accounting for maritime and air transport. The SEEA Ecosystem Experimental Accounts do not propose a clear rule in this case. A solution for ENCA-QSP may be to calculate national stocks of carbon in the atmosphere as a proportion of global GHG emissions, following the SEEA-CF definition based on residence.

b. Flows of biocarbon/inflows (or gains or increase of stocks)

The biocarbon flow account describes how much biomass is produced from managed and unmanaged vegetation, how much is available for use, how much is lost as indirect consequences of anthropogenic activities and natural disturbances, and measures the NECB of each ecosystem. The NECB is equivalent to carbon sequestration (CO2 removal) recorded by IPCC.

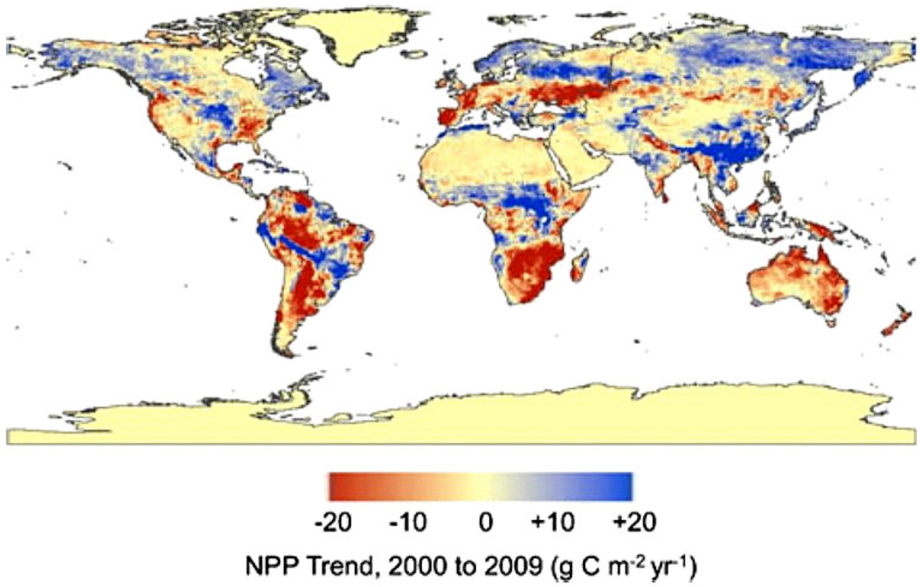
Inflows of biocarbon are called gains in IPCC guidelines and simply increases of stocks in SEEA. They are composed of net ecosystem production that is the total of the primary and secondary biocarbon resource.

11 Slezak, M. 2012. Mowing down seagrass meadows will cut loose carbon. New Scientist portal http://www.newscientist.com/article/dn21825-mowing-down-seagrass-meadows-will-cut-loose-carbon.html (accessed 14 July 2014).

Accounting Table 5-I.B: Inflows of ecosystem carbon

SEEA-EEA & ENCA-QSP land cover ecosystem units		LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
IPCC land use classification		SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
I. Ecosystem Carbon Basic Balance													
C2.1	GPP (Gross Primary Production)												
C2.2	Vegetation ecosystem respiration (autotrophic)												
C2.3	**NPP (Net Primary Production)**												
C2.4	Secondary ecosystem repiration (heterotrophic)												
C2.a	***NEP (Net Ecosystem Production) = C2.3-C2.4***												
C2.51	*Net increase of fish stocks/ fisheries*												
C2.52	*Net increase of fish stocks/ farms*												
C2.52	*Net increase of livestock*												
C2.53	*Other secondary production of bio-carbon*												
C2.5	Net increase of secondary biocarbon stocks												
C2.61	*Inflows from sea/ fish and other animal products*												
C2.62	*Inflows from sea/ vegetal products*												
C2.63	*Imports of biocarbon/ commodities & residuals content*												
C2.64	*Natural biocarbon inflows n.e.c.*												
C2.6	Inflows of biocarbon from other countries & the sea												
C2.71	*Agriculture leftover returns*												
C2.72	*Manure return and application*												
C2.73	*Forestry leftover returns*												
C2.74	*Fishery discards*												
C2.7	Production returns (leftovers, manure, discards...)												
C2.81	*Sludge and wastewater*												
C2.82	*Solid waste*												
C2.8	Consumption returns (sludge, wastewater, solid waste)												
C2.b	***s/Total secondary biocarbon resource***												
C2	**Total inflow of biocarbon (gains) = C2.a+C2.b**												

Figure 5.04 Net primary production of terrestrial ecosystems, 2000–2009



Source: Potter et al. 2012, op. cit.

CASA model of NASA and Stanford University

Gross primary production, net primary production, net ecosystem production

Gross primary production is total photosynthesis by ecosystems. It is calculated in two different ways on the basis of models based on satellite images and on *in-situ* observations provided by Eddy-Towers[12]. Satellite models combine measurements of the vegetation index (NDVI, EVI[13] or FAPAR[14]) with other data on temperature and humidity as well as, but not always, land cover, leaf area index and start and length of the growing season. *In-situ* measurements are used either to calibrate the satellite-based models or random samples are extrapolated to areas using methods such as Kriging[15]. Total ecosystem respiration (TER), which is the return to the atmosphere of part of the carbon absorbed (as CO2) during photosynthesis, is estimated in parallel with GPP. GPP - TER = net ecosystem production (NEP), which is a measure of the biomass surplus available for use. Net ecosystem production is the ecological service of carbon sequestration measured gross (a process) while NECB is a net measurement.

Total ecosystem respiration (TER) is split into two parts: autotrophic respiration (AR) which is the vegetation respiration during photosynthesis and heterotrophic respiration (HR) which is the respiration of the life-forms which consume or decompose primary and secondary biomass.

Autotrophic respiration is intermediate consumption, similar to that in the SNA production account. NPP = GPP – AR.

A measure of ecosystem biomass creation, NPP is equivalent to GVA for economic production.

Net primary production (NPP) is "*net photosynthetic accumulation of carbon by plants … provides the energy that drives most biotic processes on Earth. NPP represents much of the organic matter that is consumed by microbes and animals. Climate controls on NPP fluxes are an issue of central relevance to society, mainly because of concerns about the extent to which NPP in managed ecosystems can provide adequate food and fibre for a growing human population*"[16].

Heterotrophic respiration is the second part of TER. Heterotrophs obtain food only from organic

12 *Eddy covariance models are used to measure atmospheric variables. The global FLUXNET network groups 500 nationally managed monitoring stations working with this methodology. http://daac.ornl.gov/FLUXNET/fluxnet.shtml (accessed 14 July 2014).*

13 *Normalized Difference Vegetation Index (NDVI) is an indicator used to analyse remote sensing measurements and assess whether the target being observed contains live green vegetation. EVI stands for Enhanced Vegetation Index.*

14 *FAPAR: Fractional absorbed photosynthetically active radiation*

15 *"Kriging is a group of geostatistical techniques to interpolate the value of a random field (e.g., the elevation, z, of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations." (Wikipedia). See Chapter 3, section 3.2.2.*

16 *Potter et al. 2012. Net primary production of terrestrial ecosystems from 2000 to 2009. http://link.springer.com/article/10.1007%2Fs10584-012-0460-2 (accessed 14 July 2014).*

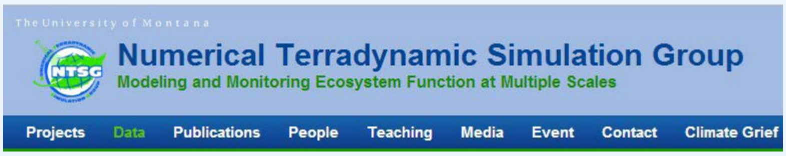
material. Unlike autotrophs, they are unable to use inorganic matter to form proteins and carbohydrates. Heterotrophic respiration is sometimes equalled to soil respiration that is the main part of it. In that case it includes the decomposition of dead surface biomass into soil. NPP - HR = NEP.

Understanding the sequence is important as long as there is not just one single source of information. In practice, accounts can start from NPP for which there are the best measurements. Heterotrophic (or soil) respiration is not estimated with the same quality as vegetation respiration because it is not a direct function of the flow of biomass but depends also on the pools. In practice, the FLUXNET global network of *in-situ* Eddy-Towers can supply data on GPP, NPP and TER. With the approximate estimation (commonly used) that NPP = 0.5 GPP and TER = 0.8 GPP, soil respiration appears as a balancing item of approximately 0.3 GPP. These proportions are orders of magnitude that need to be used with care, knowing that GPP ranges from 1 to 10 from boreal to tropical zones. Knowing GPP can however help in detecting outliers in some datasets. A way of reducing this uncertainty is proposed with a second measurement of NECB from direct observations of stock growth (identical to the difference in stocks method proposed by IPCC – see below). This will allow at least estimates of the magnitude of the gap between NECB (flows) and NECB (stocks) and accordingly proceed to arbitration by revising input data and/or finally recording an adjustment item.

For accounting, NPP input data can be downloaded from space agencies. Global datasets are available in grids of 1 km^2 (produced from NOAA/HVHRR, SPOT/VEGETATION/PROBA-V or MODIS/TERRA), or at other resolutions with other imagery. Long time-series are available, which are useful for checking the overall consistency of the data. This check is necessary as long as the data are produced globally and there may be local variations of quality depending on particular conditions. The check will include comparisons with land-cover data used for accounting. It means that re-sampling is needed using land-cover and/or higher-resolution vegetation indexes. Finally, a separate estimate of NPP for urban areas may be needed since several models clip them out (as well as bare rocks, snow and glaciers and lakes) in the calculation of NPP and vegetation indices. Since discontinuous urban fabric is a common feature, urban NPP can be found.

Gross and net primary productivity data can be downloaded from national institutions. Global datasets can be downloaded for free from NASA, or from the Copernicus Global Land Service (under the variant name of dry matter productivity). As an indication, the popular NPP datasets of the University of Montana can be downloaded, as indicated in Box 5.06.

Box 5.06 Example of downloadable NPP data



http://www.ntsg.umt.edu/project/mod17 http://www.ntsg.umt.edu/project/mod17#data-product

Example: MODIS 17 A3 (annual, 2000 to 2012)

field name:	Npp
data type:	uint16
scale_factor:	0.000100
valid_range:	0 65500
_FillValue:	65535
long_name:	MOD17A3 NPP–MODIS Gridded 1KM Annual Net Primary Productivity (NPP)
units:	kg_C/m^2

GPP and NPP delivered as GEOTIFF files with cells of 30 arc seconds (order of magnitude of km).
The NTSG belongs to the University of Montana (Dir. Steve Running)

No such data source exists for heterotrophic or soil respiration. Data based on measurements by plots can be accessed, for example from the Global Soil Respiration Database accessible on Figshare[17]. Such databases may help to improve default coefficients used for calculating soil respiration.

The secondary biomass resource

The secondary biomass resource is made up of four components: net increase in secondary biocarbon stocks; inflows of biocarbon from other countries and the sea; production returns (leftovers, manure, discards, etc.); and consumption returns (sludge, wastewater and solid waste).

The net increase in secondary biocarbon stocks summarizes the flows related to secondary biomass production by animals (and, in principle, humans). Inflows and outflows generating this increase can be monitored in some cases such as livestock grazing, other animal food consumption and manure returns, and fish farming. In other cases, such as fish stocks in the ocean, increase (or decrease) of stocks is the only variable monitored. It is therefore more realistic in the QSP to record only net flows in this case. Data can be collected from agriculture and fishery statistics.

Inflows of biocarbon from other countries and the sea (C2.6, Accounting Table I-B) are inputs of vegetal and animal biocarbon that are essential for human and animal food, as well as fertilizers in some cases. They include inflows from the sea of fish and other animal products as well as vegetal products and imports of biocarbon measured as the content of commodities (and residuals if appropriate). Note that for fish catches, those in domestic waters should be treated as inflow from the sea while catches from foreign or international sea areas are imports.

In C2.6 (Accounting Table I-B), only the biocarbon content of imports is considered, in the sense of the direct material input (DMI) concept of economy-wide material flows accounting. The embedded (or embodied) biocarbon, which is the biomass needed for these imports (e.g. the grass grazed by cattle exported as meat) is not recorded here but in Table III: Total Uses of Ecosystem bio- and geo-Carbon (see section 5.1.3).

Production and consumption returns

Returns to the ecosystem from production and consumption should be recorded as secondary resources to match the SEEA presentation of stock increases and decreases. They are the resources used by the ecosystem. While production returns occur in the same place as harvests and other withdrawals, consumption returns occur after use in the supply and use system, generally in a different place.

Production returns (leftovers, manure, discards, etc.) (C2.7) include returns of agriculture leftovers (straw, clover, etc.), manure return (to pasture) and application (on cultivated land), returns of forestry leftovers, and fishery discards. Only what is returned to the ecosystem is recorded. When leftovers are used as by-products that are not explicitly recorded in statistics, they have to be added to harvests. Production leftovers and returns have to be recorded using coefficients estimated by agronomists, foresters or fishery scientists. Information on such coefficients can be found in national agencies or ministries or at the FAO.

There are two types of manure application to land: to pasture and to cultivated land. Return of manure to pasture (and other grazed land) is estimated as a percentage of grazed grass. Such coefficients are available from agronomists or can be found in the literature. The calculation can be implemented on the grid estimates for grazing (para. 5.78 and Figure 5.05).

Manure from livestock in battery units is estimated as a proportion of livestock. Pig and poultry manure has to be added accordingly. Default values can be found in IPCC/AFOLU and in the literature. After the total amount is calculated, it still has to be downscaled to cultivated land and pasture.

Estimates of fish bycatch and discards can be found at FAO[18] but are not part of FishStat.

Consumption returns of biocarbon to the ecosystem (C2.8, Accounting Table I-B) are included in wastewater, sludge and solid waste. They can return as residuals to rivers and the sea or to land. Depending on the way these residuals are used, they can be part of a circular economy process or actual waste, reducing the health of the recipient ecosystem. Circular reuse of production/consumption residuals is recorded explicitly in the C14.5 item of the table where accessible resource surplus is calculated.

Statistics on sludge extracted by wastewater treatment plants are available in many countries. This may be used as fertilizer under certain conditions that vary from place to place, including type of soil (which should not allow infiltration down to the aquifer), type of agriculture, and distance from cities (not too near, not too far) as well as

17 *Bond-Lamberty, B. 2013. Global Soil Respiration Database (srdb_20120510a). http://dx.doi.org/10.6084/m9.figshare.868954 (accessed 14 July 2014)*

18 *Kelleher, K. 2005. Discards in the World's Marine Fisheries, An Update, FAO FISHERIES TECHNICAL PAPER 470 http://www.fao.org/docrep/008/y5936e/y5936e00.htm (accessed 14 July 2014)*

legal constraints. Maps of sewage sludge dumping are available in some countries. In their absence, models exist to define areas likely to receive sewage sludge that can be used to downscale statistics. This has to be considered since sludge, where it is used, is an important part of the biocarbon balance.

When organic solid waste is processed as compost, it is an important input to the agricultural carbon balance. Where composting is encouraged by environmental and/or agricultural agencies, data can be collected for accounting.

The total inflow of biocarbon is the sum of NEP and net secondary biomass resource.

c. Flows of biocarbon/outflows (or losses or decrease of stocks)

The outflows of biocarbon include harvesting of agricultural crops, wood, other vegetation removal, withdrawals of secondary biocarbon (in particular in fisheries), combustion of biofuels, and (net) indirect anthropogenic losses of biocarbon resulting from land use.

Accounting Table I-C: Outflows of biocarbon

SEEA-EEA & ENCA-QSP land cover ecosystem units		LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
IPCC land use classification		SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
I. Ecosystem Carbon Basic Balance													
C3.1	Agriculture harvested crops												
C3.21	*Agriculture production residuals*												
C3.22	*[-] Agriculture leftover returns [= C2.71]*												
C3.2	Removals of agriculture leftovers and byproducts (incl. straw...)												
C3.3	Vegetation grazed by livestocks												
C3.41	*Industrial roundwood removals*												
C3.42	*Woodfuel removals*												
C3.4	Wood removals												
C3.51	*Forestry production residuals*												
C3.52	*[-] Forestry leftover returns [= C2.73]*												
C3.5	Removals of forestry leftovers												
C3.6	Other vegetation removals (incl. non wood forest products, algae...)												
C3.a	***Harvest of agriculture crops, wood & other vegetation***												
C3.71	*Livestock husbandry products*												
C3.72	*Fish catches/ fishfarms*												
C3.73	*Fish catches/ fisheries*												
C3.74	*Other animal withdrawals (incl. hunting)*												
C3.7	Withdrawals of animal biocarbon												
C3.81	*Peat extraction*												
C3.82	*Other extraction of secondary bio-carbon*												

C3.8	Other removals of biocarbon (incl. peat)												
C3.b	***Withdrawals of secondary biocarbon***												
C3	**Total withdrawals of biocarbon = C3.a+C3.b**												
C4.11	*If1 Artificial development*												
C4.12	*If2 Agriculture development*												
C4.13	*If3 Internal conversions, rotations*												
C4.14	*If4 Management and alteration of forested land*												
C4.15	*If5 Restoration and development of habitats*												
C4.16	*If6 Changes of land-cover due to natural and multiple causes*												
C4.17	*If7 Other land cover changes n.e.s.*												
C4.1	Net indirect loss of biocarbon due to land use change												
C4.21	*Dumping of bio-carbon to water bodies (incl. waste and wastewater)*												
C4.22	*Leakage of soil bio-carbon to water bodies (incl. induced erosion)*												
C4.2	Dumping and leakage of biocarbon to water bodies												
C4.31	*Forest and other ecosystem fires due to anthropogenic cause*												
C4.32	*Other emissions to the atmosphere (VOC, CH_4) from anthropogenic origin (IPCC)*												
C4.33	*Combustion of biocarbon fuel*												
C4.3	Emissions of ecosystem biocarbon to the atmosphere												
C4	**Net indirect anthropogenic losses of biocarbon & biofuel combustion**												
C5	***Total use of ecosystem biocarbon = C3+C4***												
C6.1	*Natural outflows to other territories and the sea*												
C6.2	*Net internal transfers between biocarbon pools n.e.c.*												
C6.3	*Other natural disturbances*												
C6	***Natural processes and disturbances***												
C7	**Total outflow of biocarbon (losses)**												

Total withdrawals of biocarbon from ecosystems (C3)

Total withdrawals of biocarbon include harvest of agriculture crops, wood and other vegetation and withdrawals of secondary biocarbon.

Total withdrawal includes by-products, leftovers, discards and residuals from agriculture, forestry and fisheries, although these are not always recorded in official statistics, in which case they have to be estimated. This is justified for at least two reasons, one being the role of leftovers in the conservation of soil fertility and the other the growing interest in biomass residuals as a resource for second-generation biofuels.

Agriculture and forestry leftovers are not all the production residuals recorded previously. Part of these is used as animal litter, and, more and more, as fuel. An estimate of what is really leftover needs to be carried out by agronomists and foresters. This estimate of production residuals will cover several dimensions throughout the ENCA-QSP ecosystem carbon account: total residuals generated, effective returns to the ecosystem, circular returns of reusable biocarbon, and imports and exports.

In the Accounting Table I-C harvest of agriculture crops, wood and other vegetation, production (crops and wood removal) given by official statistics is supplemented with other removals. Total leftovers are measured for agriculture and forestry and split between what is effectively removed (e.g. straw) and what is returned to the ecosystems. Removals of agriculture leftovers and by-products (straw, etc.) are recorded as C3.2 and removals of forestry leftovers as C3.4. Other vegetation removals (incl. non-wood forest products and algae) are recorded as C3.6.

Agricultural crop harvest statistics should be collected in appropriate detail and grouped according to standard classifications and common characteristics of biomass and biocarbon contents per tonne. An example is given in Box 5.07. Box 5.08 illustrates how to estimate crop carbon contents.

Box 5.07 Possible detail of C.3.1 Agriculture harvested crops

C3.11	*Cereals*
C3.12	*Fiber crops*
C3.13	*Fuits excl. melons*
C3.14	*Oil crops*
C3.15	*Pulses*
C3.16	*Toots and Tubers*
C3.17	*Treenuts*
C3.18	*Vegetables and Melons*
C3.19	*Forage*
C3.1	Agriculture harvested crops

Harvests of crops, removal of wood and other forest products, fish catches and other removals such as peat extraction, are known from regular statistics. Grazing can be estimated by calculating the pressure of grazers on pastures and other grassland. Using official statistics instead of *ad-hoc* estimates (e.g. from satellite images) is very important since ecosystem accounts need to connect to the SEEA-CF supply and use tables by economic sectors and beyond to the SNA. Satellite images will be used in this case for downscaling statistics totals.

Withdrawals of secondary biocarbon (C3.7) include withdrawals of animal biocarbon (livestock husbandry products, fish catches in fish farms, fish catches in fisheries, and other animal withdrawals including hunting and angling). Other removals of biocarbon (C3.8) include peat extraction and other extraction of biocarbon.

Filling accounts tables for withdrawals of biocarbon involves several tasks:

- collect statistics by local administrative or census units with the finest spatial breakdown;
- downscale official statistics to the grid used for data assimilation;
- estimate total withdrawal, which is more than commercial crops recorded in statistics and includes the production of residuals;
- convert tonnes of products into tonnes of biocarbon.

Agricultural crop statistics have to be downscaled to the land-cover LCEF units of classes 2: homogeneous herbaceous cropland, 3: agriculture plantations and permanent crops, and 4: agriculture associations and mosaics. Some statistics may measure the production of family gardens in discontinuous urban fabric classified in 1: urban and associated developed areas, in which case a specific estimate will be needed. Starting from regional statistics (districts, counties, departments, etc.) is an important help for downscaling the data. Access to data from municipalities is sometimes possible when an agricultural census has been carried out; it is obviously an excellent source for ecosystem accounting, at least for establishing a baseline.

Crops have very different densities and carbon contents, from oily seeds and cereals, through potatoes and roots, to tomatoes and salads. Downscaling has to take this into account and be done by groups of crops with similar conversion factors into dry biomass and carbon.

Box 5.08 Example of a quick estimate of crop biocarbon
for test ecosystem accounts in Europe

Agricultural statistics (production in tonnes) of small European regions, so-called NUTS3, have been downloaded from the Eurostat website for the years 2000–2010. Groupings have been made into a small number of products corresponding to FAO Items Aggregated in FAOStat (http://faostat3.fao.org/faostat-gateway/go/to/download/Q/QC/E).
The crops have split into two groups: dry crops (yellow) and wet crops (blue).

Cereals
Fibre Crops Primary
Fruit excl. Melons
Oil Crops Primary
Pulses
Roots and Tubers
Treenuts
Vegetables & Melons

From the literature, default values to convert tonnes of crops to tonnes of dry biomass have been chosen as 0.8 for dry crops and 0.2 for wet crops. A coefficient of 0.5 has been used to convert dry biomass to biocarbon.
Each aggregated class of crop statistics has then been downscaled against agricultural land-cover classes. The mixed agricultural classes have been given a conventional cropland value of 0.6.
Finally, net harvest from agricultural product statistics has been supplemented by estimates of by-products such as straw, of clovers not available in statistics and of leftovers, in order to get total biocarbon removal.

Source: Ivanov, E. and Weber, J.-L. 2011, European Environment Agency working document.

Harvest residuals are not always clearly recorded in statistics reports on agriculture products and generally need special assessment. Ways of estimating these biomass residuals are described in the literature, in particular regarding biofuel potential. Box 5.09 gives an example of default values for agriculture products.

Box 5.09 Example of estimates of biomass residual as % of crops and energy content (gigajoule [GJ} and conversion of GJ to tonnes of carbon [C])

Table 2.2.1. Parameters used for estimating waste biomass production and amount of resources

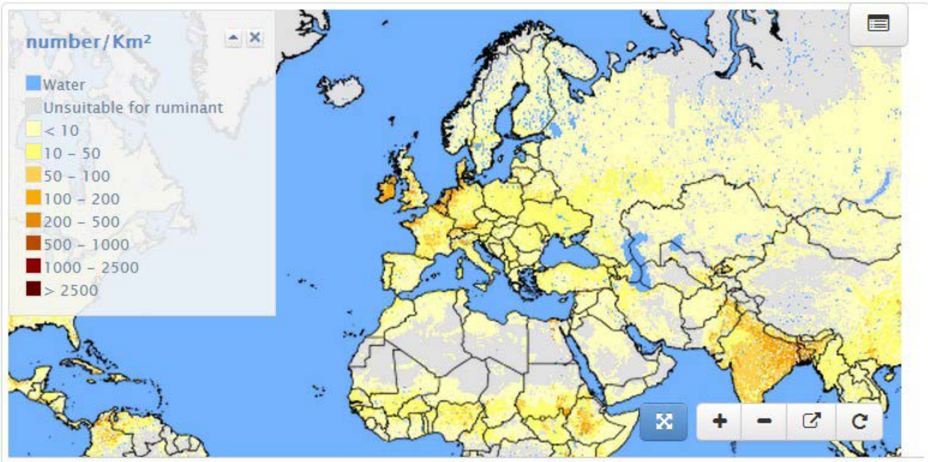
Biomass species	Ratio of waste production (t/t)	Coefficient of energy conversion (GJ/t)	*Conversion of Gj to tons of coal equivalent (1 t C = 30GJ)*
Rice	1.4	16.3	*0.54*
wheat	1.3	17.5	*0.58*
Maize (corn)	1	17.7	*0.59*
Roots and tubers	0.4	6	*0.20*
Sugar cane residues (tops and leaves)	0.28	17.33	*0.58*
Industrial log	1.17	16	*0.53*
Fuel log	0.67	16	*0.53*
Wood waste	0.784	16	*0.53*
	t/y/head		
Cattle	1.1	15	*0.50*
Swine	0.22	17	*0.57*
Poultry	0.037	13.5	*0.45*
Horses	0.55	14.9	*0.50*

Source: Asian Biomass Handbook Ch 2. Japan Institute of Energy, 2008 http://www.jie.or.jp/biomass/AsiaBiomassHandbook/English/Part-2_E.pdf except for conversion to carbon : 1 tonne carbon equivalent = 30 GJ (from http://cdiac.ornl.gov/pns/convert.html#2) (accessed 14 July 2014)

Grazing needs to be estimated as a function of grazing livestock density (cattle, sheep and goats measured in livestock unit equivalents http://en.wikipedia.org/wiki/Livestock_grazing_comparison), battery farming (non-grazing animals to be deducted), time spent on grassland, extent of grassland, and mean consumption. There is no vegetation return from grazing; the accounting balance is done with net increase of livestock + manure + leakages to the atmosphere.

The FAO *Global Cattle Density Map (2005)* is of importance for downscaling statistics on livestock, grazing and manure. It is produced using a model that combines best-available statistics on grazing livestock.

Figure 5.05 The FAO global cattle density map (2005)



http://data.fao.org/map?entryId=f8e6a720-88fd-11da-a88f-000d939bc5d8&tab=about

In the absence of local statistics on battery-farmed livestock – the best source but frequently missing – a calculation of livestock on meadows can be made for each km^2 cell using the proportion of land-cover classes with grassland and a coefficient of grazing area by livestock unit – in the European Environment Agency fast-track ecosystem accounts, a mean value of 1 ha per cow has been assumed for Europe. Agronomists can then provide mean values of grass grazed, and manure returned. The LCEU classes with grassland are 5: Pastures and natural grassland, as separately identified classes, and a percentage of other classes to be determined according to natural conditions. This is particularly the case for class 4: Agriculture associations and mosaics where pasture can range up to 50 %; several other classes may include grazing land[19].

Wood removal in tonnes of roundwood and pulp and in biocarbon do not need to be detailed here since data and measurement rules are available from FAO and IPCC, with more details in national forest agencies and surveys. References are given for stocks, and the additional comments on the relationships between ecosystem capital accounting, IPCC reporting and FAO statistics are in general valid for flows (Section 5.2.). However, two particular points need to be considered: illegal logging and the geo-location of felling.

Official statistics on forestry report roundwood and wood fuel harvests but generally do not cover illegal logging. Since its magnitude in some regions can be an important part of total logging, it needs to be integrated into the accounts as an additional and well-identified item. Estimates can be found from international organization portals and various non-governmental organizations (NGOs). Recent initiatives, such as the FAO-EU Forest Law Enforcement, Government and Trade (FLEGT) process, should result in improvements in data collection. The forest monitoring in place, and expanding with programmes such as REDD+, allows estimates of possible gaps between official statistics and logging reality. At this stage, statistics on illegal logging need to be agreed with national forest authorities, to confirm their reality and ensure that there is no double-counting with official statistics.

The geo-location of logging is also of importance. For crops, the implicit assumption is that all crops are harvested within the pure or mosaic agricultural land-cover classes, with a few exceptions such as home gardens in discontinuous urban fabric. The assumption of uniform withdrawal has some validity for wood fuel, particularly when it is collected by households. However wood fuel is not removed only from forest land-cover,

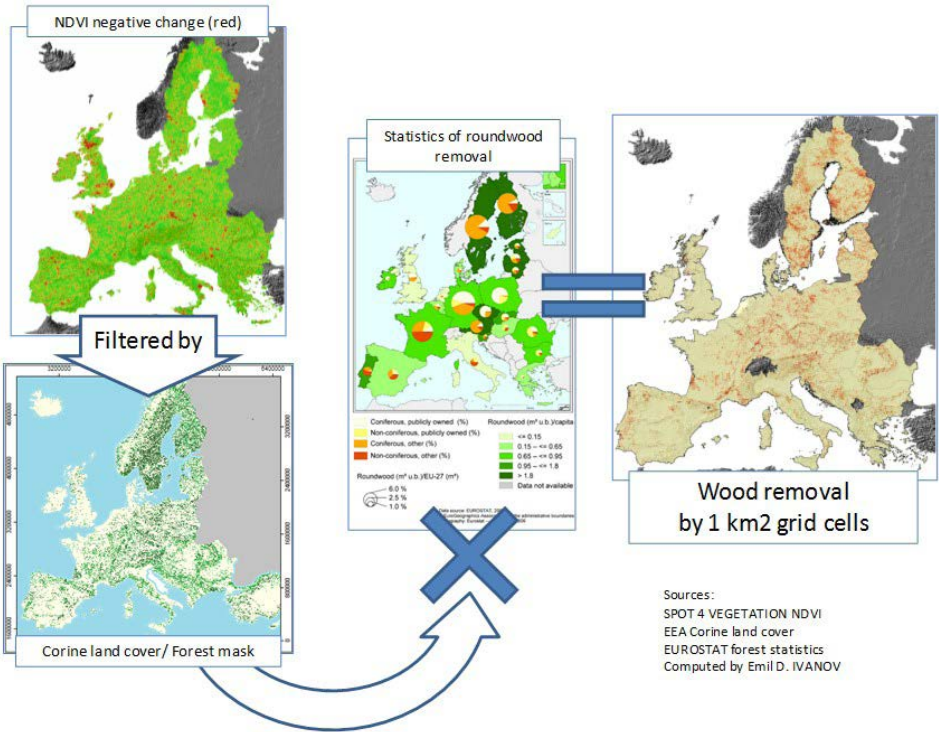
19 *For example, the theoretical SEEA reference to forests as more than 10 % of tree cover, and even the practical 20–30 % achieved with satellite image classification, leaves an amount of forested land for shrubs as well as herbaceous vegetation which can be grazed by livestock.*

but also from other land covered with woodland, in particular mixed agricultural and natural landscapes.

In the case of industrial logging of roundwood, statistics refer to a collection of specific places where removal takes place as thinning or clear-cutting, not to an average rate of uniform logging. To identify such places, several options are available using satellite images.

The first approach tested by the European Environment Agency was to use the change in the vegetation index (NDVI) between two years to detect negative values. The NDVI change was assessed relative to mean regional values (by dominant land cover types) in order to eliminate possible general climate effects. The negative NDVI pixels were then filtered by the forest mask and ultimately wood-removal statistics were downscaled to these pixels (Figure 5.06).

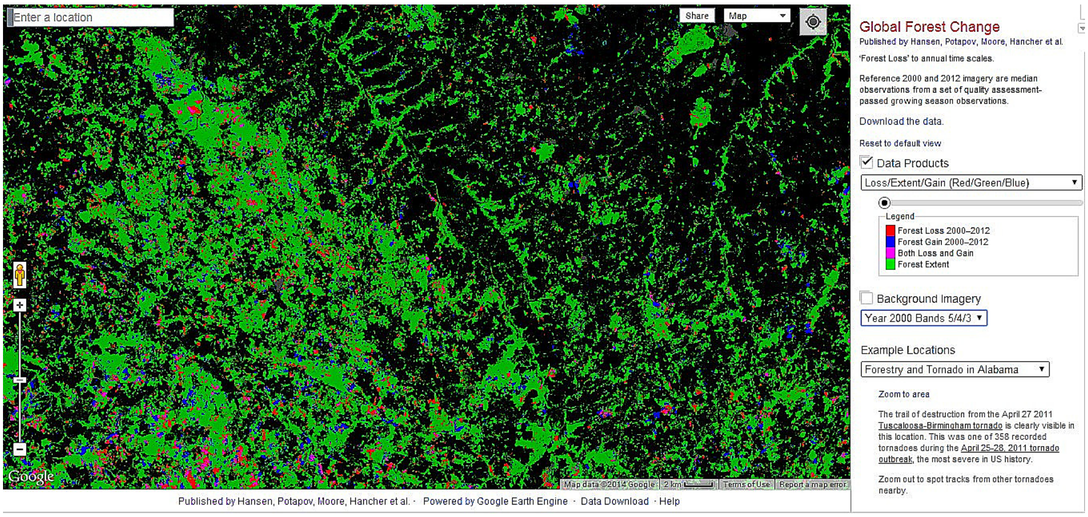
Figure 5.06 Calculation of wood removal by grid-cells from official statistics



Another solution is to use the data on forest extent and change (gains and losses) 2000–2012 produced by the University of Maryland from more than 650,000 30 m resolution Landsat images in their Global Forest Change project[20]. Data have been downloadable for free since February 2014. Wisely, the authors started mapping forest extent with a trees density of 25 %. Even with this precaution, it is better to focus first on the forest mask for which the best relevance can be found.

20 *Hansen, M.C., Potapov, P.V., Moore, R. et al., 2013. High-Resolution Global Maps of 21st-Century Forest Cover Change. Science 15 November 2013: Vol. 342 no. 6160 pp. 850-853 DOI: 10.1126/science.1244693 http://www.sciencemag.org/content/342/6160/850 (accessed 14 July 2014).*

Figure 5.07 An example of data downloadable from the Global Forest Change portal at the University of Maryland



Source: http://earthenginepartners.appspot.com/science-2013-global-forest (accessed 14 July 2014)

Fish catches and removals from fish farms have to be considered separately from inland waters, coastal waters and open seas.

Inland water catches, from rivers, lakes or reservoirs, are regular statistics. Statistical breakdowns by river basin have to be done.

Open-sea catches can be obtained from national agencies and/or FAO FishStat where times-series of more than 40 years are available. The zoning of the sea recommended in Chapter 3 combines FAO fishing areas and EEZ limits. By-catch has to be estimated as well as fish farming.

Coastal zones are given special attention. In ENCA-QSP, they are considered as an extension of land as much as near the sea. Marine ecosystem coastal units (MECU) are defined in parallel to SELU. These units echo concepts such as Japanese *satoumi* or marine areas defined for the purpose of integrated coastal zone management (ICZM). Special data gathering, in particular regarding fish and shellfish catches, needs to be considered.

Other removals of biocarbon (C3.8) include peat extraction and other extraction of biocarbon. Peat is a limit case regarding biocarbon since it can be mined as a fossil carbon resource and its renewal rate is slow. At the same time it is a rich soil and a key living component of thriving ecosystems (peat bogs) that deliver the widest range of ecosystem services and sequestrate huge amounts of carbon. The extraction of peat will be recorded in the same way as other ecosystem carbon resources.

Other extraction of biocarbon is a class to be used for the removal of soil, other than peat, for example for the development of green urban areas.

- **Net indirect anthropogenic losses of biocarbon and biofuel combustion (C4)**

Combustion and net indirect anthropogenic losses of biocarbon (C4) include net indirect loss of biocarbon due to land-use change, leakage and dumping of biocarbon into water bodies, and leakages of ecosystem biocarbon to the atmosphere and combustion.

Net indirect loss of biocarbon due to land-use change (C4.1) is the effect of land-use change that is not reflected by a recorded withdrawal of biocarbon. When a forest is felled for replacement by agriculture, total wood removal is recorded in C3.4 and C3.5 and the burning of leftovers in C4.31: Forest and other ecosystem fires due to anthropogenic cause. If the land conversion is for urban development, there will be an additional loss of biocarbon due to soil sealing. Another example of a land-use impact is when forest soil is ploughed after tree felling to prepare for new plantation: oxidation of organic matter releases CO_2 that can be recorded in this item. Drainage of wetlands for agriculture or urban development usually results in significant losses of biocarbon[21].

The loss of carbon due to land-use change is an important element in the IPCC guidelines. As explained below, the perspective of ENCA-QSP is somewhat different. In the example given in the previous paragraph, IPCC would record the whole conversion of forested land as due to land-use change. In ecosystem accounting, wood removal is identified as such.

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21 *Tubiello, F.N., Salvatore, M. et al. 2014. Agriculture, Forestry and Other Land Use Emissions by Sources and Removals by Sinks, 1990-2011 Analysis, FAO Statistics Division, Working Paper Series, ESS/14- 02. http://www.fao.org/docrep/019/i3671e/i3671e.pdf (accessed 13 August 2014)*

The loss of carbon due to land-use change is detailed according to the classification used for land-cover flows (Chapter 4):

- lf1 Artificial development;
- lf2 Agriculture development;
- lf3 Internal conversions, rotations;
- lf4 Management and alteration of forested land;
- lf5 Restoration and development of habitats;
- lf6 Changes of land-cover due to natural and multiple causes;
- lf7 Other land cover changes n.e.c. and reclassifications.

Other changes in biocarbon stocks are not a reclassification but a measure of the consequences of a reclassification. Losses will be allotted to the land cover of origin and gains to the new land cover.

Dumping and leakage of biocarbon to water bodies (C4.2) consist of intended dumping of residuals and of leakages that are unintentional effects of human practices. Dumping can be to inland or marine water bodies.

Dumping of biocarbon to water bodies includes liquid (wastewater and sludge) and solid waste. Biocarbon dumping into water ecosystems has in general a negative impact on quality and is of little or no use as biocarbon. The inflow recorded here will in principle be deducted in the calculation of the accessible resource.

Leakages recorded in C4.22 include, in particular, biocarbon loss due to soil erosion. What is considered here is the increase in soil erosion as an indirect impact of a range of human activities, and negligence. If necessary, background natural soil erosion can be recorded separately in C6: Natural disturbances.

Leakages of ecosystem biocarbon to the atmosphere and combustion (C4.3) comprise forest and other ecosystem fires due to anthropogenic cause, other emissions to the atmosphere – volatile organic compounds (VOC) and methane (CH_4) – of anthropogenic origin (as defined in the IPCC Guidelines) and combustion of biocarbon fuel. While forest and other fires occur in ecosystems, combustion of biocarbon fuel is an outflow of the supply and use system where extraction of biofuel has been recorded previously as an increase in stocks (and combustion, a decrease).

Fires are *in-situ* burning of biocarbon that does not return to the ecosystem to be reused as biocarbon but generates residuals, carbon monoxide (CO) and CO2 and a reduction of ecosystem stocks. Fires encompasses managed and unmanaged fires, as well as combustion of solid waste when dumped and recorded in returns. Guidelines and data can be found in the IPCC/LULUCF/AFOLU reporting, knowing that IPCC's target is not in this case identical to SEEA's. The IPCC focus is on flows that are the direct responsibility of economic sectors and it therefore considers all fires that cannot be directly allotted to identifiable economic agents such as natural disturbances. In the SEEA, all fires whether they have a direct or indirect anthropogenic cause, even accidental, are recorded as caused by human activities; natural fires are the exception to be established.

Other emissions to the atmosphere (VOC, CH_4) of anthropogenic origin include, in particular, emissions from flooded agriculture and husbandry.

Combustion of biofuel takes place in the supply and use system. It includes fuel wood and other harvested products or by-products, as well as fuels produced from biomass transformation.

Total use of ecosystem biocarbon (C5) is the sum of total withdrawals of biocarbon and net indirect anthropogenic losses of biocarbon and biofuel combustion.

- **Natural processes and disturbances (C6)**

Natural processes and disturbances (C6) include net internal transfers between vegetation and soil, natural outflows to other territories and the sea and other natural disturbances

Internal transfers between biocarbon pools n.e.c. are other flows taking place in the same place, mostly transfers between vegetation and soil. They do not affect the net carbon ecosystem balance but do affect the structure of the stock.

Natural outflows to other territories and the sea are mostly consequences of erosion and dumping of biocarbon into rivers and seas and transfers of sediments. Note that symmetrically, natural inflows have been recorded as a secondary biocarbon resource (C2.64 natural biocarbon inflows n.e.c.).

Other natural disturbances include changes in ecosystem biocarbon due to natural disasters that cannot be described as regular processes or recurrent events. It is mostly the consequence of exceptional storms, earthquakes, tsunamis or volcanic eruptions. Forest and shrub fires that are recurrent and difficult to split between natural and anthropogenic causes are recorded as forest and other ecosystem fires due to anthropogenic cause (C4.31).

The total outflow of biocarbon (losses) (C7) is the sum of total withdrawals of biocarbon, net indirect anthropogenic losses of biocarbon and biofuel combustion and natural processes and disturbances.

d. Net ecosystem carbon balance

Net ecosystem carbon balance (NECB) measures the increase or decrease of biocarbon stocks. It is calculated as the difference between the net ecosystem productivity (NEP) and the various uses of biocarbon net of returns, leakages, *in-situ* combustion and natural disasters. Net ecosystem carbon balance is a measurement of net carbon sequestration more comprehensive than that defined in the IPCC guidelines since NECB encompasses not only direct effects of economic activities but also indirect effects and natural perturbations. However, considering the common coverage, the budgets established for IPCC are a very useful input to ecosystem capital accounts.

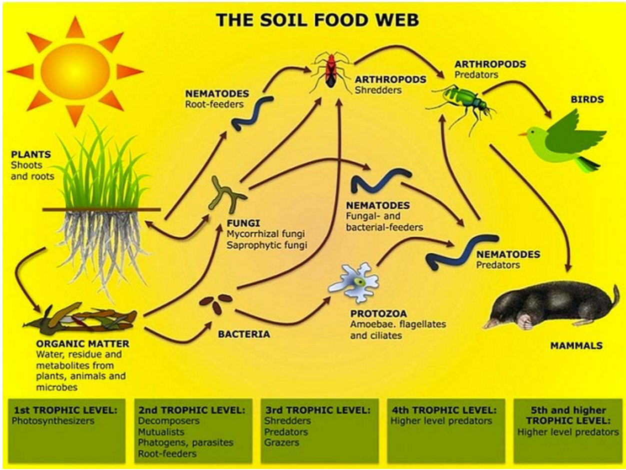
NECB[flows] versus NECB[stocks]. The measurement of NECB as the algebraic sum of natural and anthropogenic flows poses various problems of estimation, one being the measurement of HR, the secondary respiration of decomposers of plant biomass. Because of the uncertainty in the estimates, this has to be cross-checked.

A second measurement of NECB is proposed, based on direct observation of stock changes. In principle, stocks should be measured at two dates and the difference calculated. When this is not possible, estimates can be made according to the impacts of pressures from anthropogenic activities and natural disturbances. The IPCC estimates of activities can be taken as input data. They will need to be broadened to account for changes that are beyond the Kyoto Protocol conventions (Section 5.2.1).

Accounting table 5-I.D Net Ecosystem Carbon Balance (NECB) and Closing Stocks

	SEEA-EEA & ENCA-QSP land cover ecosystem units	LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
	IPCC land use classification	SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
I. Ecosystem Carbon Basic Balance													
C8.1	**NECB 1 [Flows] = Inflows - Outflows = C2-C7**												
C8.21	*Adjustment of NECB = NECB 2 - NECB 1*												
C8.21	*Reappraisals, reclassifications*												
C8.2	Adjustment and reappraisals												
C8.31	Net gains of biocarbon in aboveground biomass												
C8.32	Net gains of biocarbon in litter and deadwood												
C8.33	Net gains of biocarbon in soil												
C8.34	Other net gains of biocarbon												
C8.3	**NECB 2 [Stocks] = Change of biocarbon stocks**												
C9.11	*Trees*												
C9.12	*Shrubs*												
C9.13	*Herbaceous vegetation*												
C9.1	Biocarbon in aboveground living biomass												
C9.2	Biocarbon in litter and deadwood												
C9.3	Biocarbon in soil												
C9.41	*Biocarbon in water*												
C9.42	*Biocarbon in the atmosphere*												
C9.43	*Biocarbon in other ecosystem pools n.e.c..*												
C9.4	Other ecosystem biocarbon pools												
C9.5	Biocarbon in the supply and use system												
C9	**Closing Stocks = C1+C8.1+C8.2 or = C1+C8.3**												

Figure 5.08 Composition of soil biomass



Source: http://eusoils.jrc.ec.europa.eu/library/themes/biodiversity/ Figure adapted from Tugel, A.J. and Lewandowski, A.M. (eds.) Soil Biology Primer. (accessed 14 July 2014)

Net gains of biocarbon in above-ground biomass are mostly from trees[22]. Growth of trees can be estimated using coefficients observed in-situ from monitoring samples. Data may be available by broad types of tree species (e.g. broadleaves versus coniferous). Mean growth coefficients can first be extrapolated to the grid map of living forest above-ground biomass stocks; this first result can be refined with additional data such as tree-cover density mapped annually by MODIS[23]. Estimates of tree felling can be used for the stock losses. In the case of shrubs and grass, which may vary annually because of meteorological conditions, stock changes can be assessed using the vegetation indexes (NDVI, EVI or FAPAR) produced from various satellite images.

Net gains of biocarbon in litter and deadwood are estimated as functions of crop (litter) and removal practices. The development of second-generation biofuels results in an increase of leftover removal, which should be recorded. Deadwood is a component of the forest cycle and statistics are available. Particular attention needs to be given to forest areas suffering severe wind-throw hazards and fires, and to their intensity and the recovery processes.

Net gains of biocarbon in soil are mostly in agriculture. Natural renewal of soil nutrients is done by below-ground life, commonly called soil biodiversity. The total below-ground biomass generally equals or exceeds that above-ground, while the biodiversity in the soil always exceeds that on the associated surface by many orders of magnitude, particularly at the microbial scale. Soil biodiversity needs food, i.e. biomass.

Maintaining natural fertility in traditional agricultural systems is done by organic fertilization (manure) and crop rotations with temporary fallow land set-asides. Intensive agriculture obtains high yields with chemical nutrients (and pesticides) and deep tillage; natural fertility is less of a constraint and soil biodiversity and organic carbon content reduces. Soil processes are slow; recovery from soil degradation (when possible, before desertification takes place) is slow and this is a growing concern[24]. Monitoring is developing and data on soil biocarbon are available.

Other net gains of biocarbon are mostly changes in fish stocks.

Arbitration between NECB[flows] and NECB[stocks]. In a last step, comparing results from the two methodologies will help to identify and measure gaps, if any, and should try to proceed to what national accountants call arbitration between sources. This exercise allows the detection of anomalies and outliers, and their correction by reference to other sources of information. Working both on statistical tables, for example to detect anomalies regarding time-series, and maps, to detect local issues, allows in many cases the correction of errors. The support of experts in the areas where the main problems are identified is essential. As this kind of correction is not always possible, an adjustment item will take stock of the gaps in knowledge.

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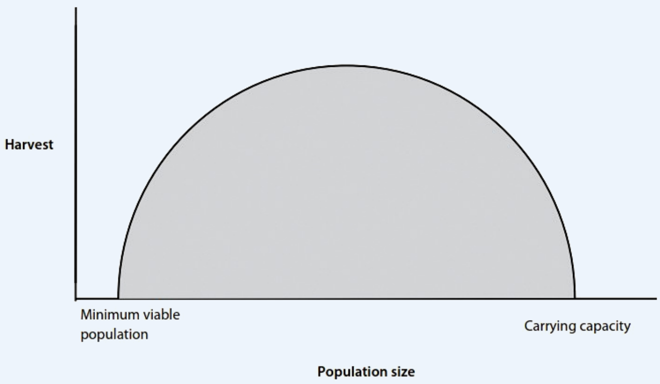
22 *Because plants compete for solar light and natural successions, vegetation growth in grassland results in shrubs, and in shrubland in trees; these changes are detected as land-cover change.*

23 *MODIS VCF (vegetation continuous fields) can be downloaded from the Global Land-cover Facility website http://glcf.umd.edu/data/vcf/ (accessed 14 July 2014)*

24 *http://eusoils.jrc.ec.europa.eu/projects/soil_atlas/pages/113.html (accessed 14 July 2014)*

Box 5.10 Presentation of the sustainable yield curve in the SEEA-CF

Figure 5.2
Stylized sustainable yield curve



"*In principle, depletion is recorded wherever the amount of extraction is greater than the sustainable yield corresponding to the population size and structure. This is reflected by points above the curve in figure 5.2 and represents the case where quantities extracted are greater than the regeneration or growth for any given population*". SEEA-CF, para. 148

A final accounting item is reappraisal and reclassification. It has to be used as an additional adjustment when data sources differ in amount and structure between the start and the end of the accounting period. When this happens, it is better to try to recalculate a homogeneous time-series. The SEEA foresees its use mostly for subsoil assets that can be re-appraised or discovered without any practical change in the real world.

5.1.2 Table II: Accessible resource surplus

Narrative

Not all biomass can be exploited as a biocarbon resource, only a surplus. Stocks of biomass are not mere stores of biocarbon that can be mined in a way similar to fossil assets; they are essential parts of the system that reproduces the resource. The depletion of these stocks is not just a loss of an economic asset; it is a degradation of the ecosystem's capability to renew itself. The need to avoid depletion of renewable natural resources is acknowledged through the calculation of sustainable yields.

The SEEA-CF para. 5.78 states: "*the ability for these* [biological] *resources to regenerate naturally means that in certain management and extraction situations, the quantity of resources extracted may be matched by a quantity of resources that are regenerated and, in this situation, there is no overall physical depletion of the environmental asset. More generally, only the amount of extraction that is above the level of regeneration is recorded as depletion*" [25].

The methodology for calculating sustainable yields is presented in the SEEA-CF. Discussion of the use of biological models and their difficulty of implementation leads to the practical recommendation to use a statistically defined normal regeneration rate. In ENCA-QSP, this is defined from the accounting items of the basic balance. It matches the concept of sustainable yields but goes beyond it as long as the whole biocarbon resource is considered, not only withdrawals from natural resource assets – typically timber and fish stocks.

Not all stocks can be exploited, only a surplus. In the case of forests, this is around 1–3 % of the stock, depending on tree growth rates, which vary according to species, age and climate. The exploitable biocarbon resource is better measured by the total inflow of biocarbon (gains) aggregate (C2) that is duly adjusted to take account of accessibility constraints or opportunities.

Only internal effects on the biocarbon cycle are recorded in the ecosystem carbon account. The effects of biomass management and harvesting on water and functional services that depend on landscape integrity and biodiversity are recorded in separate accounts. The synthesis of total ecosystem capability combines the specific outcomes of the three sets of accounts; it expresses the overall result in terms of ecosystem capital degradation or enhancement.

25 *http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf (accessed 18 August 2014)*

Accounting Table 5-II: Accessible Resource Surplus

	SEEA-EEA & ENCA-QSP land cover ecosystem units	LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
	IPCC land use classification	SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
II. Accessible Resource Surplus													
C2	**Total inflow of biocarbon (gains) = C2.a+C2.b**												
C10.1	Basic accessible stock carried over from previous years [+]												
C10.21	*Growth of immature stands of timber*												
C10.22	*Growth of environment protection forests*												
C10.23	*Growth of fishstocks under moratorium*												
C10.24	*Growth of fishstocks in protected areas*												
C10.2	Restrictions of use [-]												
C10.31	*Agriculture production residuals [= C3.21]*												
C10.32	*Forestry production residuals [= C3.51]*												
C10.3	Biomass production residuals [-]												
C10.4	Biomass consumption residuals [= C2.8] [-]												
C10.51	*Agriculture and forestry leftovers returned to the ecosystem*												
C10.52	*Manure fertilisation*												
C10.53	*Compost fertilisation*												
C10.54	*Sludge fertilisation*												
C10.55	*Products of biomass residuals gasification*												
C10.56	*Second generation biofuels*												
C10.56	*Other circular reuse of biomass residuals*												
C10.5	Circular reuse of production & consumption residuals [+]												
C10.6	Natural outflows to other territories and the sea = C6.1 [-]												
C10.7	Other bio-carbon accessibility corrections [+ or -]												
C10.8	Accessible carbon surplus in the atmosphere												
C10	**Accessibility net correction**												
C11	**Net Ecosystem Accessible Carbon Surplus = C2 + C10**												

Total inflows of biocarbon (C2) are gains or stock increases recorded in the basic balance. This is an accounting item, which includes circular elements that need be adjusted as well as elements that are not accessible to users for physical, biological, technological, economic or legal reasons.

A first correction [+] is done by taking into account the basic accessible stock carried over from previous years, for example in the case of previously immature stocks which become mature at the end of the previous accounting period for harvest or fishing.

Restrictions of use [-] limit accessibility to biocarbon and should be excluded from the resource when calculating intensity of use. It includes, in particular, gains resulting from the growth of immature stands of timber, of trees in environmentally protected forests, of fish stocks under a regeneration moratorium, and of fish stocks in protected areas.

Biomass residuals are tracked all along the basic balance; the issue is summarized in the accessible resource account in order to take stock of their fate and of the gains in biocarbon accessibility provided by their reuse or recycling. The residuals from production (C10.3) and consumption (C10.4) are recorded for their total and subtracted from the total inflows of biocarbon. This treatment allows highlighting of residuals that are reused as leftovers recycled in the ecosystem or as new products. They are recorded as circular reuse (C10.5) and added to the accessible resource.

The circular reuse of production and consumption residuals [+] includes agricultural and forestry leftovers returned to the ecosystem, manure, compost and sewage sludge fertilization, products of gasification of biomass residuals, second-generation biofuels and other circular reuses of biomass residuals.

Natural processes n.e.c. and disturbances may result in changes in total biocarbon accessibility in different ways.

Natural disturbances of a continuous type, such as droughts, have effects captured in the basic accounts via the measurement of NEP. Natural hazards such as exceptional storms, landslides, volcanic eruptions, earthquakes and tsunamis have effects on stocks of biomass; this is a deterioration or loss of stocks that is not recorded as a degradation (caused by anthropogenic activities). Their impact on flows will be recoded in NEP. There is therefore no correction in the accessible resource surplus account.

Natural processes n.e.c. are natural transfers between ecosystems and/or regions and between carbon pools other than related to photosynthesis. Natural transfers between ecosystems and/or regions are mostly driven by water flows and consist of sediments. They are recorded as C10.6 in the accessible resource surplus table for the same amount as the C6.1 item of the basic balance.

Transfers between carbon pools result mainly from the decomposition of litter and deadwood and the resulting creation of soil organic carbon. They are previously recorded as C6.2 in the basic balance and are part of C10.7. Other bio-carbon accessibility corrections [+ or -] are made in the accessible resource surplus table.

The accessibility net correction (C10) is the algebraic sum of the elements presented above. The net accessible resource surplus [C11] is the sum of total inflows of biocarbon [C2] and C10. It is the resource amount that is compared to the total used in order to calculate the index of sustainable intensity of resource use.

5.1.3 Table III: Total uses of ecosystem bio- and geo-carbon

Narrative

The biocarbon produced in the national territory and sea EEZ is not the only resource used by national ecosystems and it may not be used only in the country. The use of biocarbon takes place jointly with the use of fossil carbon in many ways, as fuel as well as material: both contribute to greenhouse gas emissions. Table III on total uses of ecosystem bio- and geo-carbon puts together these elements to give a picture which matches the paradigms underlying the approaches to ecosystem and biodiversity accounting and to climate change mitigation (greenhouse gas emissions and CO_2 sequestration) and resource efficiency (as defined on the basis of energy and material flow accounting in strategies such as Organisation for Economic Co-operation and Development (OECD) Green Growth or EU Resource Efficiency Flagship Initiative), as well as to carbon footprint calculations.

When addressing fossil carbon (called geo-carbon in SEEA), only flows are considered. Stocks of fossil carbon, which exist only as economic assets, are not recorded here. Stocks of limestone are not recorded either because of their magnitude and main role as a physical substrate; however, flows involving carbonate of calcium have been recorded in the basic ecosystem carbon balance when they are linked to a biological process.

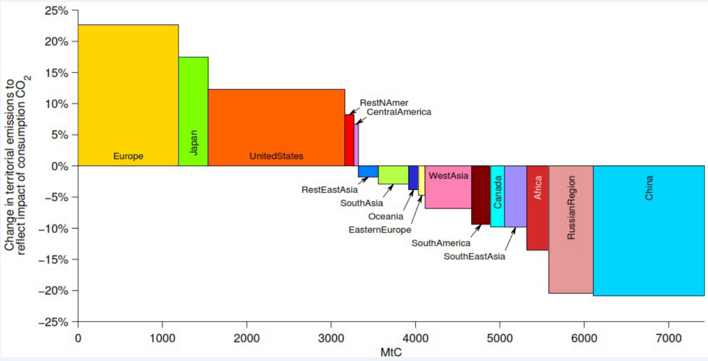
Accounting Table 5-III: Total uses of ecosystem bio- and geo-carbon

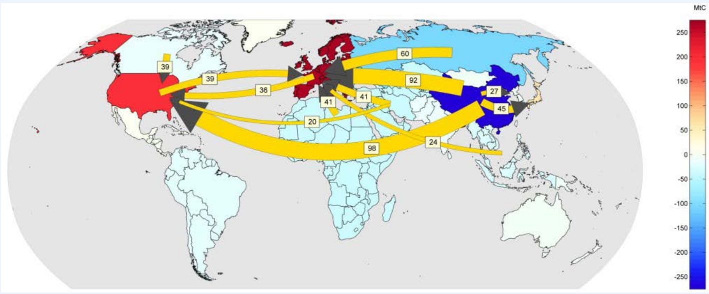
SEEA-EEA & ENCA-QSP land cover ecosystem units		LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
IPCC land use classification		SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
III. Total Uses of Ecosystem Bio and Geo-Carbon													
C3	Total withdrawals of biocarbon = C3.a+C3.b												
C4	Net indirect anthropogenic losses of biocarbon & biofuel combustion												
C5	*Total use of ecosystem biocarbon = C3+C4*												
C12.1	Imports of biocarbon/ commodities & residuals content												
C12.2	Exports of biocarbon/ commodities & residuals content												
C12a	**Direct use of biocarbon = C5+C12.1**												
C12b	**Domestic consumption of biocarbon = C5+C12.1-C12.2**												
C12.3	Virtual biocarbon embedded into imported commodities												
C12c	**Biocarbon requirement = C12a+C12.3**												
C13.11	*Direct use of fossil carbon / Fuel*												
C13.12	*Direct use of fossil carbon /Other products (incl. chemicals)*												
C13a	***Direct use of fossil carbon***												
C13.3	*Virtual fossil carbon embedded into used commodities*												
C13b	***Fossil carbon requirement = C13a+C13.3***												
C14a	Total Carbon Direct Use = C12a+C13a												
C14b	Total Carbon Requirement = C12c+C13b												

Table III starts with total use of ecosystem biocarbon calculated in Table I (C5) and a reminder of the two components of this aggregate: total withdrawals of biocarbon (C3) and net indirect anthropogenic losses of biocarbon and biofuel combustion (C4).

Imports and exports of biocarbon/commodities and residuals content (C12.1 and C12.2, respectively) are then recorded. The detail is not given in the table since it relates to official statistics classifications of commodities and countries and geographical zones of origin and destination.

Box 5.11 Importance of embedded carbon in international trade





Source: Peters, G.P., Davis, S.J. and Andrew, R. A synthesis of carbon in international trade, Biogeosciences, 9, 3247–3276, 2012 www.biogeosciences.net/9/3247/2012/ (accessed 14 July 2014)

Upper figure. The change in production-based CO2 emissions adjusted to a consumption basis (2004). The horizontal axis shows production emissions, the vertical shows the relative change. This figure disaggregates key regions from the RECCAP region set*. In particular, this highlights the significant difference between Japan and China, both in the East Asia region

Lower figure. The 12 largest inter-regional flows of carbon embodied in trade, from origin of emissions to the region of final consumption, with key regions disaggregated (2004). The largest single inter-regional flow is from China to USA (98 MtC). These 12 flows account for 40 % of all inter-regional flows using this grouping. In their 2010 paper on Counting CO_2 emissions in a globalised world: Producer versus consumer-oriented methods for CO_2 accounting, Bruckner et al. come to similar orders of magnitude **.

* RECAP is the REgional Carbon Cycle Assessment and Processes of the Global Carbon Project http://www.globalcarbonproject.org/about/index.htm (accessed 14 July 2014).

** Bruckner, M., Polzin, C. and Giljum, S. 2010. Counting CO2 emissions in a globalised world: Producer versus consumer-oriented methods for CO2 accounting. Discussion Paper, Deutsches Institut für Entwicklungspolitik, ISSN 1860-0441, http://seri.at/wp-content/uploads/2009/11/Bruckner-et-al-2010_Counting-CO2-emissions.pdf (accessed 18 August 2014).

Two resource-use indicators are then calculated. The first is direct use of biocarbon (C12a) that is the sum of use of domestic ecosystem biocarbon (C5) and imports of biocarbon. Direct use of biocarbon is a concept consistent with the direct material input (DMI) indicator of economy wide material flows (EWMF) accounting: *"direct material input (DMI) comprises all materials with economic value which are directly used in production and consumption activities. DMI equals the sum of domestic extraction and imports"*[26].

The second indicator is domestic consumption of biocarbon (C12b), which is direct use of biocarbon minus exports. Direct use of biocarbon is a measure of total direct material input, while domestic consumption refers to net use within the country. It is conceptually consistent with the direct material consumption (DMC) concept of EWMF.

Not only direct biocarbon use has to be recorded as inputs to the economy or consumption. Domestic ecosystem outflow comprises NEP and secondary production. In the case of imports, embedded flows have to be considered as well as actual direct flows. One example is meat products that have required grazing and other animal food. Accounting for biocarbon embedded in imported commodities (C12.3) allows calculation of biocarbon total requirement (C12.c) as the sum of C12a and C12.3. This indicator is consistent with the total material requirement (TMR) defined for EWMF accounting. It is a partial measurement of a biocarbon ecological footprint.

Table III adds accounts of fossil carbon flows to biocarbon.

The first sub-table includes direct use of fossil carbon (C13a), equivalent to C12a for bio-carbon. It includes, whatever the origin, the direct use of fossil carbon as a fuel and as other products (including the products of petrochemical industry). The input to the ecosystem is balanced in full by the supply and use system account so

26 http://www.materialflows.net/background/accounting/indicators-on-the-economy-wide-level/ (accessed 14 July 2014).

that there is no formal need to introduce a distinction between domestic and foreign origins. This may of course be done for policy reasons.

The second sub-table (C13.3) is for fossil carbon embedded into used commodities, of national origin and imported. The addition of C13.3 and C13a gives the TMR-type indicator, fossil carbon requirement.

The flows of carbon embedded in international trade are important since their import can be analysed as an additional export of environmental impacts. Box 5.11 shows the magnitude of the flows.

The bottom of the accounting table presents the addition of the direct use and total requirement indicators of biocarbon and fossil carbon calculated previously.

Total carbon direct use (C14a), which is the sum of C12a and C13a, has a pivotal role. It articulates ecosystem capital accounts with key policy indicators defined by IPCC for the UNFCCC and their application in strategies such as the OECD Green Growth initiative now shared with UNEP, the World Bank and the Global Green Growth Institute (GGGI). Total carbon direct use can be used for resource efficiency or green growth assessments directly or after conversion into CO_2 equivalents; comparison of total carbon use and ecosystem productivity is also an important indicator of ecological sustainability (Table IV).

Total carbon requirement (C14b), which is the sum of C12c and C13b, allows one further step: a move from production- to consumption-based assessment of carbon use[27]. Total carbon requirement is a measure of the carbon footprint in tonnes of carbon.

5.1.4 Table IV: Indices of intensity of use and ecosystem health

Narrative

Ecosystem capability to deliver services in a sustainable way relates to extent and quantities, as well as to more qualitative elements and ecosystem health. Regarding ecosystem carbon, renewal of the carbon resource, its quality and the conditions of renewal all have to be considered. These conditions can mostly be seen as internal or external to the carbon cycle, linked to the general functioning of the ecosystem and in particular the effects on other components such as water, integrity and biodiversity.

In Table IV, two indices are calculated and combined. The first is an index defined from Tables II and III to assess the sustainable intensity of use. The second is a composite index summarizing the elements not reflected in the first index. In the ecosystem carbon account, only elements related to carbon pools and cycle are recorded. They relate to the stability of the pools, their dependence on artificial inputs and their vulnerability to external stressors and other symptoms reflecting changes in ecosystem resilience regarding the carbon cycle.

The index of sustainable intensity of carbon use (C15) is the ratio of net accessible resource surplus to total use of ecosystem biocarbon. The ratio should remain ≥ 1. A ratio below 1 reveals that in the sharing of biomass between anthropogenic uses and ecosystem requirements, which can be called the food of biodiversity, not enough is left for the latter. This is a stress, the impact of which will be ecosystem degradation. The ecological quality of the biomass produced from an ecosystem with an index of sustainable intensity of carbon use < 1 is lower than when the index is ≥1.

The composite health index (CEH) summarizes other symptoms of ecosystem distress. The list of indicators closely follows the eco-health principles stated by David J. Rapport (*op. cit.*) but the items presented in Table IV are in part indicative. Other indicators can be used as long as they contribute to the overall diagnosis of ecosystem health. Their list depends on available data and knowledge as well as on the issues expected.

There is no unique solution to deriving a diagnosis from the set of indicators retained. The rationale is that of a medical diagnosis where the conclusion is not necessarily a function of the number of observations but more probably of the severity of a few or even of one. The model to produce the composite ecosystem health (CEH) index is therefore more of a decision-tree type than a statistical average. Probabilistic graph models such as Bayesian belief networks[28] are commonly used in fields such as medicine or biology to support diagnostic and/or decision-making and can be used for combining individual indicators into CEH. In any case, experts support is needed to interpret the results.

Typical indicators of ecosystem health regarding biocarbon are changes in the mean age of forest or fish stocks, and vulnerability to fire. An interesting health indicator is the dependency of biocarbon production from fossil energy inputs. Such dependency can be calculated using the ratio total biocarbon outflow to total carbon requirement [= C2/C14b]. This indicator

27 *Davis, S.J. and Caldeira, K. Consumption-based accounting of CO_2 emissions. PNAS 2010, http://www.pnas.org/content/107/12/5687 (accessed 14 July 2014).*

28 *"A* **Bayesian network, Bayes network, belief network, Bayes(ian) model or probabilistic directed acyclic graphical model** *is a probabilistic graphical model (a type of statistical model) that represents a set of random variables and their conditional dependencies via a directed acyclic graph (DAG). For example, a Bayesian network could represent the probabilistic relationships between diseases and symptoms. Given symptoms, the network can be used to compute the probabilities of the presence of various diseases." http://en.wikipedia.org/wiki/Bayesian_network (accessed 14 July 2014).*

Accounting Table 5-IV: Indices of sustainable intensity of use and ecosystem health

SEEA-EEA & ENCA-QSP land cover ecosystem units		LCEU 1	LCEU 2, 3, 4	LCEU 5	LCEU 6	LCEU 7, 8, 9, 10, 11, 12	LCEU 12	LCEU 13, 14	Total inland & coastal eco-systems	Open sea, oceans	Atmosphere	TOTAL	Supply & use system
IPCC land use classification		SL = Settle-ments	CL = Cropland	GL = Grass-land	FL = Forest Land	OL = Other Land	WL = Wetlands	Water bodies, rivers					
IV. Table of indexes of intensity of use and ecosystem health													
C11	Net Ecosystem Accessible Carbon Surplus = C2 + C10												
C5	Total use of ecosystem biocarbon = C3+C4												
SCU	**Sustainable intensity of carbon use = C11/C5**												
CEH.1	*Change in mean forest age*												
CEH.2	*Autonomy from artificial inputs/ Total carbon = C2 / C14b*												
CEH.3	*Autonomy from artificial inputs/ Other*												
CEH.4	*Change in vulnerability to fires*												
CEH.5	*CO2 driven acidification*												
CEH.6	*Other indicator...*												
CEH.x	*Other indicator...*												
CEH	**Composite ecosystem biocarbon health index**												
CIP	**Biocarbon ecological internal unit value = AVG(SCU+CEH)**												

would show, for example, that biocarbon produced with intensive use of fossil energy (for agricultural tractors and the production of inputs such as chemical fertilizers) may have lower ecological sustainability than similar biocarbon obtained from natural processes.

Final combination of the index of sustainable intensity of carbon use and the composite health index gives an index of quality (or condition) reflecting productivity and health. Such an index will be used as an equivalent to an internal biocarbon ecological price.

5.2 MINING BIOCARBON DATA IN OTHER ACCOUNTING AND STATISTICAL FRAMEWORKS

This second part of this chapter is in no way a formal comparison between frameworks, each of which have their own purpose. Instead, it aims to clarify the rationale of the various frameworks and their underlying costs in order to facilitate data-mining of the datasets for use in ecosystem capital accounting and to avoid confusion. Starting from what already exists is a pre-requisite for swift implementation of the QSP.

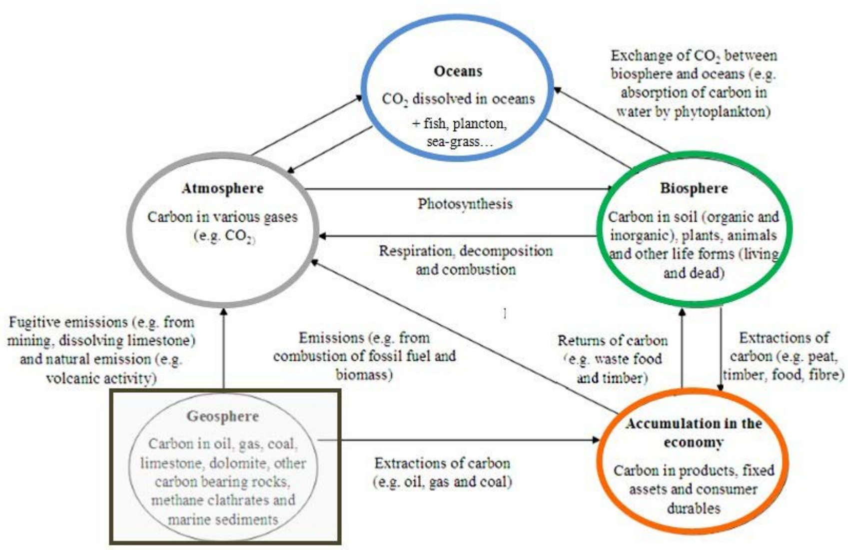
The ENCA-QSP is an experimental framework for testing SEEA-EEA, which is itself an extension of SEEA-CF; SEEA addresses carbon accounts in several chapters. Carbon accounting has also been developed in a different context as a consequence of the Kyoto Protocol and the data requirements of its Clean Development Mechanism. Coverage of the IPCC guidelines is progressively expanding, paying more and more attention to adaptation to climate change and the role of ecosystems in this context; REDD+ is an example of the ongoing progress. Other initiatives lead to the collection of useful data on ecosystem carbon, including the current update of the HANPP indicator. Last but not least, official statistics are collecting data that can be used for ecosystem accounting. One example is recent agriculture censuses that rely on a range of modern technologies including production of high-resolution maps and geo-referencing of the survey results. The situation varies from country to country and it is not possible to give a particular example. However, the most important statistics for ecosystem capital accounting relate to agriculture, forestry and fisheries and are globally centralized by FAO.

5.2.1 Biocarbon in the SEEA-CF and experimental ecosystem accounts

There is no integrated carbon account in the SEEA Central Framework. Carbon is considered: for emissions of greenhouse gases in SEEA-CF Chapter 3, Section 3.6.3, which recommends distinguishing emissions from fossil carbon and biomass; as a natural input from soil (Chapter 3, para. 3.62) and the atmosphere (CO_2) (3.63); in Chapter 4 for carbon taxes and emission permits; and is briefly addressed in Chapter 5 on asset accounts, the sections on soil and timber resource accounts, which concludes: "*a complete articulation of carbon accounting, including for example carbon sequestration in soils, is beyond the scope of the Central Framework but will be discussed in SEEA-EEA*" (SEEA-CF, 5.392).

The SEEA-EEA presents a comprehensive carbon account that includes geological and biological carbon. It starts from a representation of the carbon cycle (Figure 5.09). The ENCA-QSP accounts follow this approach but do not present complete accounts of the fossil resource stocks of the geosphere. Interpretation of the main elements of the carbon cycle in ENCA-QSP is done in following paragraphs.

Figure 5.09 The main elements of the carbon cycle in the SEEA-EEA



Source: based on SEEA-EEA Figure 4.1.

Although all are taken into account, the blocks of SEEA-EEA Figure 4.1. are not considered in the same way in ENCA-QSP, in particular in the QSP where priorities have to be set.

The biosphere is certainly at the core of ecosystem biocarbon accounts. The sea and ocean biosphere is part of the biosphere and includes fish stocks, plankton and seagrass. Seagrass beds, together with their soil, store large quantities of carbon. In ENCA-QSP, coastal waters, where seagrass beds usually occur, are attached to land systems.

Being part of the biosphere is common to all inland ecosystems, in particular the most artificial ones. The economy is therefore connected with the biosphere. The use of biocarbon by economic sectors is captured as extraction (harvest, removal, fishing, etc.) and returns to nature, land (leftovers from harvests, waste, sludge, manure, etc.), water (sludge, etc.), and the air (by combustion). Internal exchanges between economic sectors and transformation of carbon products and storage are assumed to be relevant to the SEEA-CF and not detailed in the ENCA. In Figure 4.1, accumulation in the economy is understood as the sum of all the economic flows of production and consumption that lead to it.

The geosphere's stocks of carbon are made up of fossil resources, carbon-bearing rocks and sediments. They are not recorded in ecosystem accounts, but use of carbon of fossil origin is. It is done in ENCA-QSP as an additional element of the table of carbon use. The aim is to compile the total amount of carbon included in greenhouse gas emissions and to measure the accountability of the total sector for the atmosphere/climate ecosystem.

The atmosphere ecosystem is not described in ENCA-QSP in detail but only when considering climate stability, water and greenhouse gases. It is recorded for carbon in a way similar to water where only precipitation and evaporation/evapotranspiration are recorded – not the huge masses of water contained in the clouds or evaporation from oceans. However, stocks of greenhouse gas carbon in the atmosphere are recorded as CO_2 equivalents, the way used by IPCC to assess the impacts on climate measured in degrees centigrade (°C).

Oceans are considered in ecosystem accounts although not in all aspects. A first point is that marine coastal ecosystems are considered in SEEA as extensions of inland ecosystems. The second is that oceans are part of biosphere. Also, in the figure above, additional arrows should connect the boxes on oceans and accumulation in the economy. Thirdly, however important the exchanges between oceans and the atmosphere may be, measuring them at this stage is a task to be carried out independently by climate modellers. In other words, references to climate will be to the atmosphere-ocean system.

The SEEA-EEA proposes a presentation of carbon accounts in Table 4.6 Carbon stock account. Although there is not enough experience to review all details, there appear to be no major gaps in the detailed contents of Table 4.6 and the ENCA-QSP bio-carbon accounts, but their coverage is not identical regarding flows. However stocks of fossil carbon are not recorded in ENCA-QSP.

There is a clear indication that harvests have to be recorded gross and net, after the subtraction of leftovers. Therefore the net change in stocks in both cases considers the returns to nature as a secondary input. This is not assumed in HANPP (defined above) where only gross values are taken. The SEEA solution allows both consistent accounting of stocks and flows and delivery of appropriate data for HANPP calculations.

Another important convergence is in the reaffirmation of the complete coverage of ecosystem types, natural, semi-natural, agricultural and human settlements (SEEA-EEA, para. A.45) and the possibility of using land-cover data as a way of distinguishing the more-or-less natural or managed characteristics of stocks and flows (SEEA-EEA, para. A.44). This distinction, which is done in Table 4.6 at a high level of presentation (natural versus managed expansion and contraction), is not made explicit in ENCA-QSP, which instead presents accounts by ecosystem type. As long as the methodology to distinguish natural from managed is based on land cover, the final result will be the same.

Another important point is to acknowledge that carbon balances are not a matter of quantity but also include qualitative aspects. In particular, this is done in relation to the quality of the carbon pools from which biocarbon is extracted. The cost of carbon will be different depending on whether it comes from stable pools (with long reconstitution times) or from short cycle reproduction systems.

The proposed SEEA-EEA presentation combines bio- and geo-carbon. Although not explicit, but suggested by the title of Table 4.6, the balancing item of the account is net change in stocks. In a first step, the ENCA-QSP limits the accounting framework to biocarbon; it recognises stocks and flows and net changes in stocks, NECB. This is measured twice, first as the difference between stocks at two dates and second as the net sum of flows, plus an adjustment item covering reappraisals and reclassification in Table 4.6).

Because of this combination in one account of subsoil carbon resources and biocarbon, the items are grouped in Table 4.6 in a way that does not display all the specific aspects of biocarbon flows that could be recorded. On the ENCA side, the biocarbon account presentation is aligned with those of water and functional services accounts. There are therefore minor differences in terminology. As analysed above, these formal differences do not result in major differences in content.

Box 5.12 Land-based versus activity-based accounting in IPCC

2.3.2. Protocol-specific accounting framework

2.3.2.2. Land-based versus activity-based accounting

"A carbon accounting system developed for the Kyoto Protocol must adhere to the basic scientific principles of carbon processes and the institutional terms and objectives of the UNFCCC. Two accounting approaches are discussed here that may meet these requirements. The Parties could decide to adopt either one of these approaches, or some combination of the two.

The first approach to accounting is land-based. Its starting point is the total carbon stock change in applicable carbon pools on land units subject to Kyoto activities. Implementing this rule involves first identifying land units on which applicable activities occur. Next, the total change in carbon stocks on these land units during the commitment period is determined. Adjustments can then be made to reflect decisions that the Parties may adopt regarding baselines, leakage, and timing issues, as discussed in the following sections. Aggregate emissions or removals are the sum of stock changes (net of adjustments) over all applicable land units.

The second approach is activity-based. Its starting point is the carbon stock change attributable to designated LULUCF activities. First, each applicable activity's impact on carbon stocks is determined per unit area. This impact is multiplied by the area on which each activity occurs. This equation may also include adjustments to reflect policy decisions by the Parties. Aggregate emissions or removals are calculated by summing across applicable activities. Potentially, a given area of land could be counted more than once if it is subject to multiple activities. This potential double-counting could result in inaccurate accounting if the effects of activities are not additive. Alternatively, the Parties could decide that each land unit could contain no more than one activity. In this case, the combined impact of multiple practices applied in the same area would be considered a single activity."

IPCC/LULUCF Special Report https://www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=61 (accessed 14 July 2014).

5.2.2 Biocarbon in IPCC/LULUCF and REDD guidelines[29]

a. Accounting in the IPCC context

IPCC guidelines refer to accounting in two ways: *"ACCOUNTING: The rules for comparing emissions and removals as reported with commitments."* and *"CARBON BUDGET: The balance of the exchanges of carbon between carbon pools or between specific loops (e.g., atmosphere – biosphere) of the carbon cycle. The examination of the budget of a pool or reservoir will provide information whether it is acting as a source or a sink."* (IPCC Glossary). From the perspective of ecosystem biocarbon accounting, carbon budgets correspond, to a large extent, to basic accounts as defined in Chapter 2. The IPCC Accounting standards need to be considered when assessing issues implying definition of distance to targets.

For the purpose of keeping stock of greenhouse gases in the context of the UNFCCC and the Kyoto Protocol, LULUCF is an accounting sector that includes all human management of vegetation and soils. Accounting rules provide a methodology to structure and categorize data. LULUCF applies to Kyoto Protocol Annex 1 countries only (developed nations), and should not be confused or mixed with REDD+ that concerns developing nations. The rules of REDD+ are embedded into LULUCF principles. Following the 2006 IPCC Guidelines for national greenhouse gas inventories, AFOLU consolidates the previous sectors LULUCF and agriculture.

The LULUCF rules reflect a compromise arising from the special circumstances at the Kyoto Conference where targets and the ways and means to reach them were agreed before the precise measurement rules. The primary focus of LULUCF is on greenhouse gas emission mitigation and removal from the atmosphere. Options are given to parties to implement either land-based activities or activities based on monitoring, or a mixture of the two.

In a land-based accounting system, all anthropogenic emissions and removals from relevant forest areas are accounted for. Because of the need for a strong monitoring, reporting and verification (MRV) system to assess rights for funding, REDD+ develops land-based accounting programmes using very high-resolution satellite imagery.

In activity-based reporting systems, Parties to UNFCCC account for emissions and removals attributable to a defined set of anthropogenic activities, for example deforestation, harvesting, fertilization. In IPCC language, ENCA-QSP is primarily land-based accounting, built on observations. Activities based on monitoring are of limited use for ENCA basic accounts but may be of interest for assigning ecosystem degradation to specific economic sectors.

29 *http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html (accessed 14 July 2014)*

The complexity of LULUCF accounting rules is a consequence of the priority given to supporting practical measures with financial consequences that can be agreed by various Parties. It includes: the additionality criteria, needed to detect surpluses eligible for offset credit, factoring-out direct anthropogenic effects from indirect and natural ones; permanence or non-permanence of storage in vegetation and soil; uncertainties; and reference levels (RL), which are the CO_2 emissions/removals against which future emissions/removals will be compared, generating emission credits or debits. The RL may be based either on historical periods or on business-as-usual (BAU) projections and calculations of debits and credits using various methods negotiated between parties (net-net, gross-net or gross-net with caps, etc.). These specificities have to be kept in mind when considering the use of IPCC reporting data as an input for ecosystem capital accounting.

Box 5.13 Additionality in the IPCC guidelines

- Additionality is a core aspect of quality assurance of greenhouse gas (GHG) emissions reduction and sequestration activities. The concept is used in a climate change context to mean net GHG emissions savings or sequestration benefits over and above those that would have arisen anyway in the absence of a given activity or project.
- The underlying rationale is to distinguish activities, which further contribute to climate change mitigation from those which, although they may be associated with carbon savings, offer no benefits above those expected anyway.
- Distinguishing activities, which are additional requires establishing a 'business as usual' baseline. This requires determining a counterfactual for what would have happened if the project or activity had not gone ahead, and identifying the carbon pools and other greenhouse gas emissions sources and savings covered by the assessment.
- Additionality is a multi-faceted concept. At least nine forms of legal, regulatory and institutional additionality, three of financial and investment additionality, and three of environmental additionality can be distinguished.

Source: Valatin, G. 2011. Forests and carbon: a review of additionality. Forestry Commission Research Report. Forestry Commission, Edinburgh. http://www.forestry.gov.uk/pdf/FCRP013.pdf/$FILE/FCRP013.pdf (accessed 14 July 2014).

Box 5.14 Factoring-out direct anthropogenic effects from indirect and natural

"*The capacity to partition natural, indirect, and direct human-induced effects on terrestrial carbon (C) sources and sinks is necessary to be able to predict future dynamics terrestrial C sinks and thus its influence on atmospheric CO2 growth. However, it will take a number of years before we can better attribute quantitative estimates of the contribution of various C processes to the net C balance. In a policy context, factoring out natural and indirect human-induced effects on C sources and sinks from the direct human-induced influences, is seen as a requirement of a C accounting approach that establishes a clear and unambiguous connection between human activities and the assignment of C credits and debits.*"

Source: Canadell, J. et al. Factoring out Natural and Indirect Human Effects on Terrestrial Carbon Sources and Sinks http://www.globalcarbonproject.org/global/pdf/Canadell_2007_FActorOut_FINAL-style-ed.pdf (accessed 18 August 2014)

The IPCC method has been developed, promoted and updated as a detailed handbook[30] with recommendations and guidelines for national accounting, including a software package which can be directly applied to estimate carbon accounts for any territory. The methodology is structured in three tiers of complexity which range from the simplest default emission factors and equations universally applicable to estimate stocks and flows (Tier 1) for any country, through the use of country-specific data and models to accommodate national/regional circumstances (Tier 2) to locally, spatially-explicit data and more complex models (Tier 3). The choice of tier is left to the users, it is mentioned however that "*in general, moving to higher tiers improves the accuracy of the inventory and reduces uncertainty, but the complexity and resources required for conducting inventories also increases for higher tiers*" (IPCC Guidelines).

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30 Glossary http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Glossary_Acronyms_BasicInfo/Glossary.pdf; LULUCF Good Practice Guidance for Land Use, Land-Use Change and Forestry http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html; AFOLU Agriculture, Forestry and Other Land Use http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html (accessed 14 July 2014).

Box 5.15 IPCC gain-loss and stocks difference methods to account for biocarbon pools

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EQUATION 2.4
ANNUAL CARBON STOCK CHANGE IN A GIVEN POOL AS A FUNCTION OF GAINS AND LOSSES (GAIN-LOSS METHOD)

$$\Delta C = \Delta C_G - \Delta C_L$$

Where:

ΔC = annual carbon stock change in the pool, tonnes C yr^{-1}

ΔC_G = annual gain of carbon, tonnes C yr^{-1}

ΔC_L = annual loss of carbon, tonnes C yr^{-1}

EQUATION 2.5
CARBON STOCK CHANGE IN A GIVEN POOL AS AN ANNUAL AVERAGE DIFFERENCE BETWEEN ESTIMATES AT TWO POINTS IN TIME (STOCK-DIFFERENCE METHOD)

$$\Delta C = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)}$$

Where:

ΔC = annual carbon stock change in the pool, tonnes C yr^{-1}

C_{t_1} = carbon stock in the pool at time t_1, tonnes C

C_{t_2} = carbon stock in the pool at time t_2, tonnes C

The following general accounting principles followed in IPCC accounting are similar to those recommended for ENCA-QSP, in particular transparency, all the methodologies should be clearly explained and documented; consistency, the same methodologies and consistent data sets should be used along time; completeness, estimates should include all the agreed categories, gases and carbon pools; and data quality assurance/quality control (QA/QC). Considering the IPCC comparability criteria, the experimental character of SEEA-EEA on ecosystem accounting does not make it possible to provide methodologies and formats as precise and comprehensive as those of IPCC. This will be done stepwise, once the SEEA-CF is widely implemented and more empirical experience on ecosystem accounting gained though experimentation. Comparability in the context of the ENCA-QSP should therefore mainly be based on the general principles to be followed, the aim of the accounts, and the way they deliver outcomes that are comparable in terms of their meaning.

Beyond reporting on greenhouse gas emissions, LULUCF/AFOLU records removals of CO_2 from the atmosphere, measured as changes in the above-ground and below-ground pools able to store carbon. "*The UNFCCC defines 'sink' as 'any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere. The development of policy on 'sinks' has evolved to cover emissions and removals of greenhouse gases resulting from direct human-induced land use, land-use change and forestry (LULUCF) activities and thus, the acronym LULUCF is now used to refer to this sector.*"[31]

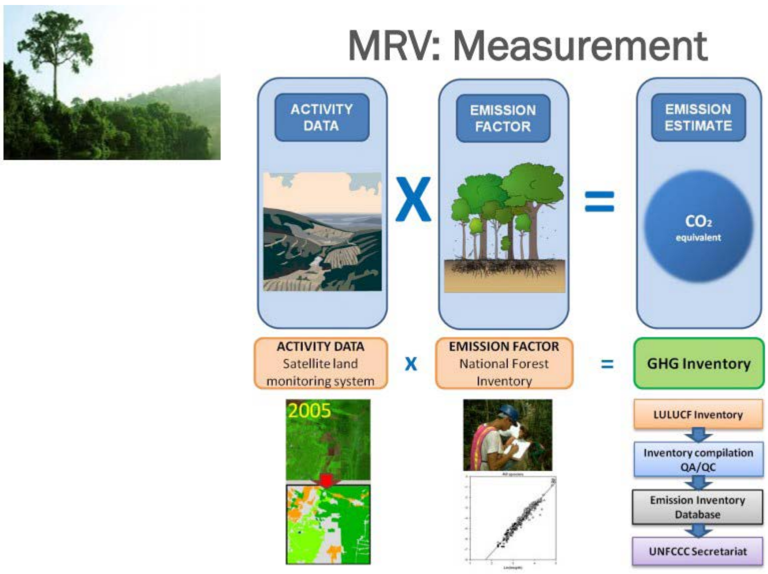
The AFOLU/LULUCF accounts for biocarbon stocks and flows can supply a wealth of data for ecosystem accounting. A summary of input data and calculation rules is presented in the IPCC summary of LULUCF/AFOLU equations[32]. This is a long list produced by years of work by hundreds of experts and it is not possible (or useful) to comment on it in any detail here. Its usefulness is as a dictionary for understanding what can be expected from the IPCC community at large. As an example of possible convergence and bridges, Box 5.15 shows that the biocarbon balance can be addressed in two ways: gain-loss and stock difference methods. The same solution is proposed for ENCA-QSP in order to have a double check of the NECB and identify where gaps should be reduced.

The estimation rules recommended in AFOLU/LULUCF and REDD+ guidelines may be solutions in many cases for implementing the ENCA-QSP. Their use may require some adaptation or translation.

31 http://unfccc.int/methods/items/2722.php (accessed 14 July 2014).

32 http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_14_An2_SumEqua.pdf (accessed 14 July 2014).

Figure 5.10 Illustration of the REDD+/IPCC methodological approach to calculate anthropogenic greenhouse gas emissions by sources and CO2 removals by sinks related to land area



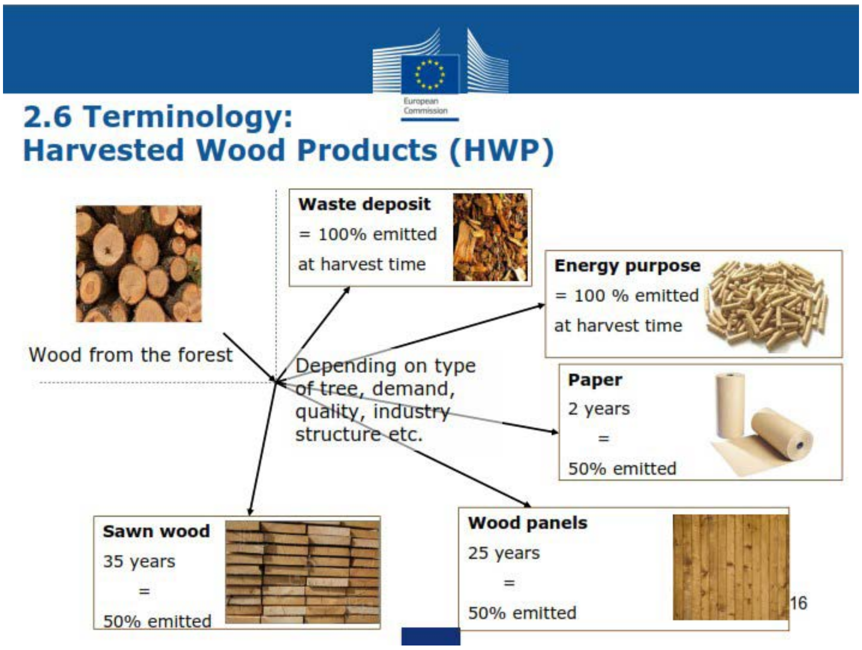
Source: Jonckheere, I. 2013. Joint FAO-INPE effort in the context of REDD+ Status and challenges. GOFC-GOLD, Wageningen, Netherlands, http://www.gofcgold.wur.nl/documents/wageningen13/19-04/Session%2012%20part%201/IJonckheere.pdf (accessed 14 July 2014).

The first issue to note is that the aim of biocarbon accounting in IPCC is to measure emissions and removals of CO_2 while ecosystem accounts aim at assessing ecosystem capability to deliver services, and degradation in the case of unsustainable use. Degradation of forests beyond carbon losses is in principle within the field of LULUCF and REDD but has not yet really been addressed in current reporting.

A related point is that the CO_2 removal model for change in stocks of biocarbon pools is well established for forests but remains to be implemented for agriculture and other land uses. The problem is particularly related to horizontalflows of biocarbon, which are in many cases excluded. The point is being discussed in terms of producer- versus consumer-oriented methods for CO_2 accounting[33]. It has implications for measuring (or not measuring) carbon embedded in international trade, domestic trade, and leakages such as erosion. The discussions on harvested wood products (HWP) illustrate the issue; Figure 5.11 illustrates the way it works now. Half-life coefficients are assigned to each pool modified by harvest, some of them being converted immediately into CO_2 emissions (residuals, fuel wood, etc.), 50 % of paper within two years, and 50 % of sawn wood over a 35 years period. From a producer viewpoint, all these emissions come from harvested forests. For ENCA-QSP, only waste deposits (leftovers, etc.) are assigned in this case to such forests. This kind of estimation make sense for a QSP as long as the local ecosystem balance does not record emissions from the use of wood happening somewhere else.

33 http://seri.at/wp-content/uploads/2009/11/Bruckner-et-al-2010_Counting-CO2-emissions.pdf (accessed 14 July 2014).

Figure 5.11 Example of estimation of greenhouse gases in the case of timber:



Source: Overview of the Land Use, Land Use Change and Forestry. LULUCF concepts and principles.
Asger Olesen, DG Climate, EC, 2012 ec.europa.eu/clima/events/0056/presentation_asger_olesen_en.pdf (accessed 14 July 2014).

For agriculture, where harvested crops go to urban areas or are exported, the forest stock model for assessing CO_2 removals results in serious misrepresentation of the measurement of carbon sequestration as an ecosystem service. Globally, it can be argued that agriculture does not permanently remove CO_2 beyond its net carbon balance and that sequestration should be restricted to gains and losses in soil content. In land-based accounting, NECB is also a relevant indicator of soil state in land-based accounting. From a flows perspective, a second indicator needs to reflect the performance of the system in terms of its capacity to deliver a service. This is the more important since the flow itself is the support of life, such as biomass and water. In the case of carbon sequestration by agriculture, accounts should take note that this is an ecosystem service that is delivered gross by agriculture and consumed by other sectors. In ecosystem accounts the (simplified) circuit will be: NPP → harvested crops (transferred from the ecosystem to the economic system) → processed and consumed in the economic use system → in part returned to the atmosphere (combustion, respiration), in part returned to the environment, for example as sewage sludge, or exported to another territory.

Other biocarbon flows are excluded from LULUCF reporting because they cannot be assigned to sectors and accounted for in calculations of carbon debits or credits. This is the case for natural disturbances, including fires that are not the result of land-use management. In fact, only activities for which sectors have direct responsibility have to be reported. Indirect responsibility is also not accounted for. In ecosystem accounting, ecosystem deterioration measured by the difference between ecosystem capabilities at two dates is split between natural disturbances and degradation assigned to economic activities. A difference is that indirect effects are also taken into account in degradation since they are non-paid externalities for the sectors that cause them. Considering ecosystem enhancement, only new improvements driven by sectoral actions, including conservation measures, are taken into account. This excludes restoration of degradation in previous periods that will appear as reduction of degradation – and of related ecological debts. The creation of ecological credits will be recorded in a way similar to carbon credits, in relation to stated reference levels (Chapters 8 and 9).

In the case of using IPCC data, if reporting is compiled from statistics with insufficient detail on land use, data will need to be downscaled to match ecosystem accounting requirements. When national results are based on geo-spatial datasets, the accountant will have to establish working agreements with the national organizations in charge of this reporting in order to access them.

At an aggregated level, the QSP land-cover classification (LCEU) has a simple match to AFOLU classes (Section 5.1, Table 5.01). As explained in Chapter 3, LCEU classifications have to be subdivided, depending on national conditions. A match with the detailed classes used for IPCC reporting will need to be achieved.

b. About REDD+

In the case of REDD+, high spatial detail is available for forests and/or areas covered by the agreements. In Chapters 2 and 3, solutions for aggregating high-resolution geo-data for ecosystem accounting have been presented. They can be used with data collected for REDD+. One point to note is that the generalization of such very high-resolution data, in particular using smoothing procedures, is in many cases an acceptable response to the problems of confidentiality that may arise in some cases.

Box 5.16 About REDD+

REDD+ is a climate-change mitigation solution that many initiatives, including the UN-REDD Programme, are currently developing and supporting. Other multilateral REDD+ initiatives include the Forest Carbon Partnership Facility (FCPF) and Forest Investment Program (FIP), hosted by The World Bank.

The REDD+ "Terrestrial Carbon Accounting Community of Practice is made up of REDD+ practitioners around the globe focused on data acquisition, land use change detection, emissions factors for terrestrial carbon, mathematics and statistics, sharing and transparency, and quality assurance".

"Reducing Emissions from Deforestation and Forest Degradation (REDD) is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. "REDD+" goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks." http://www.un-redd.org/

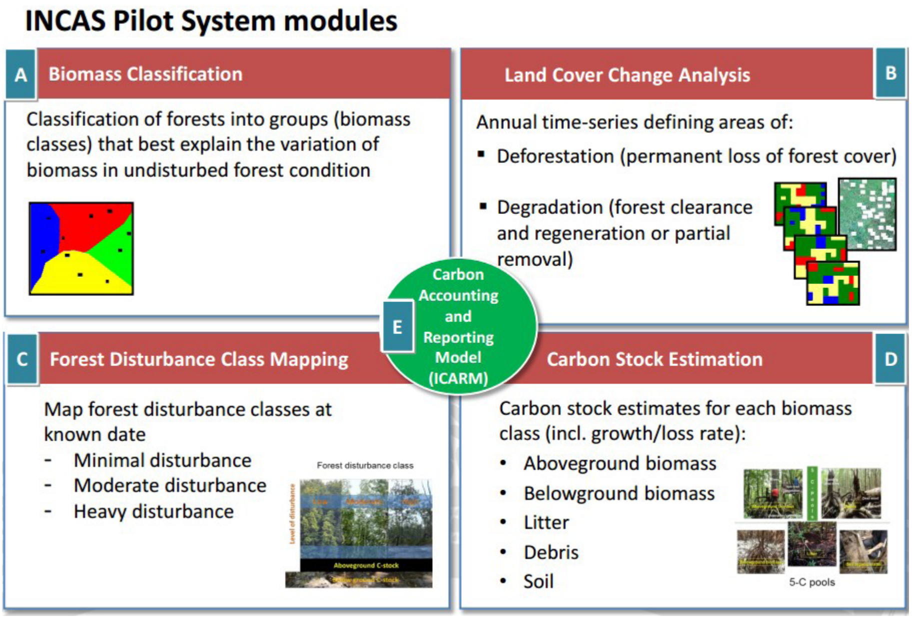
The FCPF is a global partnership launched by the World bank in 2006. It includes governments, businesses, civil society, and indigenous people focused on reducing emissions from deforestation and forest degradation, forest carbon stock conservation, the sustainable management of forests, and the enhancement of forest carbon stocks in developing countries. It aims at assisting countries in their REDD+ efforts by providing them with financial and technical assistance in building their capacity to benefit from possible future systems of positive incentives for REDD+. https://www.forestcarbonpartnership.org/ (accessed 14 July 2014).

The FCPF has developed an accounting framework. https://www.forestcarbonpartnership.org/sites/fcp/files/2013/Dec2013/FCPF%20Carbon%20Fund%20Meth%20Framework%20-%20Final%20December%2020%202013%20posted%20Dec%2023rd.pdf (accessed 14 July 2014).

REDD+ is stimulating initiatives that lead to more data of better quality and the involvement of a range of players. One initiative is participatory carbon monitoring (PCM) which is an approach to improve the vertical and horizontal institutional integration of different stakeholders for carbon accounting within a country's national REDD+ programme[34]. The various stakeholders can each contribute to the development of reference levels and a robust and transparent national forest monitoring system (NFMS) to support measurement, reporting and verification (MRV) of greenhouse gas emission reductions and enhanced removals from forests and land-use change. National and sub-national government institutions as well as local stakeholders, including local communities, all have particular roles to play in these carbon accounting requirements of national REDD+ programmes. Participatory carbon monitoring (PCM) is presented here as an approach to improving the vertical and horizontal institutional integration of

34 http://www.snvworld.org/en/redd/publications/participatory-carbon-monitoring-manual-for-local-people (accessed 14 July 2014).

Figure 5.12 the INCAS information system on forest carbon in Indonesia



Harvey, T. MRV and carbon accounting systems. Indonesia-Australia Forest Cover Partnership (IAFCP) Seminar. http://www.redd-indonesia.org/pdf/seminar/18_April_2013/MRV_carbon.pdf (accessed 14 July 2014).

different stakeholders for carbon accounting within national REDD+ programmes. The manual *Participatory Carbon Monitoring: Operational Guidance for National REDD+ Carbon Accounting* can be downloaded from the web, as can guidelines targeted to specific issues such as field monitoring[35].

In some cases, REDD+ activities are generating national information systems on forest biocarbon that will be essential resources for ecosystem accounting. An example is the Indonesian National Carbon Accounting System (INCAS; Figure 5.12).

Other sources of knowledge are the "voluntary standards" proposed by companies or NGOs. They include detailed documentation that can be of interest for fixing particular measurement issues. "*The Kyoto Protocol invented the concept of carbon emissions trading, whereby carbon credits were a 'flexibility mechanism'. Under this flexibility mechanism Annex I (developed countries) could use the carbon credits to meet their emission reduction commitments. These flexibility mechanisms were also designed to be able to assist with transferring resources and sustainable technologies to developing countries. There are two kinds of carbon credits that can be created to this end: Joint Implementation and the Clean Development Mechanism. The United Nations Framework Convention on Climate Change (UNFCCC) created methodologies for both of these kinds of credits, and also have organisations that approve, certify and register projects under these mechanisms. […] Above and beyond both the Kyoto and Voluntary standards are a number of 'Premium' standards. Projects with these premium standards are generally first certified either under the VCS or as CDM CERs or JI ERUs.*" (CarbonPlanet, 2014 – http://www.carbonplanet.com/verification_and_standards).

HANPP accounting

Human appropriation of net primary production, introduced above, is an aggregated indicator that reflects both the area used by humans and the intensity of land use. Net primary production is the net amount of biomass produced each year by plants; it is a major indicator for trophic energy flows in ecosystems. Human appropriation of net primary production measures the extent to which land conversion and biomass harvest alter the availability of NPP (biomass) in ecosystems. It is a prominent measure of the scale of human activities compared to natural processes (i.e. of the *"physical size of the economy relative to the containing ecosystem;"* Daly, 2006). As human harvest of biomass is a major component of HANPP, it is also closely related to socio-economic metabolism as measured by material flow accounts.

35 For example http://www.snvworld.org/en/sectors/redd/publications?filter=~manual (accessed 14 July 2014).

Box 5.17 Components of global HANPP and global human-induced biomass flows.

	NPP/biomass flow [Pg C/yr]**	Percentage of NPP_0 [%]
Components of global HANPP 2000		
NPP of the potential terrestrial vegetation (NPP_0)	65.51	100
NPP of the actually prevailing vegetation (NPP_{act})	59.22	90.4
NPP remaining in ecosystems after harvest (NPP_t)	49.9	76.2
NPP harvested or destroyed (NPP_h)	9.31	14.2
Change in NPP resulting from land use (?NPP_{LC})	6.29	9.6
HANPP (= ?NPP_{LC} plus NPP_h)	15.6	23.8
Backflows to nature	2.46	3.7
Global human-induced biomass flows		
*Used extraction of biomass**	6.07	9.3
* of which: harvested primary crops	1.72	2.6
* of which: harvested crop residues	1.47	2.2
* of which: grazed biomass	1.92	2.9
* of which: wood removals	0.97	1.5
*Unused extraction**	3.24	5
* of which: human-induced fires	1.21	1.8
* of which: unused belowground biomass	0.96	1.4
* of which: unused residues on cropland	0.75	1.1
* of which: felling losses in forests	0.33	0.5

** Used plus unused extraction equals NPP_h.*
*** Pg stands for Petagrams. 1 Pg = 1015 grams = 1 billion tonnes*

Sources: Haberl et al. (2007) and Krausmann et al. Encyclopedia of Earth http://www.eoearth.org/view/article/51cbede37896bb431f694846
National-level data on socioeconomic biomass flows can be downloaded from the Institute for Social Ecology: http://www.uni-klu.ac.at/socec/inhalt/1088.htm

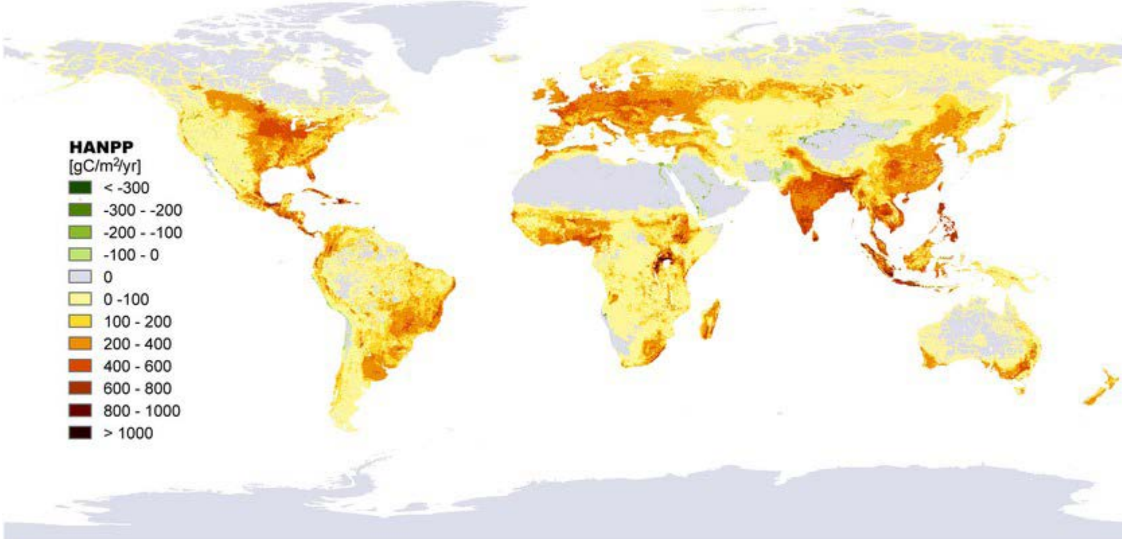
Since the early work of Vitousek[36] in the USA and Haberl (op. cit.) [37]in Austria, several definitions of HANPP have been proposed. HANPP can be defined "*as the difference between the amount of NPP that would be available in an ecosystem in the absence of human activities (NPP0) and the amount of NPP which actually remains in the ecosystem, or in the ecosystem that replaced it under current management practices [.....] NPPt can be calculated by quantifying the NPP of the actual vegetation (NPPact) and subtracting the amount of NPP harvested by humans (NPPh)."(Haberl, op. cit.)*. HANPP is to a large extent a biocarbon account which can be used, at least in part, for producing ENCA-QSP accounts.

Global HANPP assessments are done with a medium to low resolution and data which require further downscaling before integration into ecosystem capital accounts. For example, the HANPP calculated above is based on a land-use data set with a resolution of 5 arc min, equivalent on average to a 10 km × 10 km grid into which national land-use statistics for cropland and forestry at the country level are downscaled. The five land-use classes are the same as for AFOLU. For each grid cell, the sum of these five layers is 100 %. Global HANPP results for 2000 are downloadable at http://www.uni-klu.ac.at/socec/inhalt/1191.htm.

36 *Vitousek P., Ehrlich P., Ehrlich A. et al. 1986. Human Appropriation of the Products of Photosynthesis, BioScience Vol. 36, No. 6, from JSTOR http://biology.duke.edu/wilson/EcoSysServices/papers/VitousekEtal1986.pdf (accessed 14 July 2014).*

37 *Haberl, H., Erb, K.-H. and Kraussmann, F., Article on Global HANPP, Encyclopedia of Earth http://www.eoearth.org/view/article/153031/ (accessed 14 July 2014).*

Figure 5.13 Global HANPP 2000



Source: http://www.uni-klu.ac.at/socec/inhalt/1191.htm (accessed 14 July 2014).

Another set of HANPP data for 1995 is downloadable from the SEDAC website http://sedac.ciesin.columbia.edu/es/hanpp.html[38]. The data are not comparable with those previously described.

5.2.3 Biocarbon in FAO statistics

At the global level, FAO plays a central role in collecting data and statistics on biomass stocks and products. In addition to data, the FAO website provides knowledge and guidance for professionals which can be of great interest for accounting. The actions of FAO are coordinated with other international organizations in structures such as the Global Terrestrial Observing System (GTOS) and the Collaborative Partnership on Forests (CPF), an innovative inter-agency partnership on forests comprising 14 international organizations, institutions and secretariats that have substantial programmes on forests. The FAO plays a leading role in UN-REDD and participates in the UN Committee of experts on Environmental and Economic Accounting (UNCEEA) which steers the SEEA process.

The following paragraphs do not aim at presenting a comprehensive picture of the FAO programme in this field, but give the accountant an indication of what is available. From a QSP perspective, data can be downloaded directly from FAO statistical databases, but the best way, when possible, is to establish institutional partnerships with the national agencies on agriculture, forestry and fisheries – the bodies that supply national data to FAO.

One key FAO global survey is the forest resource assessment, of which FRA2010 is the most recent. "*In order to maximize synergies and streamline country reporting to international organizations, FAO incorporated the IPCC 2006 guidelines on assessment of carbon stocks in forests into its guidelines for country reporting for FRA 2010. Figures on carbon stocks in forests reported under the UNFCCC, the Kyoto Protocol and to FAO are not necessarily identical. Forest definitions may vary and furthermore UNFCCC members are requested to report on 'managed forests' which may comprise all or only part of the forest area of a given country. FRA specific methods such as calibration, reclassification, estimating and forecasting are also not always implemented in exactly the same way in the reporting under the UNFCCC and the Kyoto Protocol.*" http://www.fao.org/docrep/013/i1757e/i1757e02.pdf

FRA2010 Global tables can be downloaded as spreadsheet from: https://countrystat.org/home.aspx?c=FOR with terms and definitions at http://www.fao.org/docrep/014/am665e/am665e00.pdf. For biocarbon accounting, Table 11 on trends in carbon stock in living forest biomass 1990–2010 is of direct use to control national totals. Statistics on removal are given in 1,000 m^3 over bark (the conventional measurement of trees circumference and volume) and need to be expanded – converted to tonnes of biomass and then of carbon.

The FAO also provides experts with methodologies and tools for detailed assessments which will allow progress in future forest assessments and accounting. For example, in 2013, FAO launched GlobAllomeTree,

38 Imhoff, M.L., Lahouari B., Taylor R.et al. 2004. Data distributed by the Socioeconomic Data and Applications Center (SEDAC): http://sedac.ciesin.columbia.edu/es/hanpp.html (accessed 14 July 2014).

a web-based platform designed to improve global access to tree allometric equations and support forest and climate-change project developers, researchers, scientists and foresters to assess forest volumes, biomass and carbon stocks. Tree allometry is a methodology that establishes quantitative relationships between some key characteristic dimensions of trees, usually fairly easy to measure, and other properties often more difficult to assess. Jointly developed by FAO, the French Research Centre (CIRAD) and Tuscia University of Italy, the GlobAllomeTree platform provides a consistent and harmonized database of tree and stand volumes and biomass allometric equations, and software to compare equations and assess variables of interest, such as volumes, biomass and carbon stocks (http://www.fao.org/docrep/013/i1757e/i1757e02.pdf).

FAO has also started to drive work on forest degradation, which it defines as: "*the reduction of the capacity of a forest to provide goods and services*". Experimental guidelines were published in 2011: "*Assessing forest degradation, Towards the development of globally applicable guidelines*" http://www.fao.org/docrep/015/i2479e/i2479e00.pdf (FAO, 2002). This report goes beyond carbon balances and addresses landscape and biodiversity issues. It will be quoted again in Chapter 7.

Soil carbon data can be extracted from the Harmonised World Soil Database of FAO, IASA and JRC. The *Global Cattle Density Map* (2005) is produced using a model that combines best available statistics on grazing livestock. It is useful for downscaling the pressure of livestock on land (Section 5.1.2).

The 2014 release covers and projections of agriculture emissions to 2030 and 2050. The FAOSTAT Emissions database for the agriculture, forestry and other land use sector contains greenhouse gas emissions national statistics for all countries, with continuous time-series (agriculture, 1961-2011; forestry and other land use, 1990-2010) and useful metadata for each sector. Data and documents are available at http://faostat3.fao.org/faostat-gateway/go/to/download/G1/*/E (agriculture) and http://faostat3.fao.org/faostat -gateway/go/to/download/G2/*/E (land use). A 2014 companion analysis report on *Agriculture, Forestry and Other Land Use Emissions by Sources and Removals by Sinks, 1990-2011 Analysis (op. cit), can be downloaded at:* http://www.fao.org/docrep/019/i3671e/i3671e.pdf.

Many other useful geo-spatial data can be found on the FAO website at http://www.fao.org/geonetwork/srv/en/main.home. It includes maps of fishing zones that can be used jointly with statistics extracted from FishStatJ – software and a database for fishery statistical time-series (http://www.fao.org/fishery/statistics/software/fishstatj/en).

6. THE ECOSYSTEM WATER ACCOUNT

Water accounting is a common practice in hydrology and agronomy where water budgets and water balances are commonly-used terms. Water, just like money, can be subject to double-entry accounting.

6.1 ACCOUNTING FOR WATER

6.1.1 Background

Water accounts have been produced in France[1] and in Spain[2] since the early 1980s, using largely similar and complementary methodologies. Both accounts covered water quantity at the river-basin level and were aggregated nationally; the relationships between stocks and flows were described on the basis of systems analysis of the interaction between the water system itself, which includes natural assets and flows as well as in-stream uses, and a use system, defined restrictively in relation to water abstraction, transport and returns. Both applications considered both water quantity and quality. On the quality issue, while the French accounts attempted to use quality indicators of rivers, the Spanish accounts developed an approach based on thermodynamic measurements of water exergy losses, integrating quantity and quality aspects into one number. Both programmes included accounts of water expenditure. The water accounting methodology has been used in Chile[3] and Moldova[4]. Development of exergy-based water accounts has continued in Spain at the University of Zaragoza in the context of an overall approach to environmental accounting based on the calculation of exergy physical costs, with several regional applications developed[5], and preliminary tests carried out jointly with the European Environment Agency.

Water accounts have been implemented by the Australian Bureau of Statistics (ABS) since the early 1990s with a focus on the use of water by economic sectors. The ABS methodology follows the SEEA – ABS contributed to its development – and in particular SEEA-Water (see below). Water Account Australia (WAA) "*presents information on the supply and use of water in the Australian economy in 2011–12 in both physical (i.e. volumetric) and monetary terms. The focus of Water Account Australia (WAA) is on the interactions between users within the economy and the environment. The economy extracts water for consumption and production activities. The infrastructure to mobilize, store, treat, distribute and return water back to the environment forms part of the economy*"[6]. Water Account Australia (WAA) has been available since 1993 and has been updated annually since 2008[7].

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1 *In Les Comptes du Patrimoine Naturel, CICPN, 1986, Les Collections de l'INSEE : 535-536. Série C, 137-138.*

2 *Spanish accounts were presented to the OECD (Pilot Study on Inland Waters, OECD, ENV/EC/SE (90) 24) in 1990 and published later in Spanish Water Accounts, by Jose Manuel Naredo in Environmental Economics in the European Union, Mesonada, C.S-J. (ed.). 1997. Mundi Prensa, Madrid,*

3 *Meza F., Jiliberto R., Maldini F. et al. 1999. Cuentas Ambientales del Recurso Agua en Chile. Documento de Trabajo Nº 11, Serie Economía Ambiental, Pontificia Universidad Católica de Chile, Facultad de Agronomía y Ciencias Forestales, Santiago, Chile*

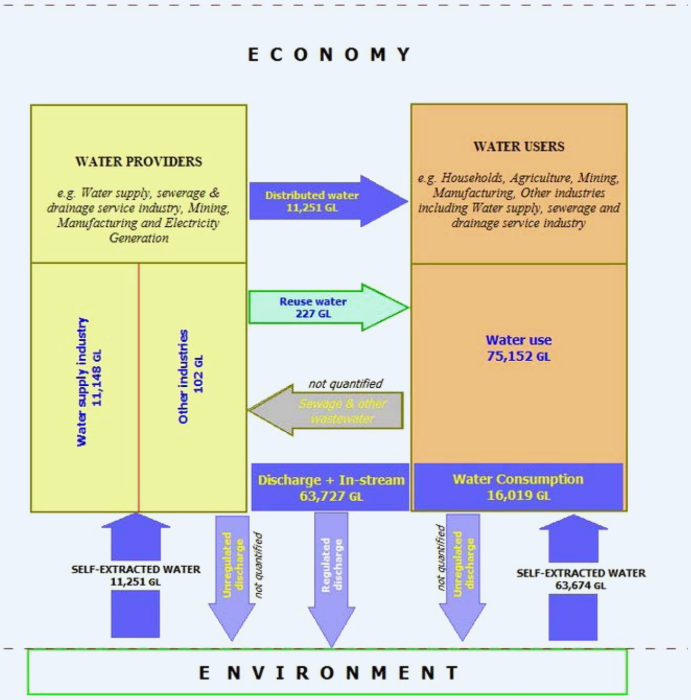
4 *Tafi J. and Weber J.-L. 2000. Inland Water Accounts of the Republic of Moldova - Preliminary Results of Resource Accounts in Raw Quantities, 1994 and 1998. Technical report, Eurostat.*

5 *Valero A. et al. 2006 Physical Hydronomics: application of the exergy analysis to the assessment of environmental costs of water bodies. The case of the Inland Basins of Catalonia. http://teide.cps.unizar.es:8080/pub/publicir.nsf/codigospub/0436/$FILE/cp0436.pdf (accessed 14 July 2014).*

6 *http://www.abs.gov.au/ausstats/abs@.nsf/mf/4610.0 (accessed 14 July 2014).*

7 *The Australian accounts from 1993 up to now are accessible at http://www.abs.gov.au/AUSSTATS/abs@.nsf/second+level+view?ReadForm&prodno=4610.0&viewtitle=~2011%9612~~&&tabname=Past%20Future%20Issues&prodno=4610.0&issue=2011%9612&num=&view=& (accessed 14 July 2014).*

Box 6.01 Water Supply in the Australian economy, 2011–12



The diagram provides an overview of key data and sets out the scope of the Water Account Australia by presenting the flows of water within the economy and between the economy and the environment.

Source: Australian Bureau of Statistics 2013, op. cit.

As a component of the water reform process, the Australian Government passed the Water Act 2007, which charged the Bureau of Meteorology (BoM) with responsibility for compiling and delivering Australia's water information, including production of the National Water Account. While ABS has a main focus (but not exclusive – see their assessment of green water below) on water supply and use in relation to the national accounts, BoM produces accounts of the water resource and abstraction for nine nationally significant water management regions[8].

The water accounts produced regularly in the Netherlands in the context of their environmental account reporting[9] are another example. They include physical water flow accounts (m^3); emission accounts, based on emission registration (kg), national and regional data; economic accounts for river basins, based on the national and regional accounts (euros, employment); and the NAMWA matrix (National Accounting Matrix including Water Accounts), including water-related monetary data – taxes, subsidies, etc.[10]. Interestingly, the Dutch water accounts make full use of the capability of SEEA-Water (SEEA-W) to produce accounts by river sub-basins parallel to national accounts. Water accounts by sub-basins are at the core of ecosystem accounting.

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8 *Australian Bureau of Meteorology, National Water Account 2012, http://www.bom.gov.au/water/nwa/2012/ (accessed 14 July 2014).*

9 *Central Bureau of Statistics, Environmental accounts of the Netherlands 2012, http://www.cbs.nl/NR/rdonlyres/090445AD-E1CB-4147-A404-0C36F02DF112/0/2013c174pub.pdf (accessed 14 July 2014).*

10 *Water accounting, Applications in the Netherlands, Sjoerd Schenau, Statistics Netherlands, 2013, presentation at the WAVES Partnership meeting, 2013. http://www.wavespartnership.org/sites/waves/files/images/Water%20accounting%20NL%20WAVES%202013.pdf (accessed 14 July 2014).*

Box 6.02 Water accounts by sub-basins in the Netherlands

3.1.9 Abstraction of groundwater per (sub-)River Basin, 2011

Fresh groundwater	NACE Rev.2	Total NL	Rhine-North	Rhine-East	Rhine-Center	Rhine West	Ems	Meuse	Scheldt
		million m³							
Total		991.9	70.5	184.7	119.1	216.4	43.9	335.1	22.2
Agriculture, forestry, fishing	01-03	88.5	2.6	21.5	9.9	2.8	2.4	47.9	1.2
Public Water supply companies	36	755.7	60.5	134.1	94.5	166.4	38.1	244.6	17.6
Industry; power plants; etc.	06-35; 37-99	147.6	7.4	29.0	14.7	47.1	3.4	42.5	3.4
Private Households		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

3.1.10 Abstraction of fresh surface water per (sub-)River Basin, 2011

Fresh surface water	NACE Rev.2	Total NL	Rhine-North	Rhine-East	Rhine-Center	Rhine West	Ems	Meuse	Scheldt
		million m³							
Total		9,069.2	387.8	222.5	687.0	4,297.7	39.9	3,106.9	357.7
Agriculture, forestry, fishing	01–03	30.9	5.7	5.7	4.0	9.4	1.4	3.2	1.5
Public Water supply companies	36	473.2	0.0	0.0	0.0	271.5	6.3	195.4	0.0
Industry; power plants; etc.	06–35; 37–99	8,565.0	382.1	216.9	683.0	4,016.8	32.2	2,908.3	356.1
Private Households		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Baas and Graveland (2011); Graveland and Baas (2012); LEI 2013; VEWIN 2012; 2013; Statistics Netherlands (2013).

Source: Environmental accounts of the Netherlands 2012

6.1.2 SEEA-Water

As a result of experience gained in Australia, Chile, France, Moldova, the Netherlands, Spain and other countries, *SEEA-Water 2007* (SEEA-W) was the first thematic manual produced in the context of implementation of SEEA. Programmes to support implementation of SEEA-W have been carried out by the UNSD and UN regional Commissions. "*In the world, there are about 50 countries that have done some elements of water accounts, or are planning to, although not all of them have institutionalized water accounting or compile them on a regular basis. Out of them, about 27 are countries in developing regions, such as Brazil, Colombia, Dominican Republic, Jordan, the Republic of Mauritius, Mexico, Peru, and South Africa*[11]."

"*To support implementation of environmental-economic accounts, the System of Environmental-Economic Accounts for Water (SEEA-Water), a SEEA sub-system, provides compilers and analysts with agreed concepts, definitions, classifications, tables, and accounts for water and water-related emission accounts. Part I of SEEA-Water was adopted as an interim international statistical standard by the United Nations Statistical Commission (UNSC) at its 38th session in 2007 - subject to re-evaluation upon completion of the revised SEEA. The UNSC also encouraged implementation of SEEA-Water in national statistical systems. SEEA-Water is fully coherent with the broader SEEA. It elaborates and expands the guidance on accounting in the International Recommendations for Water Statistics (IRWS). UNSD coordinated the preparation of SEEA-Water in collaboration with the London Group on Environmental Accounting.*"[12] The *System of Environmental-Economic Accounting for Water* (SEEA-Water) 2007 and the *International Recommendations for Water Statistics* (IRWS) 2010 can be downloaded from http://unstats.un.org/unsd/envaccounting/pubs.asp.

To support implementation of SEEA-W, *International Recommendations for Water Statistics* (IRWS) have been developed "*to help strengthen national information systems for water in support of design and evaluation of Integrated Water Resources Management (IWRM) policies. IRWS was adopted by the United Nations Statistical Commission (UNSC) at its 41st session in 2010. IRWS contains guidelines for the collection, compilation and dissemination of internationally comparable water statistics and water accounts in line with SEEA-Water*".

The ecosystem water accounts mirror the SEEA-W accounts. While the latter focus on the use of water by the economy, the former consider the water system as a component of the ecosystem in the broader sense, including its human component. Regarding economic uses of water, ENCA-QSP is aligned with SEEA-W. The connection takes place through a special column for the supply and use system and some details of abstraction

11 *Water Accounts: A new information system for policy makers. Martinez-Lagunes, R. UNDESA Inter-Regional Adviser on Environmental Economic Accounts, 2013.* http://www.wavespartnership.org/en/water-accounts-new-information-system-policy-makers *(accessed 14 July 2014).*

12 http://unstats.un.org/unsd/envaccounting/seeaw/ *(accessed 14 July 2014).*

Figure 6.01 The ENCA-QSP water account structure

I. Ecosystem Water Basic Balance	Stocks Primary and secondary production of water Transfers between water bodies and basins Actual Evapotranspiration Abstraction of water, supply and use Returns to waste water and losses	*Total inflow of water* *Net Ecosystem Water Balance*
II. Accessible Resource Surplus	Total renewable water resources Accessible stock carried over Restrictions of use Other accessibility corrections	*Net Accessible Water Resource Surplus*
III. Total Uses of Water	Total use of ecosystem water: blues, grey & green water Imports/water commodities contents Imports/ embedded water	*Total use of ecosystem water* *Direct use of water* *Total water requirement*
IV. Table of Indexes of Intensity of Use and Ecosystem Health	Sustainable intensity of ecosystem water use Composite ecosystem water health index	*Water internal ecological unit value*

and other characteristic uses by main sectors. The supply and use system column can be split into the economic sectors used for SEEA-W (the ISIC[13] classification used in the SNA).

In ENCA-QSP attention is given first to the components of the ecosystem. Regarding assets, rivers are split by type according to the usual classifications of size and/ or Strahler rank (Chapter 2, section 2.1.7, para. 2.50 and Figure 2.04), which is necessary for accounting for river ecological integrity. Soil and vegetation is split according to the land-cover LCFU classification. Because of the difference in perspective, there are a few minor differences in presentation between the current SEEA-W and the ENCA-QSP ecosystem water accounts, which are indicated in the course of the text. This is not a difference in content, and the ecosystem water accounts should be considered as an extension of the scope of SEEA-W.

Water accounts have sometimes been tested in the form of annual accounts compiled at the national level. However, SEEA-W foresees the production of accounts by river basin (a possibility used by several countries), and on a seasonal or monthly basis. These developments are a potential contribution to ecosystem water accounts where the spatial dimension is at the core and ecosystem health or distress assessment is a target.

13 *ISIC: International Standard Industrial Classification of All Economic Activities*

6.1.3 Specific characteristics of ecosystem water accounts

One purpose of ENCA ecosystem water accounts is to record ecosystem degradation, which may result from depletion and pollution of water resources. On top of the basic water balances, ecosystem water accounts calculate net ecosystem accessible water surplus (NEAWS), which is the amount of an inland water resource that can be used in a sustainable way. The actual total use of ecosystem water is measured in a consistent way with water supply and use by economic sectors, recorded in the SEEA-CF and SEEA-W. Comparing the accessible water resource with its use allows compilation of an indicator of sustainability, reflecting the impacts of water-use intensity. In addition to direct stress on ecosystems resulting from water abstraction beyond the renewable level, other variables are used to characterize the ecological health of the water system regarding water quality, water-borne diseases and other qualitative or semi-quantitative variables.

The water flow accounts track the flows from precipitation, infiltration and runoff, down to final outflow. Net water transfers between water bodies or river basins are recorded. Total available effective rainfall (in hydrological terms), which is available to feed the water bodies, is precipitation minus evapo-transpiration (ETa). Evapo-transpiration is subdivided into spontaneous and induced by irrigation and other uses. Where ETa is induced by rainfed cultivated vegetation, so-called green water, it is identified separately. Total available effective rainfall is further analysed to take account of inaccessible water due to events like floods, wastewater disposal and

Box 6.03 Definition of exploitable water resources in the FAO AQUASTAT Glossary*

Exploitable water resources in km³/year or 109m³/year

Exploitable regular renewable surface water resources: annual average quantity of surface water that is available with an occurrence of 90 percent of the time. In practice, it is equivalent to the low water flow of a river. It is the resource that is offered for withdrawal or diversion with a regular flow.

Exploitable irregular renewable surface water resources: irregular surface water resources are equivalent to the variable component of water resources (e.g. floods). It includes the seasonal and inter-annual variations, i.e. seasonal flow or flow during wet years. It is the flow that needs to be regulated.

Exploitable regular renewable groundwater resources: annual average quantity of groundwater that is available with an occurrence of 90 percent of the time. It is the resource that is offered for groundwater extraction with a regular flow.

Total exploitable or manageable water resources: that part of the water resources which is considered to be available for development under, taking into consideration factors such as: the economic and environmental feasibility of storing floodwater behind dams or extracting groundwater, the physical possibility of catching water which naturally flows out to the sea, and the minimum flow requirements for navigation, environmental services, aquatic life, etc. It is also called water development potential. Methods to assess exploitable water resources vary from country to country depending on the country's situation. In general, exploitable water resources are significantly smaller than natural water resources.

Source: http://www.fao.org/nr/water/aquastat/data/glossary/search.html?_p=100&submitBtn=-1&keywords=&subjectId=9&termId=-1&submit=Search (accessed 11 August 2014)

* http://www.fao.org/nr/water/aquastat/water_res/indexglos.htm (accessed 14 July 2014).

dilution requirements to maintain the environmental quality of water bodies (in terms of concentrations of chemicals or Biochemical oxygen demand [BOD]), additional ETa induced by irrigation, and evaporation induced by power-plant cooling towers or reservoirs, as well as constraints due to international water-sharing conventions. The accessible water resource can be increased by treating wastewater (which reduces the amount of water that cannot be used because of pollution and dilution requirements) and by constructing dams to collect water that would otherwise be lost for use[14].

In ecosystem water accounts, supply and use of water is broadly consistent with the SEEA-CF and SEEA-W definitions. Formal differences of presentation result from the fact that SEEA-CF and SEEA-W give more emphasis to the consistency of economic sectors as detailed in ISIC for the SNA, while ecosystem water accounts adopt the stand-point of spatial ecosystem accounting units and their grouping by river basins and sub-basins. The broad sectors of Table I can be subdivided according to SEEA-W categories as long as information is available with the appropriate detail, in particular by river sub-basins – as is the case for the Netherlands water accounts presented in Box 6.02 above.

However, one significant difference between ENCA ecosystem water accounts and SEEA-W needs to be mentioned; it relates to the treatment of the use of green water (the rainfall water used by cultivated vegetation) that is presented and justified in paras. 6.20 to 6.23.

Accessible water surplus

Another purpose of ecosystem water accounts is to assess the sustainability of use of the water resource. It is therefore necessary to define precisely how much water can realistically be exploited or accessed. The renewable water resource has first to be identified, then the many constraints that limit access to it: costs, location timeliness, quality, legal limitations, etc. Without a precise definition of the water which is actually exploitable, it is difficult to assess the sustainability and impacts of water use. The issue has long been discussed, in particular in the FAO AQUASTAT system and in the *Human Appropriation of Renewable Freshwater*[15],.

Water accessibility is also defined in the context of the human appropriation of renewable freshwater (HARFW), an indicator analogous to human appropriation of NPP presented in Chapter 5. Renewable fresh water supply (RFWS) is made up of evapotranspiration and total runoff (surface, connected soil and subsoil runoff). Total runoff is partly abstracted and partly used in-stream for

14 Note that in the case of a new dam, not all stored water is accessible as long as additional evaporation is generated, in particular in hot regions. Because of evaporation and of possible transfers of water to other regions, it may happen that the increase in accessible water provided by a dam in one given place has a negative effect on downstream water accessibility.

15 Source Postel S., Daily G. and Erlich P. 1996. Human Appropriation of Renewable Freshwater, Science Vol. 271. http://www.as.wvu.edu/biology/bio463/Postel%20et%20al%201996%20Global%20water.pdf (accessed 14 July 2014).

amenities, such as sailing and bathing, maintenance of aquatic life (including fisheries) and dilution of pollution, a regulating ecosystem service. Human appropriation is then calculated with reference to accessible runoff – the amount of water that can realistically be used. Postel *et al.* (1996) considered limitations are due to geographical and temporal inaccessibility, or to the share of flood water not storable as reservoirs or aquifer recharge.

Figure 6.02 Flow diagram of renewable fresh water supply for land

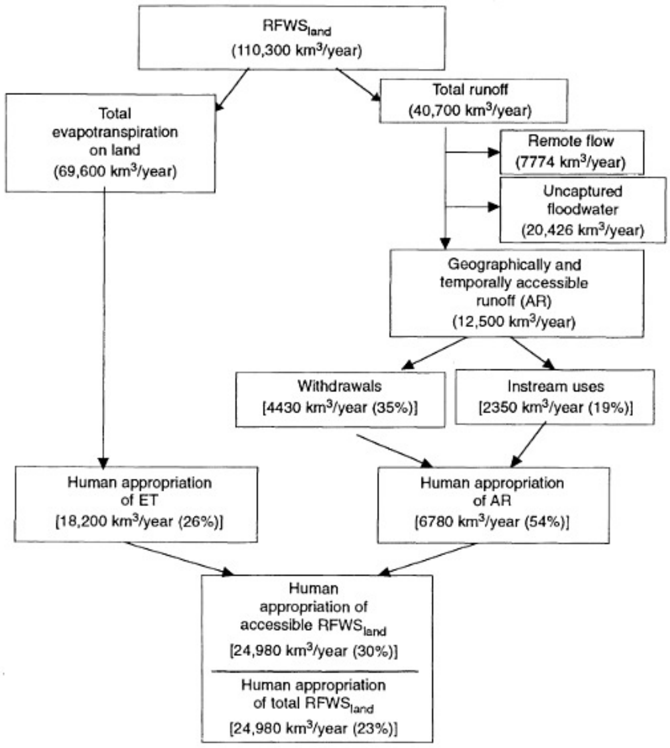


Fig. 2. Flow diagram of analysis of human appropriation of RFWS$_{land}$. The final box shows human appropriation of estimated accessible RFWS$_{land}$ to be 30% (24,980 km^3/82,100 km^3) and human appropriation of total RFWS$_{land}$ to be 23% (24,980 km^3/110,300 km^3).

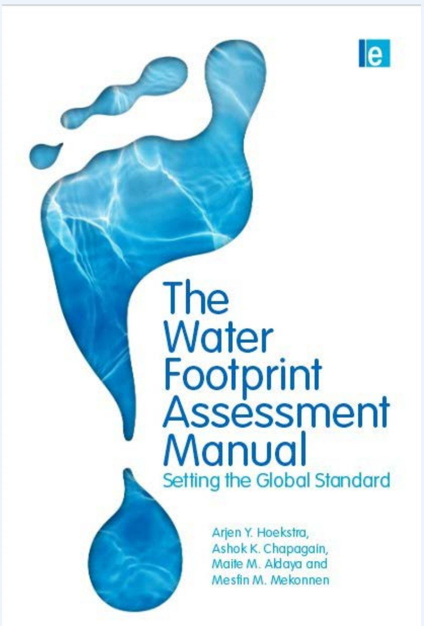
Source Postel, S., Daily, G. and Erlich, P. Human Appropriation of Renewable Freshwater, Op. cit.

An important element of HARFW is calculation of pollution dilution requirements. This indicator shows how much runoff is needed to dilute pollution (e.g. BOD) according to accepted water management norms. As an example, the default value mentioned in the article is "*an often used dilution factor for assessing waste absorption capacity is 28.3 litres per second per 1,000 population*".

The water footprint accounts use a similar definition for grey water footprint which measures the impact of emissions of pollutants to the water system. "*It is defined as the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards*"(Water Footprint Glossary[16]).

16 http://www.waterfootprint.org/?page=files/Glossary *(accessed 14 July 2014).*

Box 6.04 Water footprint



"The global water footprint standard – developed through a joint effort of the Water Footprint Network, its partners, and scientists of the University of Twente in the Netherlands – has garnered international support from major companies, policymakers, NGOs and scientists as an important step toward solving the world's ever increasing water problems. The standard is contained in the Water Footprint Assessment Manual."

http://www.waterfootprint.org/?page=files/home (accessed 14 July 2014).

The report, Water Footprint of Nations, and its appendices presents estimates (by countries, broad sectors and agriculture products) of blue, green and grey water footprints and their components in actual and virtual water, used and traded. http://www.waterfootprint.org/?page=files/WaterFootprintsNations (accessed 14 July 2014).

The HARFW study and the water footprint use the dilution requirement indicator to quantify the use of non-abstracted water runoff as the minimum flow which needs to be kept in rivers for maintaining their functions. In SEEA, in-stream use of water runoff is not recorded as abstraction from surface water. The solution adopted in ENCA-QSP ecosystem water accounts is not to consider grey water as a use but instead to subtract the volume of water needed to meet dilution requirements from the accessible water resource. This conforms to the AQUASTAT definition of exploitable or manageable resources. Estimates of the grey water footprint by country and crop types can be found in a 2011 Water Footprint Network publication[17].

Accounting for pollution dilution requirements is a way of connecting emission accounts to water quality accounts. For rivers, water quality is discussed in Chapter 7 on ecosystem ecological integrity. This follows the general recommendations of SEEA-W, in particular regarding organization of the data on the basis of the measurement of rivers in standardized river measurement units (SRMU)[18] which are presented in Chapter 2. Ecosystem health assessment is rated according to various criteria, including water quality.

17 Mekonnen, M.M. and Hoekstra, A.Y. 2011. *National water footprint accounts: the green, blue and grey water footprint of production and consumption. Value of Water Research Report Series No.50, UNESCO-IHE. http://www.waterfootprint.org/?page=files/WaterFootprintsNations (accessed 14 July 2014).*

18 *SRMU are named standard river units (SRU) in the SEEAW. In ENCA, measurement is added to avoid confusion with other river units, the statistical units called SRU.*

Green water

All water accounting frameworks consider green water, "*rainwater directly used and evaporated/transpired by non-irrigated agriculture, pastures and forests*" (AQUASTAT Glossary), although the terms used and treatment may vary. For HARFW, human appropriation of evapotranspiration is measured by vegetation evapotranspiration in the strict sense, as defined in AQUASTAT. The water footprint defines green water as: "*the precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (although not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth)*" and green water availability as "*the evapotranspiration of rainwater from land minus evapotranspiration from land reserved for natural vegetation and minus evapotranspiration from land that cannot be made productive*"[19].

The SEEA-W also acknowledges the importance of green water but measures it differently, in an implicit way as the difference between "a*bstraction from soil water*" and

19 *http://www.waterfootprint.org/?page=files/Glossary (accessed 14 July 2014).*

"*return flow from rain-fed agriculture*": "*abstraction from soil water includes water use in rain-fed agriculture, which is computed as the amount of precipitation that falls on to agricultural fields. The excess of water, that is, the part that is not used by the crop, is recorded as a return flow into the environment from rain-fed agriculture.*" (para. 3.29, p. 46). This treatment results from the separation in SEEA-W of the economy and the environment and the transposition of the SNA rule which states that the growth of crops and plantations is production because it is under the direct control, responsibility and management of institutional units, unlike, for example, virgin forests and fisheries, the natural growth or regeneration of which is not[20].

In ENCA-QSP, ecosystems encompass natural as well as more-or-less artificial systems, including agriculture and urban areas[21]. The distinction between the economy and nature is not of two separate worlds: it is two systems analyses of the same world. Natural processes take place within the economy, economic processes within nature[22]. There is therefore no need to adopt the complete accounting sequence of SEEA-W. Instead, ecosystem water accounts present a net version where use of green water by agriculture and forestry is recorded directly in terms of evapotranspiration.

20 *SNA 2008, 6.136 "The growth and regeneration of crops, trees, livestock or fish which are controlled by, managed by and under the responsibility of institutional units constitute a process of production in an economic sense".*

21 *The SEEA-EEA has the same scope of ecosystems.*

22 *This position is that of SNA 2008 when it insists that "growth [of cultivated biological resources] is not to be construed as a purely natural process that lies outside the production boundary"(6.136).*

The ENCA-QSP ecosystem water accounts build on the approaches described above to define the accessible resource, which will be compared with abstractions. There are a few differences in scope and purpose between the approaches. AQUASTAT, the water footprint and HARFW record only the natural, primary resource, while SEEA records both the primary resource and returns of water (losses in transport, wastewater, etc.) which are a new secondary water resource which may be used, depending on its quality. Human appropriation or footprint concepts are broader than the accounting term use. But these differences are minor as long as bridging tables can be constructed in all cases. This is important since it allows, to some extent, the re-use of data collected for other purposes, or at least the cross-checking of ecosystem water accounts with other sources.

Concepts from economy-wide material flow accounting are included in ENCA-QSP Table III on total uses of water. Although water is, in principle, part of material flow accounting, it has generally so far been excluded from the presentation of indicators, in particular of the aggregates of economy wide material flow accounts (EW-MFA). The argument given is that since water flows are two or three orders of magnitude bigger than the other material flows recorded, the overall total would be of little meaning. An example of the importance of the issue can be found in the 1996 article on HARFW (*op. cit.)* where estimates are based on a default value of 1,000 g (1 litre) of water for 2 g of biomass (which is equivalent to 1 g of biocarbon). However, the calculation of embedded (or embodied) flows of water has improved with the calculation of virtual water flows and water footprints (Box 6.04 and references), which are calculated in the same way as embedded carbon and carbon footprints.

6.2 THE ECOSYSTEM WATER ACCOUNTING FRAMEWORK

6.2.1 The general SEEA-Water accounting structure

The characteristic balancing items and indicators of ecosystem water accounts are:

- Net ecosystem water balance (NEWB), the basic balance of in-flowing and out-flowing water which equals the change in stocks;
- Total available effective rainfall, calculated from a hydrological perspective (water available for runoff), before evapotranspiration induced by irrigation and evaporation induced by other uses;
- Abstraction of water (by ecosystems, catchments, assets, and broad economic sectors);
- Returns of wastewater, and losses of water in transport and irrigation (detailed as abstraction);
- Total natural renewable water resources which corresponds to the AQUASTAT indicator (TNWRnatural);
- Net ecosystem accessible water surplus (NEAWS);
- Total use of ecosystem water (TUEW);
- Water intensity of use impact, which is the ratio of NEAWS to TUEW;
- Direct use of water, which adds imports of water and exchanges between economic agents to TUEW;
- Total water requirement, which, in addition to direct use, includes virtual or embedded water in international trade.

Net ecosystem accessible water surplus is the central accounting balancing item of stocks and flows. It can be compared to the withdrawals of freshwater to measure the impacts of intensity of use on the water resource. The ratio NEAWS/withdrawals should always be at least > 1. A higher target value is likely to be needed in order to allow for the variability of the water resource and the economic and social acceptability of risks of periodic deficits and thus the sustainability of the withdrawals.

Table 6.01: Aggregated ecosystem water accounts by water assets

		Lakes & reservoirs	Rivers & other streams	Glaciers, snow & ice	Ground water	Soil & Vegeta-tion	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
I. Ecosystem Water Basic Balance											
W1	Opening Stocks										
W21	Precipitations										
W22	Internal spontaneous water transfers received										
W23	Natural inflows from upstream territories										
W24	Artificial inflows of water from other territories and the sea										
W25	Waste water returns/discharge to inland water assets										
W26	Other returns of abstracted water to inland water assets										
W2	Total increase of stocks of water = SUM(W21 to W26)										
W31	Spontaneous actual evapo-transpiration										
W32	Internal spontaneous water transfers supplied										
W33	Natural outflows to downstream territories and the sea										
W34	Abstraction from water assets										
W35	Abstraction/collection of precipitation water and urban runoff										
W36	Actual evapo-transpiration induced by irrigation										
W37	Evaporation from industry and other uses										
W38	Artificial outflow of water to other territories and the sea										
W39	Other change in volume of stocks and adjustment (+ or -)										
W3	Total decrease in stocks of water = SUM(W34 to W39)										

		Lakes & reservoirs	Rivers & other streams	Glaciers, snow & ice	Ground water	Soil & Vegeta-tion	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
W4a	*Available Effective Rainfall = W21-W31*										
W4	Net Ecosystem Water Balance (NEWB) = W2-W3										
W5	Closing Stocks = W1+W4										
II. Accessible basic water resource surplus											
W2a	*Total natural renewable water resources (TNWR) = W21+W22+W23*										
W2b	*Total secondary water resources = W24+W25+W26*										
W33	Natural outflows to downstream territories and the sea										
W6	Net primary & secondary water resource = W2a+W2b-W32-W33										
W71	Total adjustment of natural renewable water resources (+ or -)										
W39	Other change in volume of stocks and adjustment (+ or -)										
W7a	*Exploitable natural water resources = W2a+W71+W39*										
W72	Total adjustment of secondary renewable water resources										
W7b	*Exploitable secondary water resources = W2b+W72*										
W7	Net Ecosystem Accessible Water Surplus = W7a+W7b										
III. Total water uses											
W81	Abstraction from water assets (W81 = W34)										
W82	Agriculture and forestry 'green water' use = W311+W312										
W83	Collection of precipitation water (rainwater harvest) (W84 = W351)										
W84	Abstraction/collection of urban runoff (W84 = W352)										
W8	Total Use of Ecosystem Water										
W91	Artificial inflows of water from other territories (W91=W241)										
W92	Withdrawal of water from the sea (W92=W242)										
W93	Use of water received from other economic units										
W94	Re-use water within economic units										
W95	Imports of Water/ commodities & residuals content										
W96	Exports of Water/ commodities & residuals content										
W9	Direct Use of Water = W8+W91+W92+W93+W94+W95										
W10	Domestic Consumption of Water = W9-W96										
W11	Virtual water embedded into imported commodities										
W12	Total Water Requirement = W9+W11										
IV. Table of indexes of intensity of use and ecosystem health											
W7	Net Ecosystem Accessible Water Surplus = W7a+W7b										
W8	Total Use of Ecosystem Water										
W13	Sustainable intensity of water use = W7/W8										
W14	Composite index of change in ecosystem health										
W15	Water ecological internal unit value = AVG(W13+W14)										

Accounts of quantities in m³ are established first for water stocks and flows by asset types (as defined by SEEA), which are the water bodies from which water can be extracted (aquifers, lakes and dams, rivers and other streams), snow and glaciers, and soil and vegetation. When needed, an additional subdivision of columns can be introduced such as lakes and artificial reservoirs or subclasses of aquifers. Rivers and other streams can be subdivided by homogeneous stream reach unit (HSRU) and soil and vegetation by land cover classes (LCEU). Such detailed is not necessarily need for the whole account but it can be useful when addressing specific issues such as evapotranspiration.

The same accounting structure is then used in parallel to present results by ecosystem accounting units, SELUs and RSUs, the river system units. The presentation proposed in Box 6.01 takes into account that inland water can be in area ecosystems (SELU) and/or in linear ecosystems in the case of rivers (RSU). It means that river water is a component of the SELU where it flows and a component of the RSU. When accounting for SELU and RSU water in the same table, a special column has to be introduced to eliminate double counting. Aggregated and detailed accounting table templates in spreadsheet format can be downloaded from http://www.cbd.int/accounting.

Box 6.05 Ecosystem water accounts breakdown by EAU classes

Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems	Adjustment due to river water double counting	Total inland ecosystems	Other territories	Sea	Atmosphere	Supply & Use Sectors
UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5							
Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals							

When using the presentation by ecosystem accounting units (Box 6.05 B), the stocks of water are subdivided according to asset types.

Box 6.06 Water accounts by EAU: stocks broken down into water assets

I. Ecosystem Water Basic Balance	
W11	Lakes & reservoirs
W12	Rivers & other streams
W13	Glaciers, snow & ice
W14	Groundwater
W15	Soil & Vegetation
W1	**Opening Stocks**

6.2.2 The Ecosystem water basic balance

Accounting Table 6-I Ecosystem water basic balance

		Lakes & reservoirs	Rivers & other streams	Glaciers, snow & ice	Ground water	Soil & Vegeta-tion	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
I. Ecosystem Water Basic Balance											
W1	**Opening Stocks**										
W21	Precipitations										
W221	*Surface runoff to rivers*										
W222	*Infiltration/percolation*										
W223	*Groundwater discharge to rivers*										
W224	*Other transfers received*										
W22	Internal spontaneous water transfers received										
W23	Natural inflows from upstream territories										
W241	*Artificial inflows of water from other territories*										
W242	*Withdrawal of water from the sea*										
W24	Artificial inflows of water from other territories and the sea										
W251	*Returns/discharge of treated waste water*										
W252	*Returns/discharge of untreated waste water/ used water*										
W253	*Returns/discharge of untreated waste water/ urban runoff*										
W25	Waste water returns/discharge to inland water assets										
W261	*Losses of water in transport and storage*										
W262	*Irrigation water*										
W263	*Return of mine water*										
W264	*Return of water from hydroelectricity production*										
W265	*Return of water from other production (incl. cooling)*										
W266	*Other returns of water*										
W26	Other returns of abstracted water to inland water assets										

		Lakes & reservoirs	Rivers & other streams	Glaciers, snow & ice	Ground water	Soil & Vegeta-tion	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
W2	**Total increase of stocks of water = SUM(W21 to W26)**										
W311	*Spontaneous actual evapo-transpiration from rainfed agriculture & pasture*										
W312	*Spontaneous actual evapo-transpiration from forests*										
W313	*Spontaneous actual evapo-transpiration from natural land*										
W314	*Spontaneous actual evaporation from water bodies*										
W315	*Spontaneous actual evaporation from artificial land*										
W31	Spontaneous actual evapo-transpiration										
W321	*Surface runoff to rivers*										
W322	*Infiltration/percolation*										
W323	*Groundwater discharge to rivers*										
W324	*Other transfers supplied*										
W32	Internal spontaneous water transfers supplied										
W331	*Natural outflows to downstream territories*										
W332	*Natural outflows to the sea*										
W33	Natural outflows to downstream territories and the sea										
W341	*Abstraction for distribution*										
W342	*Abstraction for own use by agriculture (incl. for irrigation)*										
W343	*Abstraction for own use by hydroelectricity production*										
W344	*Abstraction for own use by other production (incl. cooling)*										
W345	*Abstraction for own use by municipal and household use*										
W34	Abstraction from water assets										
W351	*Collection of precipitation water (rainwater harvest)*										
W352	*Abstraction/collection of urban runoff*										
W35	Abstraction/collection of precipitation water and urban runoff										
W36	Actual evapo-transpiration induced by irrigation										
W37	Evaporation from industry and other uses										
W381	*Artificial discharge of untreated wastewater to the sea*										
W382	*Other artificial outflow to other territory and the sea*										
W38	Artificial outflow of water to other territories and the sea										
W39	Other change in volume of stocks and adjustment (+ or -)										
W3	**Total decrease in stocks of water = SUM(W34 to W39)**										
W4a	***Available Effective Rainfall = W21-W31***										
W4	**Net Ecosystem Water Balance (NEWB) = W2-W3**										
W5	**Closing Stocks = W1+W4**										

The ecosystem water basic balance is organized according to the structure of the SEEA-W asset account which groups increases and decreases in stocks. The supply and use sectors mirror the table of ecosystems for all relevant stocks and flows. The order of presentation has been modified slightly in order to start from natural flows before recording human abstraction and returns, and to separate abstractions from inland water systems from the use of other sources such as rainfall or seawater.

In this presentation, total increase of stocks and total decrease of stocks have a meaning only in accounting terms. The totals include primary flows, as well as secondary flows which are counted twice. For example, a large part of the water returned as wastewater, irrigation water or loss in transport comes from precipitation. In the same way, the spontaneous inflows/outflows between water bodies are recorded twice (with a sum total of zero). When balancing total increase and total decrease, all the double counts are eliminated. The main balancing item of Accounting Table I is therefore net ecosystem water balance (NEWB) which is the difference between increases and decreases, and between closing stock and opening stock.

NEWB = (increase - decrease) = (closing stock - opening stock)

An additional balancing item has been introduced: available effective rainfall, which can be estimated as the difference between precipitation (W21) and spontaneous actual evapotranspiration (W31). The concept of effective rainfall or precipitation as defined here is common in hydrology, where it represents the theoretical water resource that feeds river runoff (and related water bodies) and recharges aquifers.

Box 6.07 Effective rainfall in hydrology and agronomy

Effective rainfall or precipitation has different meanings for hydrologists, who assess catchment runoff, and agronomists. In hydrology, effective rainfall – sometimes called excess rainfall – is the component of precipitation that is not lost by evaporation/evapotranspiration or retained on the land surface or stored in the soil. Recharge of aquifers, instead, is part of effective rainfall for hydrologists.

For agronomists Effective rainfall is very different, and in some ways the opposite. It is the water that is useful for plant growth, excluding surface runoff or deep infiltration as well as untimely or destructive rainfall, and takes soil moisture into account only when it can be used by crops. Calculating agricultural effective rainfall is important as it helps to assess the need for irrigation water. Ex-ante, it requires complex modelling and cannot be derived easily from water accounts. Ex-post, it is close to spontaneous actual evapotranspiration. (For more information, Dastane, N.G., 1978. Effective rainfall in irrigated agriculture, FAO, Rome. http://www.fao.org/docrep/x5560e/x5560e00.htm (accessed 14 July 2014)

6.2.3 Increase in stocks

a. Precipitation

Precipitation is defined as in SEEA-W. Basic data come from meteorological services, which publish regular reports on monitoring stations and isohyets maps[23] where point observations are interpolated. When meteorological offices are part of the ecosystem natural capital accounting project, they may be in a position to deliver all the data needed for ecosystem water accounting, using in-situ monitoring, satellite monitoring and meteorological models.

Participation of meteorological offices may be limited because of data distribution policies in which case, with less data, it may be necessary to interpolate data from monitoring stations. One solution is to use existing maps of isohyets to extrapolate point data to the accounting grid. A quick test consists of using mean isohyets over a certain period (e.g. 20 years) in order to minimize the effects of annual variability.

Another solution is to download meteorological data from programmes such as Mirador (http://mirador.gsfc.nasa.gov/) and related NASA websites which give access to the important resources of NASA and JAXA TRMM (Tropical Rainfall Measuring Mission): http://trmm.gsfc.nasa.gov/data_dir/data.html and http://pmm.nasa.gov/TRMM/products-and-applications. The Global Precipitation Measurement (GPM) satellite, which is the successor of TRMM, was launched successfully in February 2014. Another source of meteo data is the so-called reanalysis distributed by the European Centre for Medium-term Weather Forecasts (ECMWF; http://data-portal.ecmwf.int/data/d/interim_full_daily/). More on the use of these international databases is presented in Chapter 3, Section 3.1.2. paras. 3.16–3.20.

When satellite data are used to account for precipitations, it is still necessary to adjust them in order to make the total rainfall in the accounts equal to the total computed by national meteorological offices. This total, which is official data, is calibrated with more *in-situ* monitoring data than global models. It is used for official reports and applications such as national SEEA-W. Rainfall

23 *An isohyet is a line on a map connecting places having equal rainfall.*

data monitored by satellite will in this case be used to downscale official totals to the accounting grid.

b. *Internal spontaneous water transfers received*

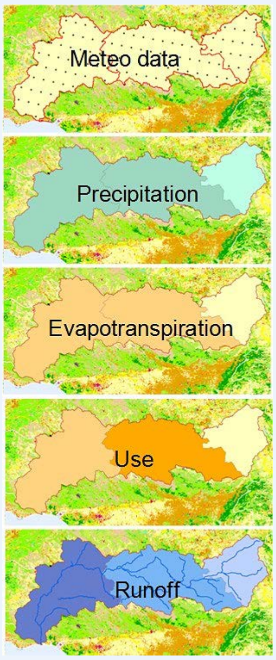
Internal spontaneous water transfers received are inflows of water between water bodies or assets within the limits of a river basin. Therefore, for each transfer, the total of received flows equals the total of the supplied flows recorded as a decrease in stocks.

Internal spontaneous water transfers include:

- surface runoff to rivers;
- infiltration/percolation of surface water to groundwater;
- groundwater discharge to rivers;
- other transfers received, such as melting of snow and ice, and agriculture drainage water.

Surface runoff to rivers is an important estimate, in particular regarding ENCA-QSP accounts in conditions where there are not enough monitoring data on river runoff. A provisional estimated account can be established, starting with the estimates within a river basin of the water productivity of each river sub-basin, which is the available effective rainfall. This productivity then has to be divided between infiltration and surface runoff. The sub-basins can be in chains, starting from the highest in the hierarchy and accounting for the natural inflows received for each. In that way, the final river outflow is equal to the total surface runoff, adjusted for effects of water use. In Box 6.04, a theoretical example shows the rationale of the estimates.

Box 6.08 A quick method for estimating river runoff by river sub-basin



A simplified theoretical sequence for a quick estimate would be the following. If actual data on river runoff are available, they can be used to calibrate the account.

Precipitation*
- spontaneous Actual EvapoTranspiration**
- net infiltration to soil/subsoil***
+ inflows from upstream runoff
+ returns of used water & irrigationµ
= Available surface water resource
- use of water by activities and householdsµ
- evapotranspiration by activities µ
= River basin runoff

Sources:
* Meteo
** Modelling from meteo data, land cover & NDVI (vegetation index)
*** Hydrogeological modelling
µ Estimation from land cover and socio-economic statistics
Bold Ital: accounting balances

c. *Natural inflows from upstream territories*

Natural inflows from upstream territories take place between sub-basins or regions within river basins or catchments. They are transfers of surface water received from upstream sub-basins. Groundwater does not respect river basin limits but, for accounting, groundwater stocks are recorded within basin boundaries, and flows of groundwater have to be recorded accordingly. When a river basin is divided by administrative or national boundaries, natural inflows may also have to be recorded.

d. *Artificial inflows of water from other territories and the sea*

Artificial inflows of water from external territories and the sea are transfers of water by artificial means, pipes or canals. These transfers bypass the limits of river basins, and water may come from far away in the case of supplies to large towns. Since the sea is outside the boundary of river basins, seawater has to be transferred to the territory of the basin, and added to stocks, before being used.

e. *Wastewater returns/discharges to inland water assets*

Wastewater returns are a potential secondary resource which can be used, depending its quality, for example for irrigation or cooling. When the wastewater discharges or pollutant loads are small compared with the recipient water body, natural processes may purify the water, an important ecosystem service. It is therefore important to classify wastewaters according to their quality. Wastewater returns to the sea are treated separately as they are not an increase in stock of inland water.

In the ecosystem water basic balance, three types of wastewater are distinguished:

- returns/discharge of treated wastewater;
- returns/discharge of untreated wastewater/used water;
- returns/discharge of untreated wastewater/urban runoff.

Recording urban runoff together with wastewater is justified for several reasons. The flows of urban runoff may be highly polluted after storms; it is collected, together with wastewater or separately, and part of it may be processed by urban wastewater treatment plants.

Chapter 4 of SEEA-W addresses water emission accounting in detail and will be referred to when accounting for wastewater returns/discharge to inland water assets. "*Emission accounts describe the flows of pollutants added to wastewater as a result of production and consumption, and flowing into water resources directly or indirectly through the sewage network. They measure the pressure on the environment caused by human activities by presenting information on those activities responsible for the emissions, the types and amount of pollutants added to wastewater as well as the destination of the emissions, such as water resources and the sea. Emission accounts form a useful tool for designing economic instruments, including new regulations aimed at reducing emissions into water. When analysed in conjunction with the technology in place to reduce emissions and treat wastewater, such accounts can be used in impact studies of new technologies*" (SEEA-W, 4.2).

f. Other returns of abstracted water to inland water assets

Other returns of abstracted water to inland water assets include:

- losses of water in transport and storage;
- irrigation water;
- return of mine water;
- return of water from hydroelectricity production;
- return of water from other production (incl. cooling);
- other returns of water.

Other returns of water include water lost by leakage in transport and storage, irrigation water and other returns of water that is generally not subject to wastewater treatment. Return of mine water is an artificial transfer of water from subsoil to surface (rivers or canals). Water used for hydroelectricity is forced by gravity to fall through the penstock to the turbine propeller; although the circuit is short, the impact on ecosystem water is high and the process is described as abstraction and return. A similar solution is adopted for cooling water. When cooling water is seawater returned to the sea, the flows do not impact inland ecosystems and are considered as inflows/outflows from and to the sea.

g. Total increase of stocks of water

Total increase of stocks of water is the conventional sum of the natural and artificial, primary and secondary inflows to the water system.

h. Spontaneous actual evapotranspiration

Evapotranspiration is the actual rate of water uptake by the plant that is determined by the level of available water in the soil (FAO AQUASTAT Glossary). Spontaneous actual evapotranspiration includes evaporation from water bodies and artificial land. It can be modified by the choice of crops or tree species. In agricultural and forest land, spontaneous evapotranspiration corresponds to the consumption of green water. The subdivisions of the class are:

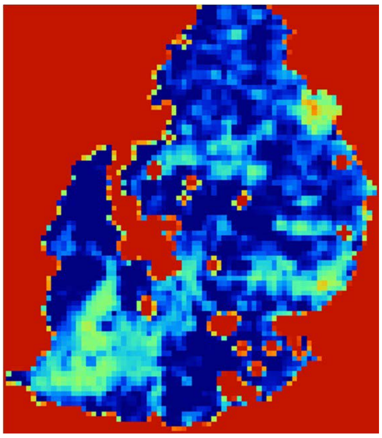
- spontaneous actual evapotranspiration from rainfed agricultural land and pasture;
- spontaneous actual evapotranspiration from forests;
- spontaneous actual evapotranspiration from natural land;
- spontaneous actual evaporation from water bodies;
- spontaneous actual evaporation from artificial land.

In accounting, the measure used is actual evapotranspiration (ETa). This differs from potential evapotranspiration (PET), which is defined as the amount of evaporation that would occur if sufficient water were available. For example, in drylands, annual potential evaporation exceeds annual precipitation.

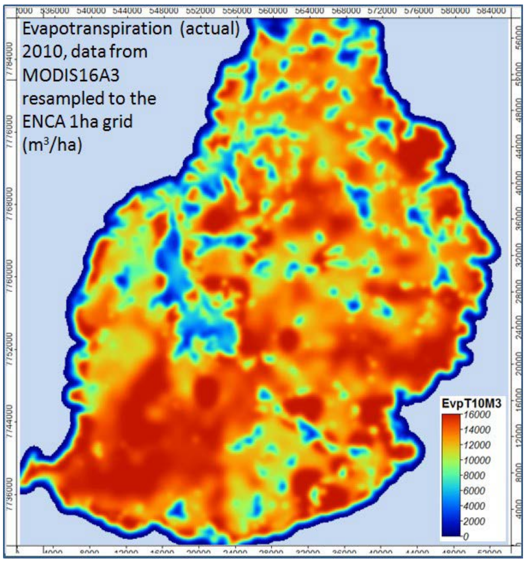
Evapotranspiration assessment uses models that combine variables such as precipitation, temperature, relief and soil, and land-use. In practice, when actual evapotranspiration is calculated from models integrating Earth observation variables (such as NDVI or EVI, the standard vegetation indexes), the spontaneous part will be the difference between total ETa and ETa induced by irrigation.

An important resource for assessing ETa is the MODIS Global Evapotranspiration Project (MOD16) developed by the Numerical Terradynamic Simulation Group of the University of Montana for NASA. Data are available on eight day, monthly and annual bases for the period 2000 to 2012 (the most recent entire year at the date of this report) at http://www.ntsg.umt.edu/project/mod16. (Chapter 3).

Figure 6.03 Evapo-transpiration: from the MODIS16A3 product to the ETa map. A test for Mauritius ENCA pilot study



↑ **MODIS16A3** input data and ETa data resampled to the accounting grid and reprocessed (2010) →



Source: Experimental Ecosystems Natural Capital Accounts Mauritius Case Study, op. cit. http://commissionoceanindien.org/fileadmin/resources/Islands/ENCA_Mauritius.pdf (accessed 11 August 2014)

i. Internal spontaneous water transfers supplied

Internal spontaneous water transfers supplied are the exact counterpart of the transfers received described in paras. 6.38–6.40:

- surface runoff to rivers;
- infiltration/percolation of surface water to groundwater;
- groundwater discharge to rivers;
- other transfers received (including from snow and ice melt or from agriculture drainage).

The subdivisions are identical and, row by row, the difference between transfers received and supplied is always zero.

j. Natural outflows to downstream territories and the sea

Natural outflows to downstream territories and the sea measure surface (rivers) and groundwater runoff. In a sequence of river sub-basins, the natural inflow equals the sum of the outflows of the adjacent upstream basins. This property can be used to estimate river runoff, as explained in Box 6.08.

k. Abstraction from water assets

In ecosystem water accounts, abstraction of water from inland water assets is clearly distinguished from other ways of supplying water. Abstraction from the sea is not a decrease of inland stocks of water, but an increase which is recorded as artificial inflow of water from the sea (para. d). Seawater is added to the water stock (probably a reservoir) before being used. Collected rainwater adds to the water resource but is not abstracted from inland water assets since it is provided by the atmosphere. Only water abstraction in the hydrological sense is recorded here.

Abstraction from water assets in SEEA-W is subdivided into economic sectors according to the ISIC classification. These detailed classes are grouped in ecosystem water accounts at the highest level as follows:

- abstraction for distribution;
- abstraction for own use by agriculture (incl. for irrigation);
- abstraction for own use for hydroelectricity;
- abstraction for own use for other production (incl. cooling);
- abstraction for own use by municipalities and households.

Data on water abstraction are generally available from water agencies.

l. Abstraction/collection of precipitation water and urban runoff

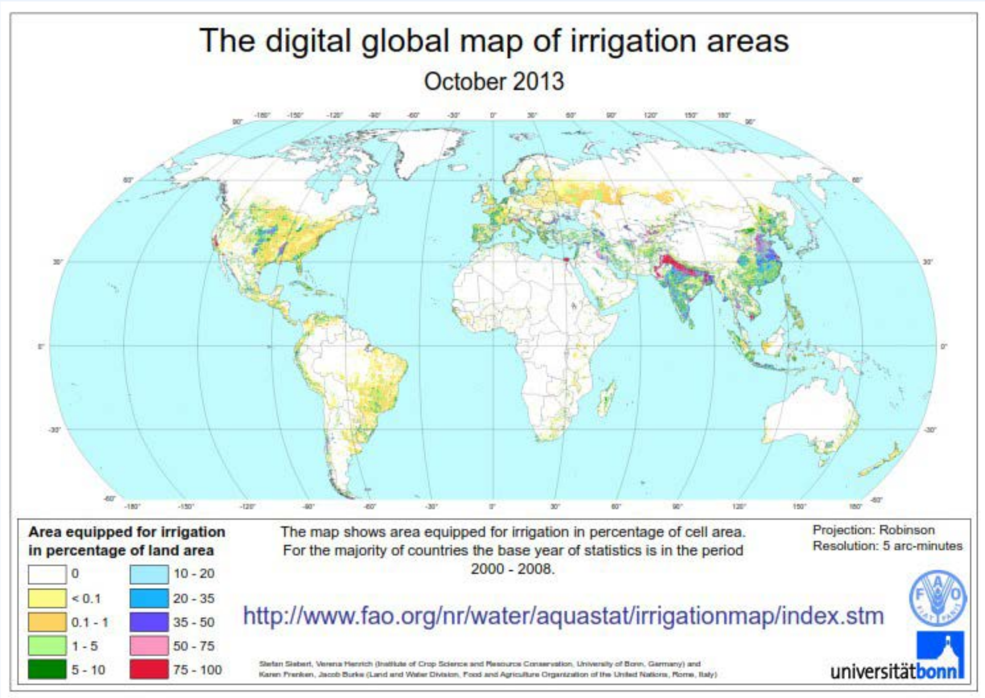
Abstraction/collection of precipitation water and urban runoff considers rainfall water which is collected as direct water harvest or as a consequence of urban runoff. The word abstraction has been kept in the flow label to indicate that the same flow of urban runoff exists in SEEA-W, where it is classified under abstraction.

m. Actual evapotranspiration induced by irrigation

Actual evapotranspiration induced by irrigation is an important flow. Irrigation increases crops yields significantly and is part of the response to human food security requirements. At the same time, agriculture is estimated to consume about 70 % of the global water resource, and the additional evaporation induced by irrigation contributes to reducing river runoff and water accessible for other uses and nature, as well as to greenhouse gas emissions in the form of vapour.

Irrigation data are collected by ministries of agriculture and agronomic institutions. When such data are not sufficient to feed the accounting grid, estimates will have to be made, combining official statistics and maps of irrigated agriculture. One difficulty may be the difference between permanently irrigated areas (including rice fields), well known and mappable with satellite images, and more occasional irrigation. Quick Start estimates can be made by combining various sources on the amounts of water used for irrigation, appropriate land-cover classes, and maps of irrigation areas such as the FAO map downloadable from http://www.fao.org/nr/water/aquastat/irrigationmap/index10.stm (Boxes 6.09 and 6.10).

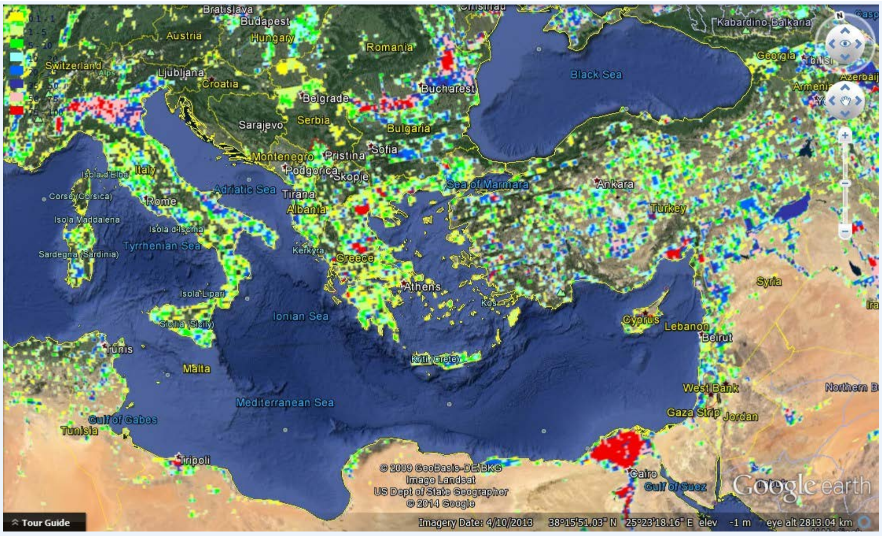
Box 6.09 FAO map of irrigation areas



"*The map shows the amount of area equipped for irrigation around the year 2005 in percentage of the total area on a raster with a resolution of 5 minutes. Additional map layers show the percentage of the area equipped for irrigation that was actually used for irrigation and the percentages of the area equipped for irrigation that was irrigated with groundwater, surface water or non-conventional sources of water*".

Siebert, S., Henrich, V., Frenken, K. and Burke, J. 2013. Global Map of Irrigation Areas. Version 5. Rheinische Friedrich-Wilhelms-University, Bonn, Germany/FAO, Rome, Italy.

Box 6.10 Illustration of the accuracy of the FAO map



This visualisation of the FAO map of irrigated areas on Google Earth shows the accuracy of the data which can be extracted as percentage of a raster with a resolution of 5 minutes.

n. Evaporation from industrial and other uses

Evaporation from industrial and other uses results partly from water used for cooling in thermo-electric and nuclear plants as well as in heavy industry, and from other activities not recorded elsewhere. Evaporation from water bodies such as reservoirs is recorded with spontaneous evapotranspiration.

o. Artificial outflow of water to other territories and the sea

Artificial outflow of water to other territories and the sea includes discharges of untreated wastewater to the sea by municipal sewers and/or industries. Other outflows are of treated wastewater to the sea and transport of water from basin to basin through pipes and canals.

6.2.4 Table II. Accessible basic water resource surplus

Assessing the sustainability of water use requires knowledge of who is using the water (the SEEA-W, Supply and Use Table), and of how much can realistically be used – exploitable or accessible water. The issue was discussed in Section 6.1. for the ENCA-QSP ecosystem water accounts, and it is essential to consider anthropogenic as well as natural requirements for water. The accessible water surplus is the quantitative limit to what can be used without social or economic risk, also considering ecosystem degradation in general, including biomass and biodiversity. The purpose of Table II is therefore to measure this surplus.

Accounting Table 6-II: Accessible basic water resource surplus

		Lakes & reservoirs	Rivers & other streams	Glaciers, snow & ice	Ground water	Soil & Vegeta-tion	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
II. Accessible basic water resource surplus											
W21	Precipitations										
W22	Internal spontaneous water transfers received										
W23	Natural inflows from upstream territories										
W2a	*Total natural renewable water resources (TNWR) = W21+W22+W23*										
W24	Artificial inflows of water from other territories and the sea										
W25	Waste water returns/discharge to inland water assets										
W26	Other returns of abstracted water to inland water assets										
W2b	*Total secondary water resources = W24+W25+W26*										
W32	Internal spontaneous water transfers supplied										
W33	Natural outflows to downstream territories and the sea										
W6	*Net primary & secondary water resource = W2a+W2b-W32-W33*										
W711	*Irregular renewable water resources (regular as > 90% of time) (-)*										
W712	*Legally reserved runoff (for dilution (BOD), aquatic life, navigation...) (-)*										
W713	*Inflow not secured through treaties, agreements, regulations or laws (-)*										
W714	*Outflow secured through treaties, agreements, regulations or laws (-)*										
W715	*Water natural resource unusable due to quality (incl. salinity) (-)*										
W716	*Remote inaccessible water resources (-)*										
W717	*Exploitable irregular renewable water resources/ annual storage (+)*										
W718	*Previous net accumulation in water stocks (+ or -)*										
W719	*Other accessibility adjustments of natural water (+ or -)*										
W71	Total adjustment of natural renewable water resources (+ or -)										
W39	Other change in volume of stocks and adjustment (+ or -)										
W7a	*Exploitable natural water resources = W2a+W71+W39*										
W721	*Secondary water resource unusable due to quality (-)*										
W722	*Other accessibility adjustments of secondary water (+ or -)*										
W72	Total adjustment of secondary renewable water resources										
W7b	*Exploitable secondary water resources = W2b+W72*										
W7	Net Ecosystem Accessible Water Surplus = W7a+W7b										

Table II involves two steps: measurement of the net primary and secondary water resource, and then possible limitations to water access. In the first step, elements of the ecosystem water basic balance are grouped to calculate significant intermediate balancing items. Possible limitations to water access require exogenous information. The ultimate balancing item of Table II is net ecosystem accessible water surplus.

a. *Calculation of total natural renewable water resources*

Total natural renewable water resources (TNWR) in ENCA-QSP is similar to the TNWR aggregate of AQUASTAT, which aggregates Internal renewable water resources (IRWR) and external renewable water resources (ERWR) in the same way. More explanations are given in the "*Glossary of terminology used in the water resources survey and in the country water balance sheets*" at http://www.fao.org/nr/water/aquastat/water_res/indexglos.htm.

b. *Total secondary water resources*

Total secondary water resources are made up of artificial inflows of water from other territories and the sea, wastewater returns/discharge to inland water assets, and other returns of abstracted water to inland water assets.

Secondary water resources are not taken into account in the AQUASTAT aggregate of exploitable or manageable resources since "*it refers to the return of primary water in the system, thus becoming available again for exploitation. In fact, it is an interaction between resources and utilization in a same area, without increasing the natural resource. Statistics on secondary resources can be useful for the complete comparison between resources and utilization. Secondary water resources can be considered as a type of non-conventional sources of water*". The ecosystem water account does take secondary water resources into account, in particular because accounts are established at a finer scale than water statistics. The ENCA-QSP accessible resource therefore has a (slightly) broader scope than the exploitable resource of AQUASTAT.

c. *Net primary and secondary water resource*

The net primary and secondary water resource is the addition of the two resources from which natural outflows to downstream territories and the sea are subtracted because such outflows are not accessed under current economic, technical or legal conditions. If, for example, a dam is built to create a reservoir from which water is extracted for consumption uses such as irrigation, this reduces water outflows and increases the net primary and secondary water resource.

d. *Adjustments of natural renewable water resources*

The second part of Table II records the adjustments which need to be made to account for the water which is not accessible (or exploitable). These adjustments are generally negative, but can be positive in the case of accumulations in previous accounting periods that make the stock of water safer from depletion. The main adjustments are listed in the table.

Irregular renewable water resource is a well-established concept in hydrology. Regular renewable water is a resource that is guaranteed in a dry year for more than 90 % of the year. Patterns of water use based on more than the regular resource are unsustainable, and an irregular resource is in principle inaccessible.

Storage of irregular renewable water resources makes them accessible. Storage can be in aquifers or dams that, in arid regions, may be replenished once every five years or more. In that case, a fraction of the previously stored water can be used annually – and is therefore accessible.

Green water, when defined in a broad (or gross) sense as the evapotranspiration from agriculture and managed forest land (water which does not run off the surface or infiltrate to aquifers) is not all accessible for plants "*because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth*"[24]. The Water Footprint Network therefore defines accessible green water as "*evapotranspiration from land that cannot be made productive*", which matches the definition of green water by AQUASTAT. This share of gross green water has to be deducted when calculating accessible water.

Legally-reserved runoff for dilution of BOD or chemicals, for maintaining aquatic life (fish in particular) during extreme droughts, and for other purposes such as navigation or leisure, is not accessible.

International treaties may be needed to secure inflows from upstream in the context of competition for water; in the absence of such treaties, some water resources can be considered as uncertain and accordingly inaccessible. However, treaties may guarantee a minimum runoff to downstream countries, which is therefore not accessible.

Natural water resources may be unusable because of poor quality (including salinity). In principle, all water can be purified but in practice there are cost limitations – without such costs, all sea water would be accessible. Water highly polluted by natural or anthropogenic actions should be excluded from assessment of the accessible resource.

Water resources in remote areas may not be an issue when assessing the water resource in a given river basin. It may be a serious issue when considering aggregation of river basins for a large country or a continent. Unlike economic values, which add up, water quantities do not always add up since transport costs may be prohibitive or transport technically not feasible. At the aggregated level, remote resources should be considered as inaccessible. Water transport infrastructures such as canals may make remote water accessible up to a net amount which can be transferred from basin to basin, net of the losses in transport by leakage or evaporation, which can be extremely high in arid regions.

24 Water Footprint Glossary, http://www.waterfootprint.org/?page=files/Glossary (accessed 14 July 2014).

Accounting Table 6-III: Total water uses

		Lakes & reservoirs	Rivers & other streams	Glaciers, snow & ice	Ground water	Soil & Vegeta-tion	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
III. Total water uses											
W341	*Abstraction for distribution*										
W342	*Abstraction for own use by agriculture (incl. for irrigation)*										
W343	*Abstraction for own use by hydroelectricity production*										
W344	*Abstraction for own use by other production (incl. cooling)*										
W345	*Abstraction for own use by municipal and household use*										
W81	*Abstraction from water assets (W81 = W34)*										
W82	*Abstraction/collection of urban runoff (W84 = W352)*										
W83	*Collection of precipitation water (rainwater harvest) (W84 = W351)*										
W311	*Spontaneous actual evapo-transpiration from rainfed agriculture & pasture*										
W312	*Spontaneous actual evapo-transpiration from forests*										
W84	*Agriculture and forestry 'green water' use = W311+W312*										
W8	***Total Use of Ecosystem Water***										
W91	*Artificial inflows of water from other territories (W91=W241)*										
W92	*Withdrawal of water from the sea (W92=W242)*										
W93	*Use of water received from other economic units*										
W94	*Re-use water within economic units*										
W95	*Imports of Water/ commodities & residuals content*										
W96	*Exports of Water/ commodities & residuals content*										
W9	***Direct Use of Water = W8+W91+W92+W93+W94+W95***										
W10	***Domestic Consumption of Water = W9-W96***										
W11	*Virtual water embedded into imported commodities*										
W12	***Total Water Requirement = W9+W11***										

e. Net ecosystem accessible water surplus (NEAWS)

All these adjustments can be summed to calculate total adjustment of natural renewable water resources and exploitable natural water resources which is the accessibility-adjusted value of net primary water resource".

A similar calculation is made for secondary water, in particular to eliminate water so highly contaminated that it cannot be used without prohibitive costs. For prohibitive cost, one can consider as a reference the monetary or exergy cost[25] of transport and desalination of seawater; when purifying polluted water costs more than processing sea water, such water is considered to be inaccessible.

Adding exploitable primary and secondary water resources gives the net ecosystem accessible water surplus (NEAWS) which is a core aggregate of ecosystem water accounts.

6.2.5 Table III. Total water uses

Table III of total water uses summarizes the uses of water recorded in ecosystem water accounts. Unlike HAFWR and the water footprint, these uses do not encompass in-stream uses which are treated not as water use[26] but as uses of functional services delivered by rivers in the account of ecosystem ecological integrity and functional services (Chapter 7).

a. Total use of ecosystem water

Total use of ecosystem water refers to the water accessible in the ecosystem accounting unit. It is composed of abstraction from water assets, abstraction/collection of urban runoff (the urban runoff which is collected into sewer systems), collection of precipitation water (rainwater harvest), and agricultural and forestry green water use.

Use of green water corresponds to the FAO AQUASTAT definition of what is actually used by plants in agriculture and managed forests (6.1.3) or to exploitable green water in the water footprint sense (although only crops are considered in the latter case). Agriculture and forestry green water use is subdivided into spontaneous actual evapotranspiration from rainfed agriculture and pasture, and spontaneous actual evapotranspiration from managed forests.

Total use of ecosystem water is the aggregate which will be compared to NEAWS for calculating water intensity of use impact in Table IV.

Use of secondary water resource, direct use, domestic consumption and total water requirement

Secondary water resource uses are artificial inflows of water from other territories and withdrawal of water from the sea, and use of water received from other economic units and re-use of water within economic units.

Imports and exports of water are the water contents of commodities (food/drink products) and residuals. This is similar to the recording of biocarbon and fossil carbon, in line with economy wide material flows accounting.

Total use of ecosystem water plus secondary water resource and Imports of water/commodities and residuals contents equals direct use of water. Direct use of water minus exports of water/commodities and residuals contents equals domestic consumption of water.

Virtual water embedded in imported commodities is the water which has been used in the production process, for whatever purpose. This is an important component of the water footprint[27]. A minor difference is that only virtual consumption of water is recorded in ecosystem water accounts, not the amount of in-stream water use of grey water which in ENCA-QSP is a deduction from the accessible resource (see discussion in paras. 6.16–6.20).

The total of direct use of water plus virtual water embedded in imported commodities is total water requirement.

6.2.6 Table IV Indices of intensity of use and ecosystem health

Table IV of indices of intensity of use and ecosystem health brings together the impacts of water intensity of use and other water ecosystem health components.

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25 See para. 6.2.
26 See para. 6.17–6.20.

27 See Water Footprint Glossary http://www.waterfootprint.org/?page=files/Glossary (accessed 14 July 2014).

Accounting Table IV Table of indices of intensity of use and ecosystem health

		Lakes & reservoirs	Rivers & other streams	Glaciers, snow & ice	Ground water	Soil & Vegeta-tion	Total Inland Water System	Other territories	Sea	Atmosphere	Supply & Use Sectors
IV. Table of indexes of intensity of use and ecosystem health											
W7	Net Ecosystem Accessible Water Surplus = W7a+W7b										
W8	Total Use of Ecosystem Water										
W13	Sustainable intensity of water use = W7/W8										
W141	Bio-chemical quality										
W142	Nutrients excess, eutrophication										
W143	Change in biotic indexes, bio-markers										
W144	Water borne diseases										
W145	Dependency from artificial inputs										
W146	Change in intensity of water natural stress										
W147	Other...										
W14	Composite index of change in ecosystem health										
W15	Water ecological internal unit value = AVG(W13+W14)										

a. *Sustainable intensity of water use*

The index of sustainable intensity of water use is the ratio of NEAWS:TUEW. This should always be ≥ 1, otherwise there is ecosystem degradation resulting from water use. It is important to note that the stress in a given year is calculated at the end of the accounting period and that the impact of the intensity of water use will therefore be felt in the next period.

b. *Composite index of change in ecosystem health*

This index is constructed from diagnoses based on the observation of various symptoms. The list of symptoms may vary depending on ecological conditions and the available data and knowledge, but the rationale follows the general principles of ecosystem distress syndrome assessment defined by D. J. Rapport (op. cit.), discussed in Chapter 7. Formulation of a composite ecosystem health index may vary, but not the purpose, which is a measurement of change in health. As in medicine, the diagnosis will be done with more or less sophisticated means and will be more or less exact. In the case of accounting for ecosystem health, the metaphor is mainly that of preventive health care that brings important results from rather simple investigation procedures and rather low unit costs (Chapter 7). The composite index may be the result of statistical aggregation or, preferably, of an expert system decision tree, since one single symptom may be sufficient for the diagnosis.

The symptoms to look for relate in particular to changes in bio-chemical quality, excess of nutrients, eutrophication, change in biotic indexes, bio-markers, water-borne diseases, dependence on artificial inputs, or trends in intensity of water use.

Ideally, inclusive water quality accounts should be used at this stage to produce a health index. The possibility and interest of such accounts was mentioned at the beginning of this chapter, in particular referring to the thermodynamic approach developed in Spain where the quantity and quality of water of a river are assessed using one single measurement of exergy. SEEA-W includes a chapter on water quality where the basic principles are presented, based on experience in France and Australia. Several attempts have been made to integrate the various water quality indicators into a consistent accounting framework, including tests steered by European Environment Agency in France, Ireland, Slovenia and the UK. The ECA accounts at the European Environment Agency will eventually include elements of water quality accounts. However, these tests have been only partial and have not yet led to regular production of water quality accounts.

In the context of the QSP, the choice is made of not producing comprehensive water quality accounts but of leaving that for a subsequent stage. Instead, water quality variables are integrated as (important) indicators in the tables related to ecosystem health, in particular in the ecosystem water account (pollution) and in the account of ecosystem integrity where quality is approached via the functioning of rivers and includes assessment of biodiversity change. Should an attempt at producing water quality accounts be considered at an early stage, the data infrastructure produced for QSP (definition, classification and measurement of river units, water quantity accounts by sub-basins, relation of quantity to quality via dilution requirements, etc.) would enable a start to be made.

c. Water ecological internal unit value (or price)

The combination of the quantitative index of sustainable intensity of water use and the other more qualitative composite index of change in ecosystem health is a measure of "water ecological internal unit value" (or water ecological internal "price"). This is based on physical variables, not money. At this stage, it does not consider the external effects of water condition on biomass and ecosystem integrity; the integration will be done in a next step where ecosystem ecological value will be calculated in ecosystem capability units (Chapter 8).

7. THE ECOSYSTEM INFRASTRUCTURE FUNCTIONAL SERVICES ACCOUNT

Accounts of ecosystem infrastructure and related functional services measure the sustainable capability of ecosystems to produce services such as biomass or water which are not directly measurable as material resources. These intangible services correspond to regulating and cultural services in the provisional Common International Classification of Ecosystem Services (CICES).

7.1 ACCOUNTING FOR ECOSYSTEM INFRASTRUCTURE FUNCTIONAL SERVICES

7.1.1 Physical flows of functional services cannot be measured directly because they are intangible.

Ecosystems are multifunctional and potentially deliver a bundle of material and intangible services which are used in various proportions according to the natural or socio-economic contexts. Services may be delivered directly to final users, protection from floods by forests, for example, or indirectly though intermediate inputs to services such as agricultural products or timber from managed forests. Uses can be either exclusive or synergetic. Uses can take place in the same ecosystem accounting unit (EAU: SELU, MCU or RSU[1]) as their generation, or in a different zone. In the absence of complete modelling of these interactions, including input-output analysis and imports-exports between EAUs, attempts to describe ecosystem capital capability by summing of ecosystem services would result in omissions and/or double counting.

The SEEA-EEA acknowledges the accounting issue in paragraph 3.45, "*if a choice is made to use an alternative boundary for the measurement of ecosystem services related to crops and other plants, then some adaptation of the CICES would be required. It is noted that if ecosystem services are measured using flows of harvested crops, then it is necessary to exclude flows relating to the growth of these plants such as pollination, abstraction of soil water, etc. Put differently, both pollination and harvested crops should not be combined in a measure of "final" ecosystem services. This would represent a "double count" in accounting terms*".

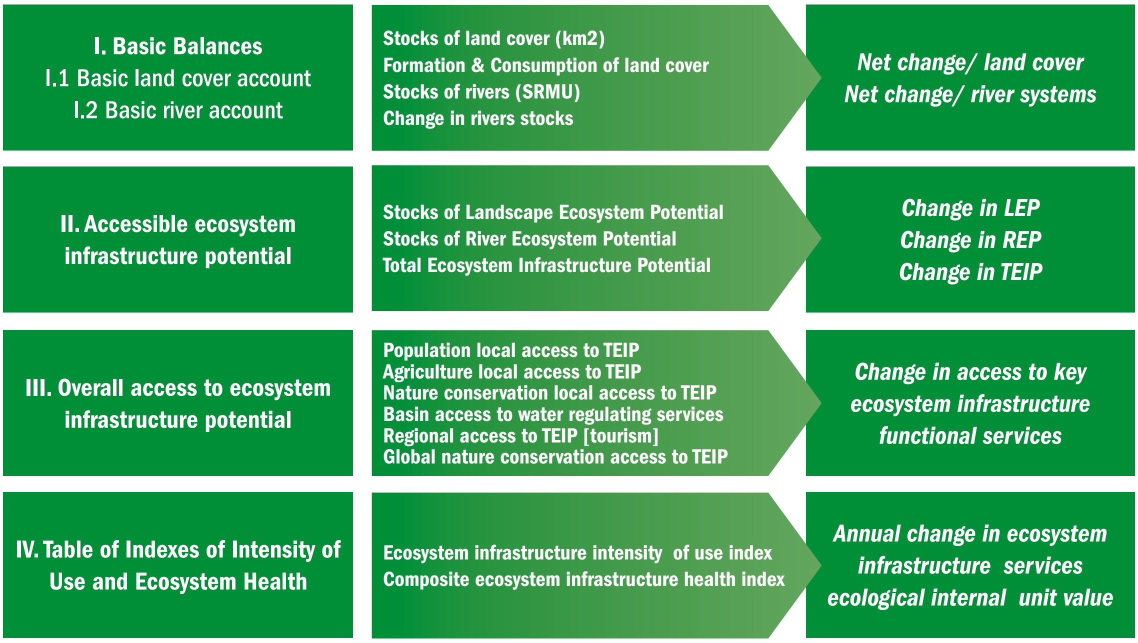
The ENCA-QSP approach to ecosystem services follows the option given in SEEA-EEA paragraph 3.45 where harvested crops are all included. This is done in the biocarbon account, where crops are considered as a joint economy-ecosystem outcome. This approach is consistent with the common definition of ecosystem services in the Millennium Ecosystem Assessment, in The Economics of Ecosystems and Biodiversity (TEEB)[2] or in the EU Mapping and Assessment of Ecosystems and their Services (MAES)[3] accounting project. As a consequence, no sum total of ecosystem services is presented – which would be difficult to achieve anyway in physical terms

1 *SELU: Socio-ecological landscape unit; MCU: Marine coastal unit; RSU: River system units.*

2 *The TEEB project is steered by UNEP. http://www.teebweb.org/ (accessed 14 July 2014)*

3 *MAES refers to the CICES 4.3 version. Provisioning services include "all material and biota-dependent energy outputs from ecosystems; they are tangible things that can be exchanged or traded, as well as consumed or used directly by people in manufacture". Mapping and Assessment of Ecosystems and their Services (MAES), an analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Discussion paper – Final, April 2013 http://biodiversity.europa.eu/ecosystem-assessments/about-1/an-analytical-framework-for-ecosystem-assessments-under-action-5-of-the-eu/download (accessed 14 July 2014)*

Figure 7.01 the ENCA-QSP ecosystem infrastructure functional services



due to the multiplicity of dimensions and measurement units – and there is no double counting issue[4].

Regarding intangible services, the option taken in ENCA-QSP is to consider the potential of the system itself, its extent and condition – productivity, integrity, resilience, etc. The capacity of the ecosystem to deliver biomass and freshwater in a sustainable way can be measured as the resource that is accessible without depletion or degradation. For intangible functional services, the measurement is indirect, assuming that the supply of potential services is correlated with a good state of the ecosystem: degradation of ecosystems can result in loss of these services. No measurement of these intangible services is done in the core accounts that record only potentials. Instead, actual ecosystem services are addressed in ENCA one by one in functional accounts where they can be quantified with appropriate indicators.

4 The other solution presented in SEEA (3.44) is more restrictive: "in the case of cultivated crops and other plants, the "final" ecosystem services are not the crops or other harvested products. Rather they are flows related to nutrients, water, and various regulating services, such as pollination". The motivation relates to a formal alignment to the SNA definition of the production boundaries where "cultivated biological resources, natural growth and regeneration are treated as production only in cases where these are under the direct control, responsibility and management of institutional units" [SNA 2008, A3.88, p. 589 and paragraph 10.88]. One of the consequences of this proposal is that the economy and ecosystem are mutually exclusive entities and what is produced by one (e.g. food, timber, etc.) cannot be produced by the other. This is not the solution chosen for ENCA-QSP where the two systems exist, interact and co-evolve in every place.

The indicators related to biocarbon and water are calculated in their specific accounts and are not recorded here. In a further step, they will be incorporated together with ecosystem infrastructure in the overall ecosystem capability assessment.

7.1.2 Basic accounts of ecosystem infrastructure functional services expressed in weighted hectares

The potential of ecosystem infrastructure to deliver functional services is measured as a combination of areas recorded in the land-cover account (Chapter 4) and attributes of condition or health. This combination provides a measure of overall performance.

Two types of indicator are considered: for ecosystem infrastructure, and for functional services accounting. The first relates mainly to ecosystem biophysical integrity. The indicators are derived from maps, in the same way as land cover, and from wall-to-wall geographical information, and are combined in an aggregate called net landscape ecosystem potential" (NLEP).

In river basins, landscape SELUs coexist with river system units (RSU), which overlay them. The river ecological infrastructure potential is first calculated separately on the basis of measurements of rivers in standardized river measurement units (SRMU; Box 7.01). To calculate the river potential, SRMU values are then weighted according to integrity variables such as fragmentation and the green ecotones index (an ecotone is the zone between two major ecological communities). In a third step, the river potential is converted to average values per km2 and combined with the land ecosystem potential.

Box 7.01 Measuring rivers

River systems stocks and changes are measured in standardized river kilometre (Srkm), a metric defined by Heldal and Østdahl* to measure a population of rivers with the aim of optimizing sampling of water quality in a river basin. The methodology was used later in France and Spain to weight rivers of uneven size and to produce accounts of water quality. In ENCA, Srkm has been renamed SRMU**. The value, in SRMU, of a stretch of river of length (L) and flow (q) is L multiplied by q, i.e. **1 SRMU = 1 km x 1m3/second**. In the QSP, a baseline year is chosen for water flows; it is generally the annual flow for an average of the past 20 or 30 years. Values in SRMU are additive, allowing aggregation of data on large rivers (including shorter rivers with large discharge) and small rivers and brooks (with small discharge but long networks).

* Heldal, J., and Østdahl, T. 1984. Synoptic monitoring of water quality and water resources: A suggestion on population and sampling approaches. Statistical Journal of the United Nations ECE, Vol. 2, pp. 393-406.

** Accounting for water quality is described in the SEEA-Water manual, Chapter VII. In SEEA-W, standardized river kilometres are renamed standard river units (SRU). Because of the vagueness of this naming and risks of confusion with other units, ENCA-QSP uses standardized river measurement unit (SRMU). The calculation is identical in all cases.

The second type of indicator relates to other health symptoms and includes, in particular, biodiversity measurements at the species and biotope levels, intoxication by chemicals and assessments of population health. It supplements ecosystem integrity assessment with variables that are not currently established from analysis of spatial data. Indicators of the first and second type will finally be integrated using spatial analysis techniques.

The selection of health indicators follows the need to achieve a diagnosis. The approach is that of preventive medicine when entire populations (or sub-populations) are followed on a regular basis (e.g. annually) in order to detect particular diseases and critical individual states of health. The basic check-up is followed by more comprehensive medical investigations if distress symptoms are detected.

The metaphor of ecosystem health comes from Aldo Leopold's writings of 1941[5] where the famed biologist advanced the notion of land health where land encompasses the entire ecosystem, and proposed to *"determine the ecological parameters within which land may be humanly occupied without making it dysfunctional"*. In the early 1970s, Gilbert Long presented a similar view of the health assessment of socio-ecological systems in *About ecological diagnosis applied to mankind's life environment*[6].

Ecosystem health assessment has developed since then in a more formal way. One expression of the approach is the ecosystem distress syndrome (EDS) formulated by Rapport, empirically derived from comparative studies of ecosystem behaviour under stress (Rapport *et al.*, 1985; Rapport and Whitford, 1999). "*These studies pointed to the common signs and symptoms of ecosystems under stress. These include losses in biodiversity, inefficient nutrient cycling, alterations in primary productivity (eutrophication in aquatic systems, nutrient depletion in terrestrial systems), simplification of food webs and community organization, alterations in the size distributions of biota (generally entailing losses of larger life forms), increases in the prevalence of invasive or non-endemic species, and an increase in disease prevalence (including diseases in humans, such as malaria and cholera in tropical countries).*"[7]

Ecosystem distress syndrome is not limited to bio-physical characteristics of ecosystems: it includes the human dimension by addressing human health and capacity to deliver services. Thus EDS is "…*a collection of symptoms signalling that an ecosystem is being pushed to its limits. EDS presages the transformation of an ecosystem into something different, usually something less productive, something less useful to humans*". (Rapport, 1999).

Health is total absence of disease, and capability to achieve one's fullest potential. Ecosystem health is closely related to ecosystem ecological integrity. Ecosystem health can be summarized by a few categories of ecosystem properties which relate to the maintenance of ecosystem functional diversity: *"organization, autonomy and resistance to stress, vitality or vigour, and resilience"* (Rapport 1985, 1996, 1999, Constanza 1992, Cosier 2010).

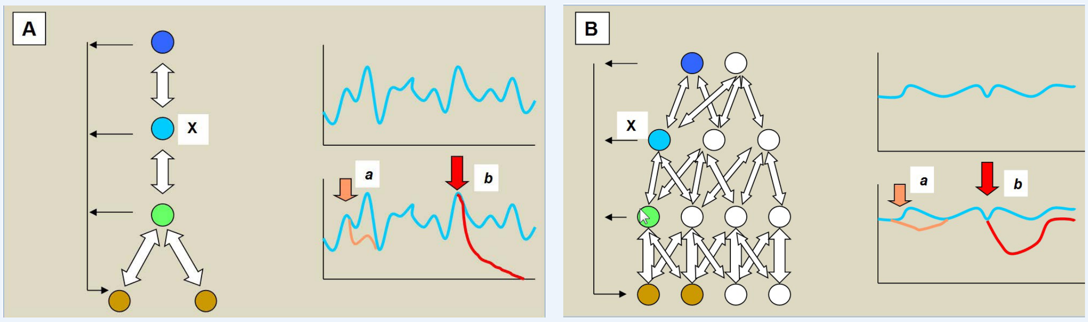
Ecosystem health is a metaphor which has been discussed at length, considering its power as well as the

5 *See e.g. Leopold, A. Wilderness as a Land Laboratory, (1941); ASCA 195-96; cf. RMG 288 and The Land-Health Concept and Conservation ms. (1946) – quoted in Earth Encyclopedia, http://www.eoearth.org/view/article/152704/ (accessed 14 July 2014).*

6 *Long, G. 1972. A propos du diagnostic écologique appliqué au milieu de vie de l'homme, (About ecological diagnosis applied to mankind's life environment) Institut Agro Méditerranéen, Montpellier http://om.ciheam.org/om/pdf/r13/CI010462.pdf (in French; accessed 14 July 2014).*

7 *Rapport, D.J. and Singh, A. 2006. An EcoHealth-based framework for State of Environment Reporting, Ecological Indicators, 01/2006; DOI:10.1016/j.ecolind.2005.05.003*

Box 7.02 Biodiversity and ecosystem stability



Ecological stability as a function of biodiversity: comparison of a simplified, less diverse system [A] with an ecosystem of high biodiversity [B].

There are many relations among the species composing ecological systems, mostly of trophic nature (white arrows). It means that the species are mutually interdependent and rely on others for their own survival. Let's assume that we are interested in the presence of any one species (X) considered as a service. Its presence is much more fluctuating in simplified system ([A], top right chart) than in a system with higher diversity ([B], top right chart) . This is the consequence of natural or human induced variation of other species of which (X) depends. In a system with higher diversity, one species (source of the food or nutrients) may be replaced by another one, the competitors may be controlled by their predators etc.; the fluctuations are thereafter much lower and the system is more stable, including if we consider the desired specie (X). More, as shown on bottom right graphs, a simplified system is able to accommodate small disturbances (a), but may collapse because of a larger one (b); whereas the diverse system is able to survive even a major perturbation – a property so called resilience.

Source: Ladislav Miko (personal communication)

limitation of the analogy between ecosystems and living organisms: unlike ecosystems, living organisms have clear boundaries, they reproduce, and they are subject to genetic selection and evolution. The debate is synthesised by Rapport *et al.* in *Ecosystem Health: Principles and Practice*[8] where the limitation is acknowledged while highlighting that health is not just an individual issue, that public health deals with problems of communities and contamination, that ecosystem health and human health are related, and that ecosystem dysfunction can be measured using methodologies similar to those used for health diagnosis.

Biodiversity is an essential part of ecological diagnosis. Together with energy-driven cycles of biomass production and accessible water regeneration, and the proper functioning of ecosystem infrastructures, biodiversity is an essential constituent of the ecosystem – its data and information basis. Redundancy of species is an important factor of ecosystem stability since several species can perform the same function. In the case of redundancy, the fittest specie will take the lead, depending on conditions; if only one species is performing this function and cannot adapt to a change in conditions, for example to pollution levels or climate change, the whole ecosystem is at risk of a flip. Loss of species may therefore be a sign of loss of resilience. The ability of ecosystems to adapt to fluctuating conditions and recover after severe stress can be assessed in terms of their species composition and indicators such as the ratio between endemic and opportunistic species.

7.1.3 Biodiversity in the ecosystem capital accounting framework

Accounting Table IV of indices of intensity of use and ecosystem health gives an important place to biodiversity. However, the purpose of this account is not to produce a comprehensive indicator of species biodiversity but to use biodiversity indicators to make a diagnosis of ecosystem health. Biodiversity is not recorded as stocks and flows. The number of species in one ecosystem compared with another is not necessarily of interest; instead, biodiversity change is an essential indicator of the present and future state of an ecosystem. Even with such change, losses or increases of species need to be interpreted in the context of the ecosystem health assessment and considering appropriate reference states (paras. 7.112–7.116).

8 *Rapport D.J., Gaudet, C.L., Constanza, R., Epstein, P.R. and Levins, R. (eds.). 1998. Ecosystem Health: Principles and Practice, Wiley-Blackwell, New York, USA.*

Data, statistics and expertise

Standard statistics of species abundance or diversity are not sufficient to inform on biodiversity. Data, models and expert judgments are necessary to develop meaningful indicators. This is clearly acknowledged by many. For example the Norwegian Nature Index, an advanced statistical programme, integrates expert knowledge and data on biodiversity to measure state and trends within and across ecosystems: "*data on indicators were collected from experts who provided estimates of the indicator values at several points in time using expert judgement, monitoring data or models. Experts also provided an estimate of uncertainty with each data point in the form of quartiles, and they were asked to indicate where insufficient information was available to provide an estimate of the indicator value*"[9]. The biodiversity indicators computed for ecosystem accounting at the European Environment Agency are based on maps, data and expert judgement on the status of species reported by countries in compliance with Article 17 of the Habitats Directive.

Benchmarking indicators of biodiversity change

Measuring biodiversity change requires definition of benchmarks against which current observations can be compared to decide whether there is degradation, stability or improvement. Several possibilities exist and can to some extent be combined:

- The first benchmark relates to the principles of accrual accounting: change is observed at the end of the accounting period and compared with the situation at the beginning. Annual changes can be chained in that way. The implicit historic benchmark will in this case be the date of the first account compiled.
- A second benchmark, commonly used, refers to a climatic situation defined according to geological, relief and climate conditions or to a pristine (or quasi-pristine) situation corresponding to no disturbance by human activities. Several approaches are presented below.
- A third approach to benchmarks considers that they are not purely scientific paradigms but that they should take into account the views of society on a desirable ecological state. This, for example, is the approach of the EU Water Framework Directive where good environmental status of river basins has been defined by scientists, water agencies and endorsed by national governments, with the related obligation to progress towards the stated target. Other policy targets, translated into laws, directives, regulations or international conventions, can be used as benchmarks. In the case of the Nature Index (NI), the proposed benchmark has been endorsed by society as NI and is now part of the "*Norwegian official set of indicators for sustainable development, presented annually in the reporting on sustainable development indicators by Statistics Norway and by the Ministry of Finance in the National Budget*" and it "*will be considered, in cooperation with Statistics Norway, how results from the Nature Index can be applied for inclusion in Experimental Ecosystem Accounting and other approaches to supplement the national accounts with regard to biodiversity and ecosystems*".

There are various ways of combining monitoring data and expertise with an agreed benchmark in order to produce assessments of biodiversity change. The format of the indicator or indicators should be distinguished from the datasets and the way in which they are processed. For the diagnosis foreseen in accounting, various indicator formats are acceptable, but not every methodology is valid for ecosystem health assessment.

"*The Living Planet Index reflects changes in the state of the planet's biodiversity, using trends in population size for vertebrate species from different biomes and regions to calculate average changes in abundance over time. It includes data from more than 9 000 different wildlife monitoring schemes collected in a wide variety of ways – ranging from counting the number of individual animals, to camera trapping, to surveys of nesting sites and animal traces.*"[10] The benchmark reflects the 1970 situation and the index was updated to 2008 in the 2012 report. It can be described as an accrual approach, with no reference to a pristine situation. The Living Planet Index (LPI) estimates which are based on scattered data have a global meaning and can be broken down into major regions, but they do not correspond to the scale needed for ecosystem accounting.

The Biodiversity Intactness Index (BII) (Scholes, 2005)[11] provides an overall indicator suitable for policy makers. The index links data on land use with expert assessments of how this impacts on the population densities of well-understood taxonomic groups to estimate current population sizes compared with pre-modern times. It uses land-use degradation of habitats as a way to weight indicators of theoretical species richness. Typically, the BII format is used (or referred to) in several approaches

9 *Certain, G. and Skarpaas, O. 2010. Nature Index: General framework, statistical method and data collection for Norway. NINA Report 542. 47 pp. http://unstats.un.org/unsd/envaccounting/seeaLES/egm/NINA542_bk.pdf (accessed 14 July 2104).*

10 *Living Planet Report 2012, WWF, ZSL and GFN, http://awsassets.panda.org/downloads/1_lpr_2012_online_full_size_single_pages_final_120516.pdf (accessed 14 July 2014).*

11 *Scholes, R. J. and Biggs, R. 2005. A biodiversity intactness index. NATURE. Vol. 434. https://www.cbd.int/doc/articles/2005/a-00262.pdf (accessed 14 July 2014).*

Box 7.03 Determination of reference states in the Norwegian Nature Index Framework

Table 2*. Examples of practical definitions that can be used to estimate the reference value.*

Name	Description
Carrying capacity	A theoretical value for a population number or density for example, according to the natural limit of a population set by resources in a particular environment. .
Precautionary level	Recommendations provided by scientific and independent group of reflexion. Refers to a value below which the indicator, and therefore the major habitat to which it is related, is endangered
Pristine or near-pristine nature	An estimated value that refers to pristine, untouched or low impacted natural system
Knowledge on past situation	An estimated value derived from a known past situation, when the indicator was in good condition, and a situation that is always ecological relevant today
Traditionally-managed habitat	A value observed under traditionally managed habitat, such as extensive, biological agriculture
Maximum sustainable value	A value below which no detrimental effects are observed for the major habitat to which the indicator is related.
Best theorical value of indexes	If the indicator refers to an already developed index, such as a biodiversity index, it's best (the value corresponding to the "best" state in term of biodiversity) expected value depending on the location and the major habitat
Amplitude of fluctuations observed in the past (for cylcing of fluctuating species)	For fluctuating populations (typically rodents or small pelagic fishes): the amplitude of fluctuations over a given temporal windows that is observed in natural or low impacted conditions (specific case for pristine or past knowledge)

Source: Certain and Skarpaas. 2010. Nature Index, General framework, statistical method and data collection for Norway, op. cit.

as a good synthesis of stability versus change. The aim of BII calculation was primarily to support, with indicators, the CBD target to halt biodiversity loss by 2010. Because its calculation is based on effective land-use degradation of habitats, it can be incorporated into ecosystem accounting as a way to weight land-cover/use change with a biodiversity factor.

In Australia, the Accounting for Nature model developed and implemented by the Wentworth Group of Concerned Scientists refers to "*condition benchmarking. Environmental condition indicators based on reference condition benchmarks are conducive to statistical accounting, because they create a standardised numerical unit capable of addition and comparison. They can assess and compare the condition of environmental assets across regions and between assets, and upscale and aggregate over multiple spatial scales. The reference condition benchmark is a scientific estimate of the natural or potential condition of an ecosystem in the absence of significant human, post-industrial alteration. This allows every environmental asset to be described relative to its un-degraded 'reference' condition, as an index between 0 and 100*"[12].

12 *Cosier, P. and Sbrocchi, C. 2013. Accounting for Nature: A Common Currency for Measuring the Condition of Our Environment, Auckland, New Zealand*

The way reference state is understood in the Norwegian Nature Index is an interesting example of a combination of data and expertise. "*The use of reference state in the NI Framework answers to both a theoretic and a pragmatic need, in the sense that it gives the context within which each observed indicator value will be interpreted, and provides a way to express all observed indicator values on a comparable scale.*

"*A reference state is defined as follows: "The reference state, for each biodiversity indicator, is supposed to reflect an ecologically sustainable state for this indicator. The reference value, i.e. the numerical value of the indicator in the reference state, is a value that minimises the probability of extinction of this indicator (or of the species/community to which it is related), maximises the biodiversity of the natural habitat to which it is related, or at least does not threaten biodiversity in this or any other habitat.*

"In practice, the indicator value in a reference state is used to scale the observed value of each indicator, so that all scaled indicator values are directly comparable. The estimate of the reference value has to be done by each expert in charge of an indicator. There is no need that all indicators share the same reference state. Reference states can be defined specifically for each indicator, according to the current state of knowledge on each indicators and ecosystems. The constraints are that the reference state chosen by the expert does not deviate substantially from the definition above, it corresponds to well formulated

hypotheses and assumptions so that it is tractable, and points toward high biological diversity. There are, in practice, several ways to estimate such a reference value. To ease experts estimating these reference values, we provided some examples" (Box 7.03).

The Mean Species Abundance index (MSA), used in particular in TEEB, is another indicator referring to an historic benchmark: "*MSA is an indicator of naturalness or biodiversity intactness. It is defined as the mean abundance of original species relative to their abundance in undisturbed ecosystems. An area with an MSA of 100 % means a biodiversity that is similar to the natural situation. An MSA of 0 % means a completely destructed ecosystem, with no original species remaining*"[13]. The GLOBIO model is used to calculate biodiversity loss. "*To by-pass species biodiversity data problems, a pressure-based version of the Natural Capital Index (NCI) has been developed at the European and global levels, using a number of proximate drivers (or pressures) as a crude measure for ecosystem quality. These relationships between pressures and species abundance are based on extensive literature reviews. Initially called NCI-pressure based, this indicator has been renamed Mean Species Abundance (MSA). The main difference between NCI and MSA is thus that NCI is mainly based on actual observations in a studied area, while the MSA uses relations between pressures and impacts on species abundance. The MSA can be calculated with the GLOBIO model*"[14].

As with other approaches, MSA and NCI calculations start from an historic benchmark based on species distribution areas. However, unlike other methodologies, MSA and NCI do not use any monitoring data on species or habitats but use a model to derive estimates of biodiversity loss from assumed impacts of pressures, in particular land-use data over a theoretical natural or undisturbed state. In ecosystem capital accounts, species biodiversity is information aimed at enhancing the assessment of ecosystem infrastructure integrity carried out from geographical data on land cover and land use. Because of time and scale issues, dynamics, and threshold effects, species diversity is not linearly related to ecosystem infrastructure integrity. Trends in species biodiversity give early warning of ecosystem degradation. There is therefore a need in ecosystem accounting for an index based on real monitoring data, which MSA and NCI do not provide.

13 *http://www.globio.info/what-is-globio/how-it-works/impact-on-biodiversity (accessed 18 August 2014).*

14 *http://www.pbl.nl/en/dossiers/biodiversity/faqs#vraag7 (accessed 18 August 2014).*

About data on species biodiversity

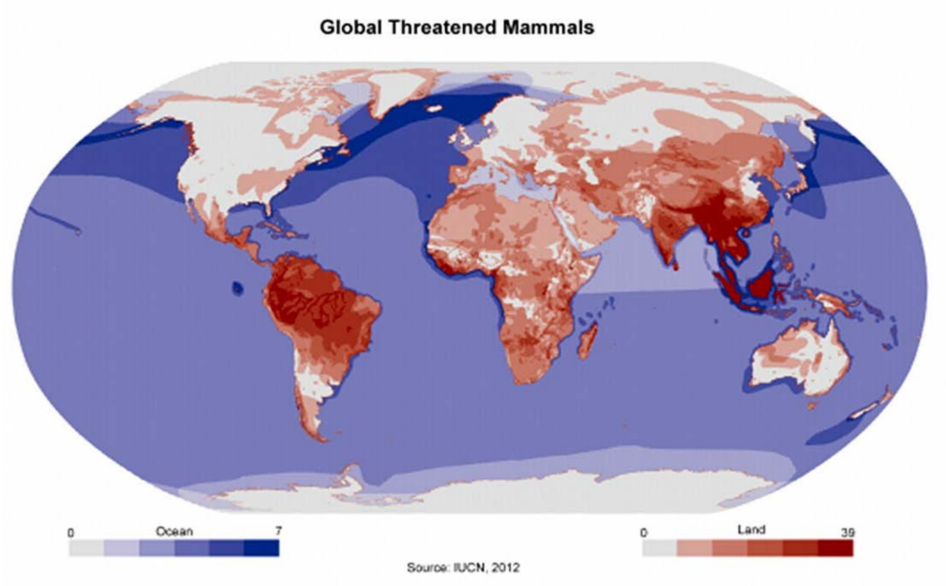
Species biodiversity change indicators used in ecosystem accounting need to be based on monitored data. Such data are relatively abundant, and under-exploited. They do not, however, come in a format that makes them directly recordable into the primary grid on which accounts are built up. Geo-statistical processing of raw data is needed.

Important databases on habitats, species and genes have been developed in countries and at the regional level. They result from joint efforts of government agencies, museums of natural history, universities and NGOs, bringing together professional scientists and amateurs. The internet has enabled systematic centralization of individual observations; biodiversity data crowd -sourcing is widespread. It is therefore not possible to list all data sources. Instead, the examples of two, the Global Biodiversity Information Facility (GBIF) and IUCN, are used below to illustrate the data issue.

Using IUCN Data

The IUCN Red List of Threatened Species™ is widely recognized as the most comprehensive, objective global approach to evaluating the conservation status of plant and animal species. The IUCN disseminates important geographic datasets for a large number of species on its website.

Figure 7.02 Example of a geo-dataset downloadable from the IUCN website



Source: IUCN, Spatial Data Download http://www.iucnredlist.org/technical-documents/spatial-data (accessed 14 July 2014)

For birds, data are collected and disseminated by the IUCN partner organization BirdLife International[15].

Although Red Lists are a non-representative sample of total species biodiversity, they can be considered for use by default or jointly with other indicators as long as one can assume that priority has been given by experts to these species, and not to others, on the basis of a particular concern. The level of threat can be used as a first estimate of ecosystem degradation or stability.

IUCN also provides tables of change in status that give a better insight on trends. However, IUCN warns against a naïve use of changes in threat status[16]. Change may be for "*non-genuine reasons*" such as new information being made available since the previous assessment or possible taxonomic revisions resulting in splits or mergers that change ranges or populations size, as well as for "*genuine reasons*" such as the disappearance of the threat or the effect of conservations measures which improve the status or, in the opposite direction, a continuation or increase in threats or the appearance of new threats.

Because of the importance of the IUCN database, methodologies have been developed to calculate a Red List Index that uses information from the IUCN Red List to track trends in the projected overall extinction risk of sets of species. Recent improvements aim to eliminate biases due to uneven frequency of assessments and newly evaluated species with the aim of determining the overall level of extinction risk as well as trends over time[17]. Once these necessary improvements have been carried out, the IUCN database will be able to contribute to the production of ecosystem accounts.

Using GBIF data

"*The Global Biodiversity Information Facility (GBIF) is an international open data infrastructure, funded by governments. It allows anyone, anywhere to access data about all types of life on Earth, shared across national boundaries via the Internet. By encouraging and helping institutions to publish data according to common standards, GBIF enables research not possible before, and informs better decisions to conserve and sustainably use the biological resources of the planet. GBIF operates through a network of nodes, coordinating the biodiversity information facilities of Participant countries and organizations, collaborating with each other and the Secretariat to share skills, experiences and technical capacity*."[18] The map in Figure 7.03 shows the coverage of the planet with species observations for animals.

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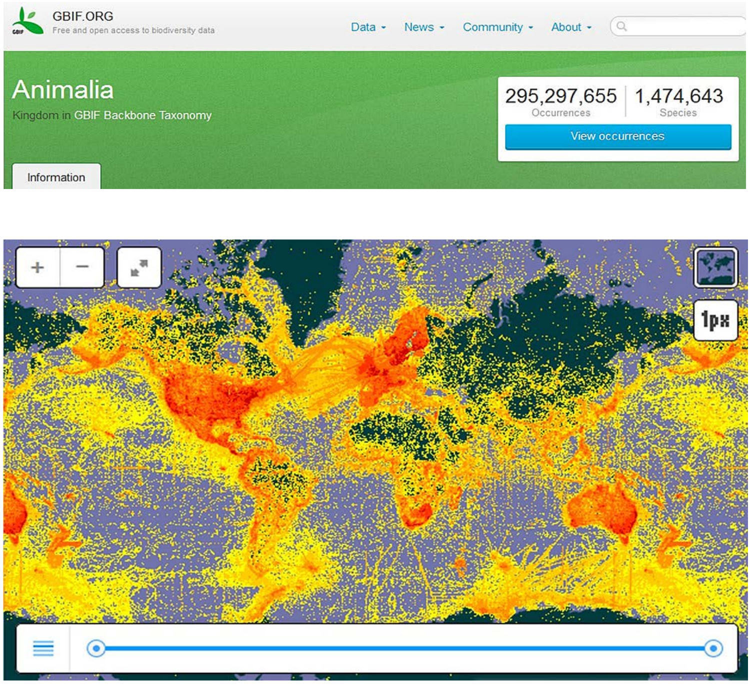
15 http://www.birdlife.org/datazone/info/spcdownload (accessed 14 July 2014)

16 http://www.iucnredlist.org/about/overview (accessed 14 July 2014).

17 Butchart, S.H., Resit Akçakaya, H., Chanson, J. et al. 2007. Improvements to the Red List Index. PLoS ONE 2(1): e140. http://www.plosone.org/article/fetchObject.action?uri=info%3Adoi%2F10.1371%2Fjournal.pone.0000140&representation=PDF (accessed 14 July 2014).

18 http://www.gbif.org/ (accessed 14 July 2014).

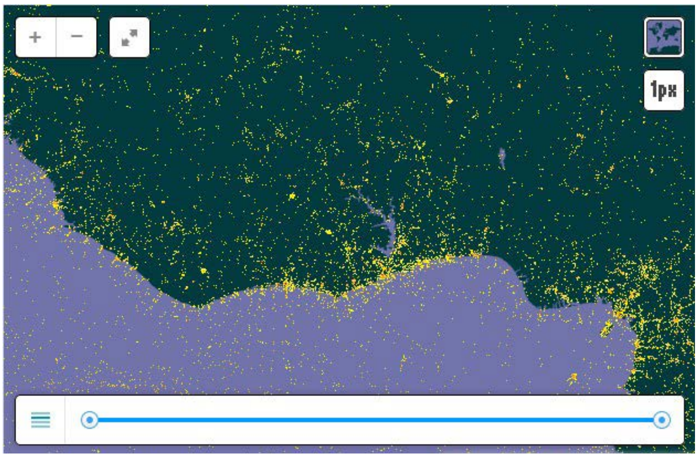
Figure 7.03 Representation of animals observations in GBIF



Source: http://www.gbif.org/ (accessed 14 July 2014).

When using such data, two specific problems need to be kept in mind. The first is that species data refer to point observations. The very small-scale map, Figure 7.03, magnifies points up to pixels of about 10 km x 10 km. Using a larger scale shows that these points may be very scattered (Figure 7.04).

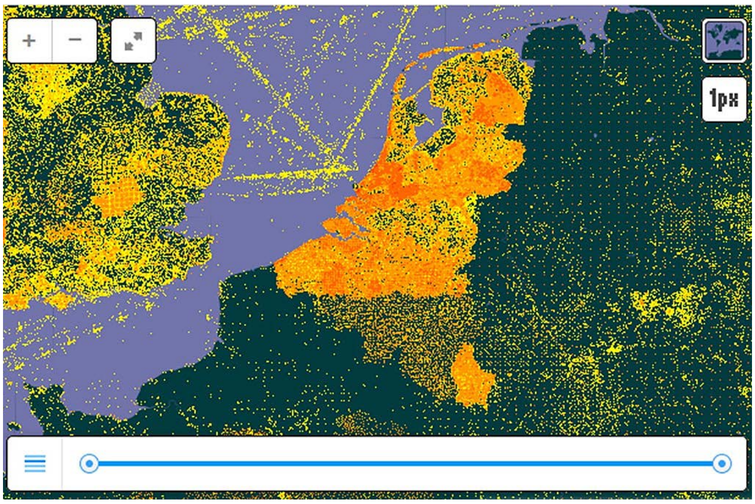
Figure 7.04 A zoom on the GBIF animalia data global view (Western Equatorial Africa)



Source: http://www.gbif.org/ (accessed 14 July 2014).

The second problem is the uneven density of observations, from country to country or region to region, which relates to the density of observers. This is illustrated in Figure 7.05.

Figure 7.05 Distribution of GBIF recordings for plantae in Northwest Europe



Source: http://www.gbif.org/ (accessed 14 July 2014).

A review of species data shows that data exist and that raw data need to be carefully analysed and processed. Since the aim is to assess the health of ecosystems described as spatial entities mapped with grids or as objects (SELU, MCU, SRU, etc.), generalization of species point data has to be done according to spatial features. This is done, for example, in ecological niche modelling (paras. 7.44 and 7.45) where historic and newly-monitored species data are associated with observed and probabilistic maps of suitable habitats. A similar attempt has been made at EEA to redistribute species data, collected in a coarse grid for Article 17 reporting to the Habitats Directive of the EU, to probable areas of distribution mapped with the 1 km x 1 km standard accounting grid.

When doing such ecological and spatial analysis and resampling raw input data collected from various sources, it is important to remember that it is not the stock of species which matters but the change over a period. The use of data on threatened species (IUCN Red Lists, EU Article 17 reporting) should not be excluded because of their well-known intrinsic bias since they are the best-monitored and their relation to the ecosystem is easy to understand. Because of the variety of possible data and data formats, it is not possible to define exact calculation rules, but some principles can be set out.

The correspondence between species and maps has to be considered at two different scales. At the micro or site scale an exact match can be found. Look-up tables cross-classifying species and habitats are based on this knowledge. At the landscape scale, things are different as long as land-cover classifications match habitat classifications only very poorly and, more important, because of the difference in scale which makes land-cover units only rarely pure and may include significant numbers of micro-habitats. Another problem is that species very often use more than one land-cover type. It maybe therefore more efficient not to use basic land-cover maps with crisp boundaries or homogeneous pixels but to adopt the more probabilistic approach of landscape distributions.

A possible approach is based on land-cover smoothing methodologies (Gaussian smoothing, filtering or blurring) discussed in Chapter 3. These allow the definition of dominant land-cover types (DLCT) and dominant landscape types (DLT) when relief is integrated into the definition. Both DLCT and DLT can be tuned according to rules corresponding to the theoretical look-up of species with habitats. For example, two DLCT thresholds are used by the European Environment Agency. The first, for DLCT51, corresponds with smoothed values > 50 %, in which case only one dominant type is recorded in each cell. Note that this recording is not binary as long as the density values used for the selection can be recorded as attributes (from 51 to 100). The second threshold is for DLCT34, which corresponds to smoothed values > 34 %, in which case the cell can be classified as one type or a combination of two types. This fuzzy description of the properties of landscapes supports a less precise correlation but is more realistic considering the density of species input data.

Ecological niche modelling (ENM)[19], also called species distribution modelling, is an advanced method for extrapolating point data and stretching them to areas which can be used as an input to ecosystem accounting.

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19 Stockwell, D. 2006. Niche modeling — what is it? http://landshape.org/enm/niche-modeling-what-is-it-2/ (accessed 14 July 2014).

Ecological niches can be defined as the conjunction of ecological conditions within which a species is able to maintain populations without immigration (Grinnell, 1917). Specifically, models "*relate ecological characteristics of known occurrence points to those of points randomly sampled from the rest of the study region, developing a series of decision rules that best summarize those factors associated with the species' presence*" (Peterson, 2002[20]). Commonly-used models[21] include GARP[22], Maxent[23], openModeller[24], DIVA-GIS[25] and Biomapper[26].

Ecological niche modelling methodologies and models are used in ecological management for planning nature conservation programmes, reintroductions of species, and assessments of possible impacts of climate change on biodiversity. The data used refer to environmental and geographical spaces. They take into account climatic and relief factors that limit the development of given species as well as other observable variables such as the Normalised Difference Vegetation Index (NDVI) extracted from satellite images. This is used to define the probability of a species being found in a given area, which is compared with historic data, similarly to BII, and with recent species monitoring data. The probabilistic approach and combination of these dimensions allow problems linked to the uncertain and static character of historic data on species distribution, and monitoring data problems such as their generalization and completion, to be overcome. One problem addressed by the models is that an absence of observations of a species may be either a real absence or a pseudo-absence. From the point of view of ecosystem accounting, ENM is an interesting methodology that can be used to generalize species monitoring data available as points. With appropriately designed ENM applications, a connection may even be possible with the basic ecosystem infrastructure integrity account.

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20 Townsend Peterson, A. et. al. 2005. 2002-2005, Ecological Niche Modeling as a New Paradigm for Large-Scale Investigations of Diversity and Distribution of Birds, USDA Forest Service Gen. Tech. Rep. PSW-GTR-191. http://www.fs.fed.us/psw/publications/documents/psw_gtr191/psw_gtr191_1201-1204_peterson.pdf (accessed 14 July 2014).

21 Townsend Peterson, A. et. al. 2011. Ecological Niches and Geographic Distributions. Monographs in population biology 49, Princeton University Press

22 GARP: Genetic Algorithm for Rule-set Prediction http://www.nhm.ku.edu/desktopgarp/index.html (accessed 14 July 2014).

23 Elith, J. et al. 2011. A statistical explanation of MaxEnt for ecologists, Diversity and Distribution. Vol. 17, Issue 1 http://onlinelibrary.wiley.com/doi/10.1111/j.1472-4642.2010.00725.x/pdf (accessed 14 July 2014).

24 http://openmodeller.sourceforge.net/ (accessed 14 July 2014).

25 http://www.diva-gis.org/ (accessed 14 July 2014).

26 http://www2.unil.ch/biomapper/ A presentation of the methodology by A.H. Hirzel (2006) is downloadable from http://www2.unil.ch/biomapper/Presentations.html (accessed 14 July 2014).

7.2 THE ECOSYSTEM ECOLOGICAL INTEGRITY AND FUNCTIONAL SERVICES ACCOUNTING FRAMEWORK

In the ENCA-QSP framework, the ecosystem infrastructure is described using the available concepts and data. These relate to statistical units and to available monitoring data and statistics. The statistical units used for ecosystem accounting are those defined in Chapter 3. They include EAUs, LCEUs and grids used for data assimilation and computation as well as surrogate units such as administrative or cadastral units that can be used for data collection, analysis or synthesis. In the current Quick Start Package, the compilation of ecosystem accounts by administrative units is not addressed from an analytical point of view; instead administrative units are considered only as reporting units.

Box 7.04 Ecosystem accounting units

Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total landscape ecosystems	Total inland ecosystems	Marine ecosystem Coastal Units (MCU			Total inland & coastal ecosystems	Open sea	Atmosphere
UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_ GR	MC_ CR	MC_ NC			
Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals			Seagrass	Coral reefs	Other			

The EAUs used in the ecosystem infrastructure functional services accounting framework are inland and coastal marine accounting units (SELUs and MCUs) and RSUs. The corresponding primary functional units are respectively LCEU and homogenous stream reaches (HSR). Land-cover accounts and LCEU are discussed in Chapter 4. SELU are classified by dominant land-cover or landscape types (DLCT or DLT). Seas, beyond coastal units, and the atmosphere are not covered in the QSP ecosystem infrastructure functional services account.

At this stage, it is important to remember that the relationships between ecosystems and services are scale-dependent. In the simplified accounting framework, biocarbon services are fairly well correlated with LCEUs: trees are mostly in forests or mixed land-cover areas, grass in grassland, etc. Functional services can be correlated with LCEUs but in most cases they depend on a cluster of these that can be described by SELUs, MCUs or RSUs or at the scale of river sub-basins or basins.

Table 7.01 Summary ecosystem infrastructure functional services accounts

	Ecosystem Accounting Unit Types	Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems	Total inland ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems	Open sea	Atmosphere
		UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_GR	MC_CR	MC_NC			
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals			Seagrass	Coral reefs	Other			
I. Basic balances																						
I.1 Basic land cover accounts [km²]																						
LC01	Urban and associated developed areas																					
LC02	Homogeneous herbaceous cropland																					
LC03	Agriculture plantations, permanent crops																					
LC04	Agriculture associations and mosaics																					
LC05	Pastures and natural grassland																					
LC06	Forest tree cover																					
LC07	Shrubland, bushland, heathland																					
LC08	Sparsely vegetated areas																					
LC09	Natural vegetation associations and mosaics																					
LC10	Barren land																					
LC11	Permanent snow and glaciers																					
LC12	Open wetlands																					
LC13	Inland water bodies																					
LC14	Coastal water bodies and inter-tidal areas																					
	Sea (interface with land)																					
LC1	**Opening stock of land cover**																					
F_LF1	Artificial development																					
F_LF2	Agriculture development																					
F_LF3	Internal conversions, rotations																					
F_LF4	Management and alteration of forested land																					
F_LF5	Restoration and development of habitats																					
F_LF6	Changes due to natural and multiple causes																					
F_LF7	Other land cover changes n.e.c. and reclassification																					
F_LF	**Formation of land cover**																					
C_LF1	Artificial development																					
C_LF2	Agriculture development																					
C_LF3	Internal conversions, rotations																					
C_LF4	Management and alteration of forested land																					
C_LF5	Restoration and development of habitats																					

	Ecosystem Accounting Unit Types	Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems	Total inland ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems	Open sea	Atmosphere
		UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_GR	MC_CR	MC_NC			
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals			Seagrass	Coral reefs	Other			
C_LF6	Changes of land-cover due to natural and multiple causes																					
C_LF7	Other land cover changes n.e.c. and reclassification																					
C_LF	**Consumption of land cover**																					
LC01	Urban and associated developed areas																					
LC02	Homogeneous herbaceous cropland																					
LC03	Agriculture plantations, permanent crops																					
LC04	Agriculture associations and mosaics																					
LC05	Pastures and natural grassland																					
LC06	Forest tree cover																					
LC07	Shrubland, bushland, heathland																					
LC08	Sparsely vegetated areas																					
LC09	Natural vegetation associations and mosaics																					
LC10	Barren land																					
LC11	Permanent snow and glaciers																					
LC12	Open wetlands																					
LC13	Inland water bodies																					
LC14	Coastal water bodies and inter-tidal areas																					
	Sea (interface with land)																					
LC2	**Closing stock of land cover**																					
I.2 Basic river systems account [SRMU]																						
RS1	**Opening basic stock of rivers**																					
RSF1	Change of due to water use and rivers management																					
RSF2	Change due to natural causes & unknown																					
RSF3	**Net change in river basic stocks**																					
RS2	**Closing basic stock of rivers**																					

Ecosystem Accounting Unit Types		Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems	Total inland ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems	Open sea	Atmosphere
		UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_GR	MC_CR	MC_NC			
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals			Seagrass	Coral reefs	Other			
II. Accessible ecosystem infrastructure potential																						
LC1	Opening stock of land cover in km^2																					
LEP_ avg	*Average LEP composite index by km^2*																					
NLEP1	Net Landscape Ecosystem Potential = LC1 x LEP_avg																					
RS1	Opening stock of rivers in standardized river measurement units (SRMU)																					
REP_ idx	*REP composite index*																					
NREP1	Net River Ecosystem Potential = RS1 x REP_idx																					
REP_ avg	*Average NREP by km^2*																					
LREP1	Landscape River Ecosystem Potential = LC1 x REP_avg																					
TEIP1	Opening stock of Total ecosystem infrastructure potential =NLEP1+LREP1																					
CH_ TEIP	Change in Total ecosystem infrastructure potential = TEIP2 - TEIP1																					
LC2	Closing stock of land cover in km^2																					
LEP_ avg	*Average Landscape Ecosystem Potential composite index by km^2*																					
NLEP2	Net Landscape Ecosystem Potential = LC2 x LEP_avg																					
RS2	Closing stock of rivers in standardized river measurement units (SRMU)																					
REP01	*River ecosystem background index*																					
NREP2	Net River Ecosystem Potential = RS2 x REP_idx																					
REP_ avg	*Average NREP by km^2*																					
LREP2	Landscape River Ecosystem Potential = LC2 x REP_avg																					
TEIP2	Closing stock of ecosystem infrastructure potential =NLEP2+LREP2																					

Ecosystem Accounting Unit Types		Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)								River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes							Marine ecosystem Coastal Units (MCU)					
		UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_GR	MC_CR	MC_NC			
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover	**s/total landscape ecosystems**	Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals	**s/total river systems**	**Total inland ecosystems**	Seagrass	Coral reefs	Other	**Total inland & coastal ecosystems**	**Open sea**	**Atmosphere**
III. Overall access to ecosystem infrastructure functional services																						
TEIP1	**Opening stock of Total ecosystem infrastructure potential =NLEP1+LREP1**																					
AIP1	Population's local access to TEIP = sqrt(TEIP1xAIP13)																					
AIP2	Population's local access to agro-ecosystems services = sqrt(AIP1xAIP23)																					
AIP3	Local access to TEIP for Nature conservation = sqrt(TEIP1xAIP31)																					
AIP4	Basin access to water regulating services = sqrt(AIP41xAIP42)																					
AIP6	Regional access to TEIP [tourism] = sqrt(TEIP1xAIP53)																					
AIP7	Global access of nature conservation services = sqrt(TEIP1xAIP71)																					
IV. Table of indexes of intensity of use and ecosystem health																						
EIU	**Ecosystem infrastructure use intensity = TEIP2/TEIP1**																					
EIH01	Change in threatened species diversity																					
EIH02	Change in species population																					
EIH03	Change in biotopes health condition																					
EIH04	Change in species specialisation index																					
EIH05	Other indicator																					
EIH06	Other indicator																					
EIH07	*Composite index of rivers species diversity, mean value by SELU*																					
EIH08	*Index of change in rivers water quality, mean value by SELU*																					
EIH09	*Index of other rivers health change, mean value by SELU*																					
EIH	**Composite ecosystem health index**																					
EIIP	**Annual change in ecological internal unit value = AVG (EIU, EIH)**																					

7.2.1 The basic balances of land cover and river systems

The land-cover account is discussed in Chapter 4. Land cover includes all inland areas as well as marine systems whose bottom land cover can be mapped, called marine coastal systems. In Chapter 4 the land-cover account is presented by LCEUs and by EAUs (paras. 7.47 and 4.78). As measurement units are different, two sub-tables are compiled, one for the area EAUs (SELUs and MCUs recorded in km2) and the other for linear EAUs (RSUs recorded in standard river measurement units – Box 7.01).

Accounting table 7-I.1 Basic land cover accounts (in km^2)

Ecosystem Accounting Unit Types		Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems
		UR	LA	AM	GR	FO	NA	ND		MC_ GR	MC_ CR	MC_ NC	
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Seagrass	Coral reefs	Other	
I. Basic balances													
I.1 Basic land cover accounts [km^2]													
LC01	Urban and associated developed areas												
LC02	Homogeneous herbaceous cropland												
LC03	Agriculture plantations, permanent crops												
LC04	Agriculture associations and mosaics												
LC05	Pastures and natural grassland												
LC06	Forest tree cover												
LC07	Shrubland, bushland, heathland												
LC08	Sparsely vegetated areas												
LC09	Natural vegetation associations and mosaics												
LC10	Barren land												
LC11	Permanent snow and glaciers												
LC12	Open wetlands												
LC13	Inland water bodies												
LC14	Coastal water bodies and inter-tidal areas												
	Sea (interface with land)												
LC1	**Opening stock of land cover**												
F_LF1	Artificial development												
F_LF2	Agriculture development												
F_LF3	Internal conversions, rotations												
F_LF4	Management and alteration of forested land												
F_LF5	Restoration and development of habitats												
F_LF6	Changes due to natural and multiple causes												
F_LF7	Other land cover changes n.e.c. and reclassification												
F_LF	**Formation of land cover**												
C_LF1	Artificial development												
C_LF2	Agriculture development												
C_LF3	Internal conversions, rotations												
C_LF4	Management and alteration of forested land												
C_LF5	Restoration and development of habitats												
C_LF6	Changes of land-cover due to natural and multiple causes												
C_LF7	Other land cover changes n.e.c. and reclassification												
C_LF	**Consumption of land cover**												
LC01	Urban and associated developed areas												
LC02	Homogeneous herbaceous cropland												
LC03	Agriculture plantations, permanent crops												
LC04	Agriculture associations and mosaics												
LC05	Pastures and natural grassland												
LC06	Forest tree cover												
LC07	Shrubland, bushland, heathland												
LC08	Sparsely vegetated areas												

LC09	Natural vegetation associations and mosaics												
LC10	Barren land												
LC11	Permanent snow and glaciers												
LC12	Open wetlands												
LC13	Inland water bodies												
LC14	Coastal water bodies and inter-tidal areas												
	Sea (interface with land)												
LC2	Closing stock of land cover												

River homogenous reaches can be grouped by size and/or according to their position in the hierarchical graph that describes rivers and streams from spring to estuary (Strahler stream order). The QSP tables propose to start with a classification of streams in a small number of classes (Chapter 2, para. 2.50 and Figure 2.04 and Chapter 6, paras. 6.28, 6.29 and Box 6.05); as an example, four classes for river streams plus one for canals are presented:

- HSR1 Large rivers, main drains ;
- HSR2 Medium rivers, main tributaries;
- HSR3 Small rivers;
- HSR4 Brooks, small streams;
- HSR5 Canals.

Accounting table 7-I.2 Basic river systems account (in SRMU)

	Ecosystem Accounting Unit Types	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems
		HSR1	HSR2	HSR3	HSR4	HSR5	
		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals	
I. Basic balances							
I.1 Basic land cover accounts [km²]							
RS1	Opening basic stock of rivers						
RSF11	*Change due to water consumption*						
RSF12	*Change due to damming*						
RSF13	*Change due to water transfers between basins*						
RSF14	*Other anthropogenic change*						
RSF1	Change of due to water use and rivers management						
RSF21	*Erosion/sedimentation process*						
RSF22	*Climate causes*						
RSF23	*Other change due to natural causes & unknown*						
RSF2	Change due to natural causes & unknown						
RSF3	**Net change in river basic stocks**						
RS2	Closing basic stock of rivers						

Change in basic river stock is only indicative at this stage. It includes change of rivers due to water use and river management, and changes due to natural causes. Anthropogenic changes include the consequences of water consumption, in particular for irrigation, and induced evapotranspiration, of damming on the river regime, and of water transfers between basins. Natural changes can be due to erosion/sedimentation processes and climate.

River systems stocks and changes are measured in standard river measurement units (SRMUs; Box 7.01).

Calculating SRMUs requires a database on rivers with lengths by class of river and measurements or estimates of the discharge of each reach or stretch. This is feasible but requires access to enough river discharge monitoring data. If this exists and has been collected for the purpose of ecosystem water accounts, calculation of SRMUs is just an additional step. If monitoring data are not easily accessible, a surrogate methodology can be implemented, following the rationale used for estimating river runoff by sub-basins in ecosystem water accounts (Box 6.04). In this case, values will be statistical, by types of homogeneous streams (para.7.49).

In Accounting table I.2, only quantities of SRMU are recorded; river length is background information used for calculating SRMU quantities as well as river ecotones. River runoff is part of the ecosystem water account. In Accounting Table II, on the accessible resource, a set of indicators will be attached to SRMUs in order to calculate river potentials in a way similar to that used for land.

7.2.2 Accounting Table II: Accessible ecosystem infrastructure potential

The ecosystem accessible infrastructure potential combines wall-to-wall geographical datasets in order to assess the basic capacity of ecosystems to deliver functional services. This is done in a macroscopic way, looking at distinctive ecosystem features. The number of datasets used is limited because of availability and by the fact that complex combinations of many layers make it more difficult to understand the meaning of the indicator. Ecosystem infrastructure potential is a loose concept that is useful for spatial comparison of ecosystems, and for temporal monitoring of degradation or enhancement. There is no single formula to calculate the indicator but some principles may be followed in the QSP. Depending on data availability, ecosystem condition, and tests of sensitivity, the indicator may have to be refined and some coefficients adjusted.

Accounting Table 7-II: Accessible ecosystem infrastructure potential

Ecosystem Accounting Unit Types		Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems	Total inland ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems
		UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_GR	MC_CR	MC_NC	
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals			Seagrass	Coral reefs	Other	
II. Accessible ecosystem infrastructure potential																				
LC1	**Opening stock of land cover in km²**																			
LEP01	*Green background landscape index (GBLI) (average by km²)*																			
LEP02	*Landscape high nature conservation value index (average by km²)*																			
LEP03	*Landscape fragmentation index (average by km²)*																			
LEP04	*Landscape green ecotones index (average by km²)*																			
LEP05	*Other LEP index (average by km²)*																			
LEP_avg	**Average LEP composite index by km²**																			
NLEP1	**Net Landscape Ecosystem Potential = LC1 x LEP_avg**																			
RS1	**Opening stock of rivers in standardized river measurement units (SRMU)**																			
REP01	*River ecosystem background index*																			
REP02	*Rivers nature conservation value index*																			
REP03	*Rivers fragmentation index (obstacles by km²)*																			
REP04	*Rivers green ecotones index*																			
REP05	*Other REP index*																			
REP_idx	**REP composite index**																			
NREP1	**Net River Ecosystem Potential = RS1 x REP_idx**																			

Ecosystem Accounting Unit Types		Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems	Total inland ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems
		UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_GR	MC_CR	MC_NC	
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals			Seagrass	Coral reefs	Other	
REP_avg	**Average NREP by km²**																			
LREP1	**Landscape River Ecosystem Potential = LC1 x REP_avg**																			
TEIP1	**Opening stock of Total ecosystem infrastructure potential =NLEP1+LREP1**																			
CH_ TEIP1	Change in ecosystem infrastructure potential due to land use																			
CH_ TEIP2	Change in ecosystem infrastructure potential due to fragmentation																			
CH_ TEIP3	Change in ecosystem infrastructure potential due to ecotones																			
CH_ TEIP4	Change in ecosystem infrastructure potential due to rivers																			
CH_ TEIP5	Change in ecosystem infrastructure potential due to other causes																			
CH_TEIP	**Change in Total ecosystem infrastructure potential = TEIP2 - TEIP1**																			
LC2	**Closing stock of land cover in km²**																			
LEP01	*Green background landscape index (GBLI) (average by km²)*																			
LEP02	*Landscape high nature conservation value index (average by km²)*																			
LEP03	*Landscape fragmentation index (average by km²)*																			
LEP04	*Landscape green ecotones index (average by km²)*																			
LEP05	*Other LEP index (average by km²)*																			
LEP_avg	**Average Landscape Ecosystem Potential composite index by km²**																			
NLEP2	**Net Landscape Ecosystem Potential = LC2 x LEP_avg**																			
RS2	**Closing stock of rivers in standardized river measurement units (SRMU)**																			
REP01	*River ecosystem background index*																			
REP02	*Rivers high nature conservation value index*																			
REP03	*Rivers fragmentation index*																			
REP04	*Rivers green ecotones index*																			
REP05	*Other REP index*																			
REP01	**River ecosystem background index**																			
NREP2	**Net River Ecosystem Potential = RS2 x REP_idx**																			
REP_avg	**Average NREP by km²**																			
LREP2	**Landscape River Ecosystem Potential = LC2 x REP_avg**																			
TEIP2	**Closing stock of ecosystem infrastructure potential =NLEP2+LREP2**																			

Accounting Table II on accessible ecosystem infrastructure potential calculates potentials for ecosystems described in surface units (e.g. km2) and rivers in SRMU. Calculations of NLEP and NREP are made separately but following similar principles. In an additional step, NREP values are computed as averages per SELU and multiplied by their surface that gives landscape river ecosystem potential (LREP). NLEP and LREP are additive and can be combined to calculate total ecosystem infrastructure potential (TEIP).

Box 7.05 Calculation of net landscape ecosystem potential (NLEP) and net river ecosystem potential (NREP)

II. Accessible ecosystem infrastructure potential	
LC1	**Opening stock of land cover in km²**
LEP01	*Green background landscape index (GBLI) (average by km²)*
LEP02	*Landscape high nature conservation value index (average by km²)*
LEP03	*Landscape fragmentation index (average by km²)*
LEP04	*Landscape green ecotones index (average by km²)*
LEP05	*Other LEP index (average by km²)*
LEP_avg	**Average LEP composite index by km²**
NLEP1	**Net Landscape Ecosystem Potential = LC1 x LEP_avg**
RS1	**Opening stock of rivers in standardized river measurement units (SRMU)**
REP01	*River ecosystem background index*
REP02	*Rivers nature conservation value index*
REP03	*Rivers fragmentation index (obstacles by km²)*
REP04	*Rivers green ecotones index*
REP05	*Other REP index*
REP_idx	**REP composite index**
NREP1	**Net River Ecosystem Potential = RS1 x REP_idx**
REP_avg	**Average NREP by km²**
LREP1	**Landscape River Ecosystem Potential = LC1 x REP_avg**
TEIP1	**Opening stock of Total ecosystem infrastructure potential =NLEP1+LREP1**
CH_TEIP1	Change in ecosystem infrastructure potential due to land use
CH_TEIP2	Change in ecosystem infrastructure potential due to fragmentation
CH_TEIP3	Change in ecosystem infrastructure potential due to ecotones
CH_TEIP4	Change in ecosystem infrastructure potential due to rivers
CH_TEIP5	Change in ecosystem infrastructure potential due to other causes
CH_TEIP	**Change in Total ecosystem infrastructure potential = TEIP2 - TEIP1**
LC2	**Closing stock of land cover in km²**
LEP01	*Green background landscape index (GBLI) (average by km²)*
LEP02	*Landscape high nature conservation value index (average by km²)*
LEP03	*Landscape fragmentation index (average by km²)*
LEP04	*Landscape green ecotones index (average by km²)*
LEP05	*Other LEP index (average by km²)*
LEP_avg	**Average Landscape Ecosystem Potential composite index by km²**
NLEP2	**Net Landscape Ecosystem Potential = LC2 x LEP_avg**
RS2	**Closing stock of rivers in standardized river measurement units (SRMU)**
REP01	*River ecosystem background index*
REP02	*Rivers high nature conservation value index*
REP03	*Rivers fragmentation index*
REP04	*Rivers green ecotones index*
REP05	*Other REP index*
REP_idx	**River Ecosystem Potential composite index**
NREP2	**Net River Ecosystem Potential = RS2 x REP_idx**
REP_avg	**Average NREP by km²**
LREP2	**Landscape River Ecosystem Potential = LC2 x REP_avg**
TEIP2	**Closing stock of ecosystem infrastructure potential =NLEP2+LREP2**

The net landscape ecosystem potential (NLEP)

The stock of landscape ecosystem potential is calculated as the sum of weighted km². The weight is given by a combination of several dimensions into a composite index, where net means that both positive and negative values have been considered, greenness reflects less artificiality, conservation value means areas (green or less green) of particular ecological interest, fragmentation by artificial features reduces ecosystem exchanges, and ecotones are areas where greenness is particularly favourable for biodiversity. The selection of indicators takes into account that biomass and water are captured in other accounts and that species biodiversity is introduced later in Accounting Table IV.

The Green Background Landscape Index (GBLI) is a conventional rating of land-cover classes according to their artificiality and/or greenness and intensity of land use as deduced from land cover. There is no rigorous way of doing the scoring and a simple formula can be used in the QSP, tested in terms of its sensitivity and fine-tuned depending on first results. The land-cover input data will reflect the quantity of each class, duly weighted, in the landscape. The easiest solution is to use the regular assimilation grid to compute the GBLI. To avoid segmentation and scale effects, it is better to use smoothed land-cover layers instead of raw statistics by grid cell. Such layers have already been calculated to produce Dominant Land Cover Types (Chapter 3, Section 3.2.2) and can be easily reused.

For GBLI calculation, each aggregated layer is given a weight. The formula is conventional and keeping it simple provides an understanding of the source of possible problems. For example, in Europe the formula has been revised to give some weight to artificial areas and broad agriculture, initially both scored at 0 but now given weights of 0.1 and 0.2 respectively on a 0-1 scale. There are also discussions on the possibility of splitting the forest class between traditional forests managed on a long cycle, and plantations of eucalyptus and poplars with a short rotation and therefore little potential to host biodiversity; this downgrading of the tree-production-plantations score has not yet been introduced because data consistent with the Corine land-cover map are not available. Score tuning could also be done for artificial areas, split between dense and discontinuous fabric, and pastures – intensively managed versus more natural types.

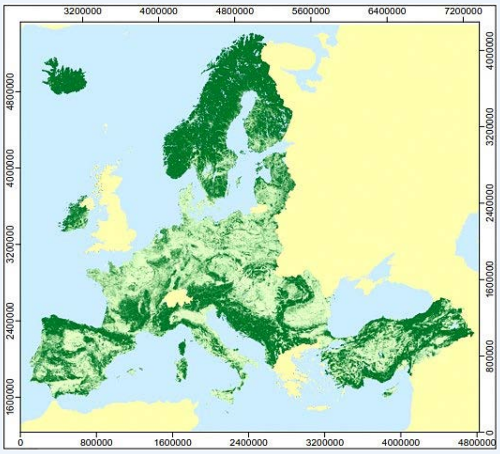
As illustrations of the kind of rating grid that can be used, examples from Europe and Mauritius are compared in Box 7.06

Box 7.06 Examples of scoring tables for GBLI calculation

EEA member countries

The GBLI calculation for Europe (EEA member countries) is based on an aggregation of land cover in 7 classes. The data have been computed on a 1 km2 grid and smoothed with a radius of 5 km. The scores on a 0 to 1 grid are:

Artificial Areas: 0.1

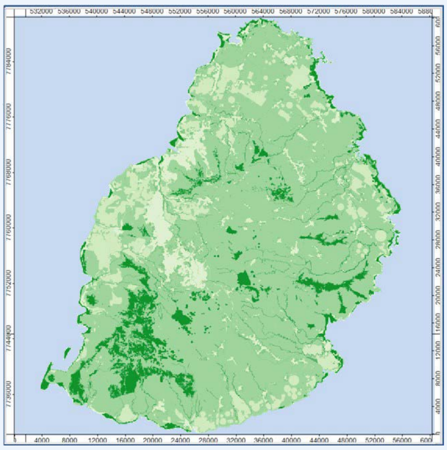


Data source: GBLI2006, EEA 2011 (missing data for Greece and the UK)

Mauritius

The GBLI calculation for the Mauritius test accounts is based on an aggregation of land cover in 8 classes. Data have been computed on a 1 ha grid and smoothed with a radius of 1 km. The provisional scores on a 0 to 1 grid are:

Urban/ artificial: 0.1



Data source: GBLI 2010, Statistics Mauritius and J.-L. Weber, 2013

The landscape nature conservation value index may be useful for introduction into the NLEP calculation in order to nuance the picture provided by GBLI. The GBLI scores are based on the picture of biophysical characteristics given by rather aggregated land-cover maps; they do not reflect specific situations. Box 7.07 illustrates this.

Box 7.07 Greenness and nature conservation value

	Designated	Not designated
Green	e.g. natural parks, reserves…	e.g.common forests, shrubland, grassland…
Less green	e.g. protected areas in agriculture landscapes	e.g. urban areas

The landscape nature conservation value index can be calculated on the basis of existing maps of protected or designated areas. The integrated map can be made in a simple way as the sum of all protection classes, or with distinctions between various types of protection or designation, as classified for example by IUCN, and different weightings according to strong or less strong protection. Since there may be multiple designations, areas can be weighted according to the number of such designations. In each case, the expected outcome is an indication of the particular nature conservation value of the area, acknowledged by governments on the basis of assessments and recommendations by scientific experts. Also in each case, the nature value may not be restricted to the crisp boundaries of the protected areas but may overlap with their neighbourhood; it is therefore recommended that the combined map of all protections should be smoothed, as is done for land cover.

Landscape fragmentation by artificial features is an important dimension of landscape integrity. The landscape fragmentation index will correct the image given by the greenness and nature conservation value indices by taking into account the barrier effects which restrict exchanges between ecosystems.

Fragmentation is a well-known issue in landscape ecology and many indicators are published. A widely-used resource is FRAGSTATS, a computer software programme designed to compute a wide variety of landscape metrics for categorical map patterns. FRAGSTATS was developed by the Landscape Ecology Laboratory of the University of Massachusetts. In addition to the programme itself, the website offers detailed documentation on landscape metrics (http://www.umass.edu/landeco/research/fragstats/fragstats.html).

Fragmentation in ecosystem capital accounting is considered as a negative effect, for example of barrier effects and noise, of artificial infrastructures on the functioning of natural ecosystems. Therefore, not all fragmentation is included in the landscape fragmentation index used to calculate NLEP. Mosaic landscapes with small patches are generally rich in ecological niches and ecotones. Up to some point, fragmentation of forests by small roads with little traffic has as many positive effects (by opening the way to sunlight for plants other that trees) as negative ones. The landscape fragmentation index will therefore only consider hard fragmentation by roads and railways of some importance, ideally measured by their size and the traffic that they support. It will also include fragmentation by build-up areas.

In practical terms, there are several ways of calculating the landscape fragmentation index. Some metrics have been developed, for example using the FRAGSTATS programme, and can be used as long as they match the purpose stated in the previous paragraph.

A commonly-used indicator, the mean patch density of the land-cover map has to be used with care since its meaning is unclear because of barrier effects. Mean patch density will not distinguish between patchy areas with or without urban development, with the risk of confusion between degraded landscapes and rich patchy mosaics of natural land cover with small agriculture holdings. In addition, the mean patch density is calculated in some publications as the arithmetic mean of patche sizes, which is not the appropriate formula for processing statistical populations with large and small units. In this case, the geometric average, or root mean square, would give more correct results.

An advanced methodology for assessing fragmentation measures effective mesh size and effective mesh density (Meff)[27]. The methodology has been used at the European Environment Ageny for spatial assessment of fragmentation in Europe[28] and to calculate NLEP. Large roads, highways and railways, as well as urban areas, have been clipped out of the map to get the input meshes. Because mesh size varies from extremely large to very small and because, beyond a threshold, situations are equivalent (probabilities are the same in large and very large areas), the values taken are the natural logarithm (ln) of Meff. So the Fragmentation Index = 1/ ln(Meff). The Meff methodology is illustrated in Box 7.08.

In Mauritius, a simpler methodology has been used which consists of selecting the main roads and rasterizing them with a pixel of 1 ha, corresponding to the accounting grid. The calculation of the ratio roads/total surface is then done by SELUs. As long as the SELUs are small, the risk of bias linked to uneven spatial distribution of fragmenting structures is minimal and the Fragmentation Index can be used for NLEP calculation.

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27 Meff is part of the FRAGSTATS package. http://www.umass.edu/landeco/research/fragstats/fragstats.html (accessed 18 August 2014).

28 Jaeger, J., Soukup T. et al. 2011. Landscape fragmentation in Europe. Joint report by the European Environment Agency and the Swiss Federal Environment Agency (FOEN), EEA Report No 2/2011 http://www.eea.europa.eu/publications/landscape-fragmentation-in-europe (accessed 14 July 2014).

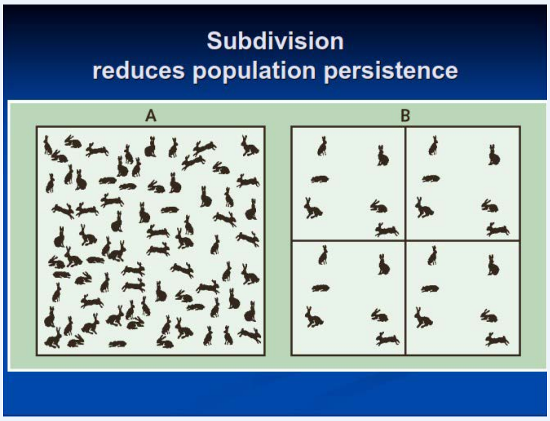
Box 7.08 Calculation of effective mesh size – an illustration

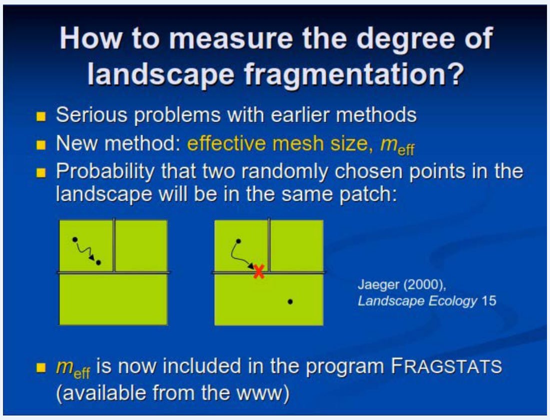
Effective Mesh Size (Meff) measures the probability that two individuals will encounter each other (e.g. gene flow) in a given area A, knowing that it maybe fragmented (in the example, into A1, A2 and A3). The probability of this encounter is multiplied by the total surface of the area to give a Meff value.

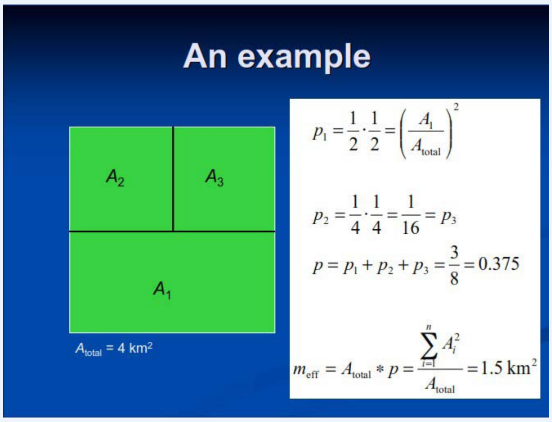
The Effective Mesh Density (Seff) equals 1/Meff

The Seff value rises when fragmentation increases. In the example, it would be 1/1.5 = 0.667 per km2 for area A.

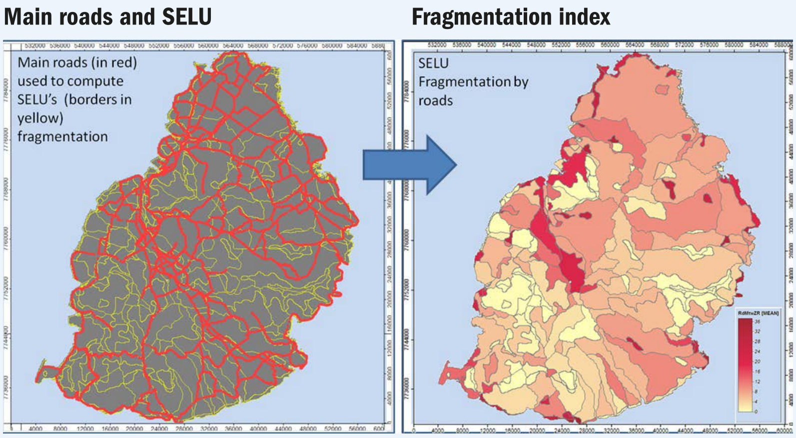
Source: Jochen Jaeger, Calgary, 2008







Box 7.09 A simplified method for measuring fragmentation of SELUs by roads



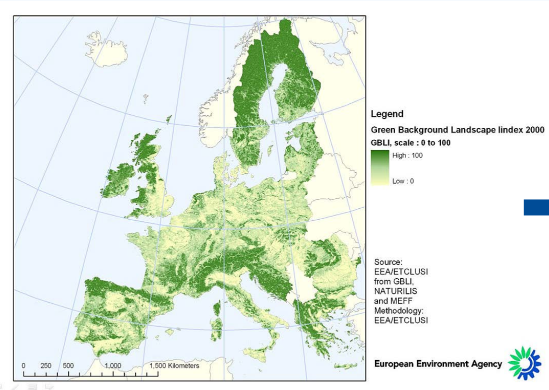
Source: Weber, 2014, op. cit

The sequence for producing NLEP can be summarized in the case of the European Environment Agency work by Box 7.10. More details are given in the 2006 European aEnvironment Agency report on land and ecosystem accounting for Europe[29].

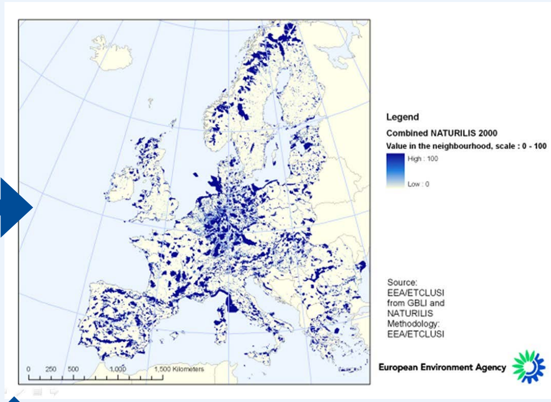
29 *Haines-Young, R. and Weber, J.-L. (eds.). 2006. Land accounts for Europe 1990–2000, Towards integrated land and ecosystem accounting. EEA Report No 11/2006, http://www.eea.europa.eu/publications/eea_report_2006_11 (accessed 14 July 2014)*

Box 7.10 The making of NLEP, EU member countries, 2000

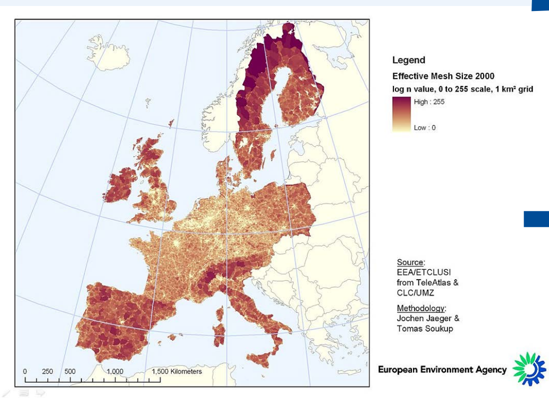
The green background landscape index ...



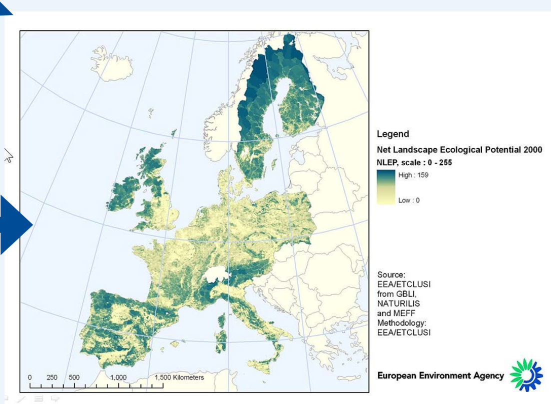
... combined with the nature conservation value index ...



... and combined with landscape fragmentation index ...



... gives the NLEP



Green ecotones index

The NLEP index is made up of geographical wall-to-wall layers. It can be combined with other data collected in different ways such as sampling, for example for species biodiversity (see below). It can also be combined with the grid layers produced in biomass/biocarbon and water accounts. Other enhancements can be envisaged, including a map of ecotones that can be derived from the land-cover maps used for accounting.

"*An ecotone is a transitional area between two different ecosystems, such as a forest and grassland. In landscape ecology, an ecotone is the border area where two patches meet that have different ecological composition. The ecotone contains elements of both bordering communities as well as organisms which are characteristic and restricted to the ecotone … Ecotones often have a larger number of species and larger population densities than the communities on either side. This tendency for increased biodiversity within the ecotone is referred to as the edge effect.*"[30] Ecotones can be observed at various scales from very large (micro level) to very small (ecotones between biomes).

Maps of ecotones have been produced by the European Environment Agaency from its CORINE land-cover inventories made on a scale of 1:100 000. Ecotones have been defined as pairs of land cover and grouped according to similar characteristics. The analysis has been done at the level of the 44 CORINE classes and aggregated in two steps.

30 *The Encyclopedia of Earth, article on Ecotones by Rose Graves, http://www.eoearth.org/view/article/152345/ (accessed 14 July 2014).*

Box 7.11 Example of ecotones definition and classification based on land cover classes

CORINE Land cover aggregated classes		Artificial areas	Arable land & permanent crops	Irrigated agriculture	Pastures	Mosaic farmland	Standing forests	Transitional woodland & shrub	Semi-natural vegetation	Open spaces/ bare soils	Wetlands	Inland water bodies	Sea
		a	b	c	d	e	f	g	h	i	j	k	l
Artificial areas	a	a*a	a*bc		a*de		a*fg		a*hij			a*k	a*l
Arable land & permanent crops	b		bc*bc		b*de		bc*f	bc*g	b*hi		b*j	b*k	bcde * l
Irrigated agriculture	c				c*de				c*hi		c*j	c*k	
Pastures	d				de*de		de*f	de*g	de*hi		de*j	de*k	
Mosaic farmland	e												
Standing forests	f						fg*fg		f*hij			fg*k	fg*l
Transitional woodland & shrub	g								g*hij				
Semi-natural vegetation	h								hi*hi		hi*j	hi*k	h*l
Open spaces/ bare soils	i												i*l
Wetlands	j										j*j	j*k	j*l
Inland water bodies	k											k*k	k*l
Sea	l												l*l

In the semi-aggregated table, 41 ecotones are defined as the edges of land-cover classes or groups of classes. For example, cell a*a means ecotones internal to artificial areas (e.g. between urban fabric and industrial areas within artificial areas). The code de*f is given to the ecotones between pasture or mosaic farmland and forests.
The scores given to aggregated ecotone classes to calculate the Green Ecotones Index are consistent with those used for GBLI.

Source: EEA, 2012, A. R. Oulton and J.-L. Weber, working document

Green Ecotones Index:	ecotones weighting
Urban*Urban	1
Nature_agriculture*Urban	10
Broad _agriculture*Broad _agriculture	25
Mixed_agriculture*Broad_agriculture	50
Nature*Broad _agriculture	50
Mixed_agriculture*Mixed_agriculture	75
Nature*Mixed_agriculture	100
Nature*Nature	100

The type of patches meeting in ecotones influence biodiversity in various ways, ecotones between natural and artificial ecosystems having a lower ecological value. An experimental green ecotones index has been calculated by the European Environment Agency for 1990, 2000 and 2006, the ecotones being scored in a way consistent with the green background landscape index. Results are calculated as green ecotone value 1–100 by cells of the 1 km^2 standard grid. The green ecotones index has not yet been used for NLEP calculation, but has been for river ecotones.

"*Small linear landscape features (SLF) play a crucial role in landscape functioning. Vegetation linear features serve as natural habitats or bio-corridors (green infrastructure) in intensively used open landscapes. Secondly, they provide important provisioning (genetic, wood), regulating (climate, soil erosion protection, water purification) and cultural (landscape character) ecosystem services*"[31]. Small linear features, natural (small streams, riparian forests) as well as artificial features (hedgerows, small walls or lanes bordering fields) are an important component of landscape diversity and biodiversity.

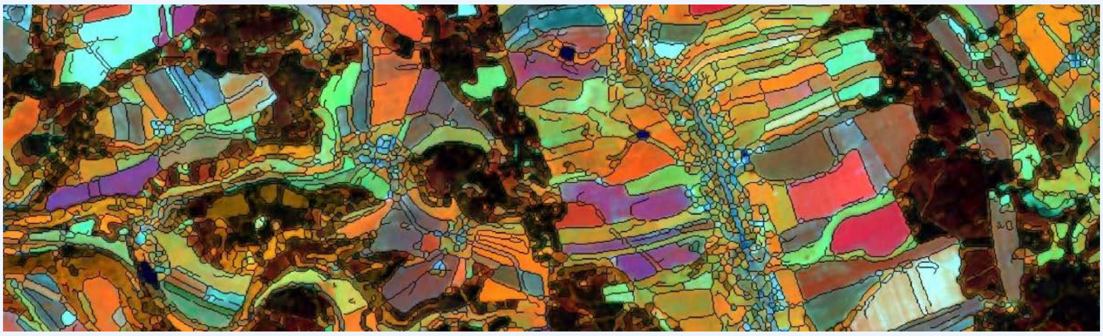
Recent research at the European Environment Agency and the European Space Agency (ESA)[32] has resulted in methodologies to detect SLF, characterise micro-ecotones and calculate a heterogeneity index from high-resolution satellite images (Box 7.12). This index

31 *Brodsky, Lukas, et al. 2013. Mapping and Monitoring Small Linear Landscape Features, ESA Living Planet Symposium 2013, Edinburgh, European Space Agency www.livingplanet2013.org/abstracts/852126.htm; http://seom.esa.int/LPS13/e9c7f56b/ (accessed 14 July 2014).*

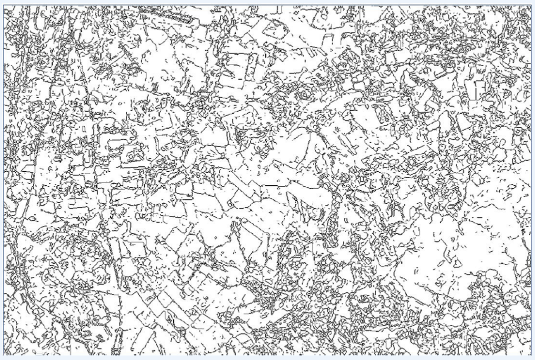
32 *op.sit.*

can be updated in the same way to highlight processes such as urban densification or conversion from family agriculture to broad agriculture at early stages. The landscape heterogeneity index can be usefully integrated in an enhanced NLEP calculation.

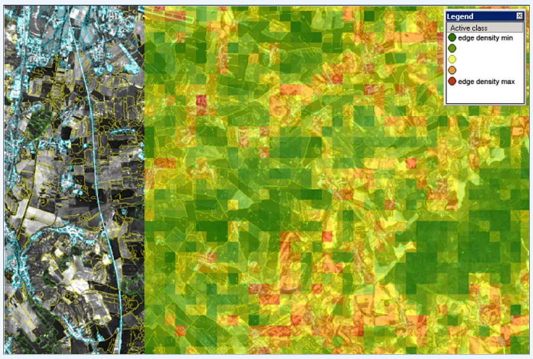
Box 7.12 Illustration of the calculation of a landscape infrastructure heterogeneity index



Small linear features detection on satellite image (© ESA, 2009 / SPOT4)



Heterogeneity detection
Data processing: Brodsky, L., (2011) GISAT for EEA (working document)



Edges characterisation and landscape heterogeneity index (right, 1 km^2 cells)

The Net River Ecosystem Potential

The net river ecosystem potential is a measure of the contribution of rivers to the accessible ecosystem infrastructure potential. The accessible water resource of rivers is calculated in the ecosystem water account (see Chapter 6). The river infrastructure is considered for its capability of bringing water as well as other services and contributing indirectly to the maintenance of the landscape services that depend on rivers. The basic stocks measurement is not the surface (as for landscape) or length of the river but the river value in SRMU. The structure of the NREP account is presented in Box 7.05

The net river ecosystem potential (NREP) is calculated by weighting the stock of SRMUs with an index composed in the same way as for LEP. The stock RS1 is estimated from the average value of river discharges over a period of 20 to 30 years, depending on available hydrological data.

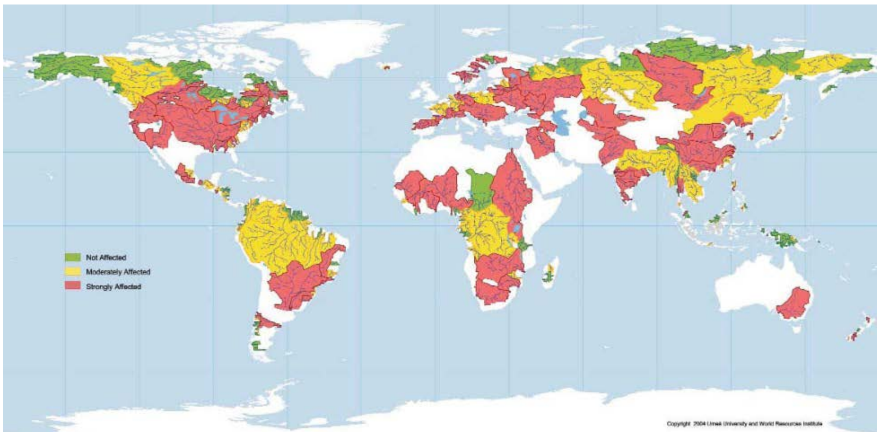
The river ecosystem background index reflects the variability of the river runoff. It can be calculated as the number of days when the discharge is > 90 % of the long-term average (calculated over 20–30 years). The estimate is made with the data used for the ecosystem water account when assessing water accessibility.

The river conservation nature index is identical to the landscape index. Designated rivers are extracted by GIS analysis.

River fragmentation by dams is a cause of significant problems. One is that fish cannot move along the river, a serious concern for migratory fish coming to spawn upstream. Another is related to the blocking of sediments which contributes ultimately to coastal erosion. The beneficial aspect of dams in terms of increase of accessible water in reservoirs is measured in the ecosystem water account. The contribution of dams to amenities is (to some extent) included in NLEP.

Fragmentation of rivers can result from large dams, small dams and the presence of cities and other artificial features on their course. From an ecological point of view, the negative impacts of small dams are slightly different but comparable to those of large dams; there are very many small dams.

Figure 7.06 Rivers fragmentation and flow regulation indicator



The indicator is presented at http://webworld.unesco.org/water/wwap/wwdr/indicators/pdf/E1_Fragmentation_and_flow_regulation_of_rivers.pdf (accessed 18 August 2014).

Fragmentation impacts in a river basin are related not only to the size of the dams but also to their location in the river catchment, the distance between obstacles, and the problem considered, in particular the ability of fish to adapt to the condition and/or successfully overpass the obstacle. Measurement or calculation of fragmentation impacts therefore requires complex hydrological and biological modelling[33]. However, for important river fragmentation impacts, simple metrics have been tested initially, for example by joint activities of the University of Umeå, the World Resource Institute and UNEP-WCMC (Figure 7.06).

In a way consistent with the accounting framework, the river fragmentation index will be calculated as number of obstacles in catchments expressed as number per km2. The index is multiplied by the stock in SRMUs. Note that while the fragmentation index is recorded as a negative in the infrastructure account, the water resource made accessible by dams and reservoirs is recorded as a positive in the ecosystem water account.

River ecotones are derived from the general ecotone methodology. However, provided that only large rivers, those generally wider than 100 m, are mapped in land-cover inventories, the river ecotones will be detected by an overlay of the rivers with the land-cover map. The definition and scoring of ecotone types for calculating the River Green Ecotones index are the same (see Box 7.11, rivers being in the nature group of the scoring table).

Other components of the NREP index relate to water quality. In ecosystem infrastructure accounts, water quality is an attribute of rivers while in ecosystem water accounts, it is an attribute of water quantities, stocks and flows; the link between the two is made by calculation of river potential in SRMUs.

Data on water quality are abundant but are not normalised. They are generally collected at points for a series of physical (suspended matter), chemical, biochemical (e.g. BOD) and biological variables (e.g. pathogen germs and/or indicative species such as fish or invertebrate species) or other biomarkers. These variables are in many cases assigned maximum threshold values, often defined by regulations and laws; they are then combined to produce a synthetic indicator summarizing them (or a small number of them). The principles of water quality measurement are discussed in SEEA-W Chapter 7, pp. 104 to 109, and examples of indicators of water quality are given.

A particular case is the assessment of water quantity and quality in thermodynamic terms developed in Spain by Naredo, Valero *et al.*[34]. The principle consists in calculating the potential of water bodies in terms of their specific exergy in their reference environment. Degradation is then calculated as exergy losses due to human uses, a physical cost. The exergy of a system is the energy that is available to be used. It is measured as energy components (thermal, mechanical, chemical, kinetic and potential exergy) which are additive, some of them being quantitative, other qualitative regarding water use. . Since the methodology is implemented on the same river data infrastructure as the ecosystem

33 Crouzet, P. Assessment of Challenges raised by obstacles in rivers: advances and developments, French-Austrian Seminar, Vienna, July 2008 http://www4.ffg.at/veranstaltungen/Downloads/8626B4A4.pdf (accessed 18 August 2014).

34 Valero A. et al. Fundamentals of Physical Hydronomics: a new approach to assess the environmental costs of the European Water Framework Directive http://teide.cps.unizar.es:8080/pub/publicir.nsf/codigospub/0386/$FILE/cp0386.pdf (accessed 14 July 2014). See also Chapter 2, Annex III.

accounts (SRU, HSR, weighting in Srkm, the initial acronym of SRMU, etc.), its integration into ENCA is straightforward. However, its implementation requires some investment, which prevents it from being used in a QSP of ecosystem natural capital accounts. It is mentioned as a powerful reflection of the real cost of using nature and a way of integrating multiple dimensions in order to measure it.

Defining methodologies for water quality is not the responsibility of accountants but of hydrologists and hydro-biologists, and of epidemiologists who monitor water quality in the context of public health. The accountant has to take stock of the best available data fit for accounting. The data supplier will generally be a water agency or a ministry of public health.

Data on water quality can be displayed by points, i.e. measuring stations, sometimes from real-time access to automated monitoring stations. In that case, summaries need to be requested from the monitoring authority. When reports are delivered by measuring stations, results will have to be extrapolated, in principle to rivers; in practice, the extrapolation can initially be done for river basins and the value used as an average for the rivers. The situation may be easier when results for river basins are reported by water authorities, as long as the basins are not too large.

The best option to start accounting for water quality is to use maps with rivers coloured according to four or five quality classes, from good to bad. Such maps exist in many countries. They have the advantage of integrating raw point data under the control of experts who can detect whether or not linear extrapolations are realistic and make the required adjustments. Such maps can be used as baselines. The river stretches (or reaches, elementary streams, etc.) will therefore have two values attached to them: quantity of SRMUs and a quality class, which will be used for accounting.

River quality maps are generally updated about every ten years, but need annual updating. The methodology will consist of using point monitoring data by basins as samples to estimate quality change.

The REP composite index summarizes its five components. The NREP is calculated by multiplying SRMU values by the REP index (Box 7.05).

The integration of the rivers and the landscape potentials is done by area. NREP is first calculated as an average value in km2 and then transferred to inland SELU.

Change in Total Ecosystem Infrastructure Potential

The table of changes in Total ecosystem infrastructure potential distinguishes between changes due to land use and other changes. Change in TEIP is recorded only for inland and marine SELU.

Changes in land use are recorded according to the land-cover flow classification:

- change due to LF1 Artificial development;
- change due to LF2 Agriculture development;
- change due to LF3 Internal conversions, rotations;
- change due to LF4 Management and alteration of forested land;
- change due to LF5 Restoration and development of habitats;
- change due to LF6 Changes due to natural and multiple causes;
- change due to LF7 Other land-cover changes n.e.c. and revaluation.

The other changes are:

- change in ecosystem infrastructure potential due to fragmentation;
- change in ecosystem infrastructure potential due to ecotones;
- change in ecosystem infrastructure potential due to rivers;
- change in ecosystem infrastructure potential due to other causes.

7.2.3 Accounting Table III. Overall access to ecosystem infrastructure functional services

The various intangible ecosystem services made available are recorded in specific functional accounts; this is done one by one, according to the kind of service provided (CICES classification) and supports the valuation of benefits. In ecosystem capital core accounts, ecosystem services are summarized into three groups: accessible carbon, accessible water and intangible functional services measured indirectly from the potential of the ecosystem infrastructure to supply them. Unlike carbon and water, where the accessible resource exists independent of any actual use, intangible functional ecosystem services need to be both accessible and actually accessed to exist.

The purpose of Accounting Table III, overall access to ecosystem infrastructure functional services, is to assess access to services by bringing together supply and demand. Access is an opportunity to use. Access to services is not equivalent to effective use, which has to be recorded in the functional account of ecosystem services. However, overall access gives a useful indication of the importance of the intangible services and is a link between accessibility and effective use of ecosystem services.

A list of seven broad services is proposed for the QSP. This list is indicative and can be modified and/or expanded as necessary and different indicator formats tested. The list distinguishes between specific scales of access to ecosystem services: local access (e.g. amenities

Accounting Table 7-III Overall access to ecosystem infrastructure functional services

	Ecosystem Accounting Unit Types	Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems
		UR	LA	AM	GR	FO	NA	ND		MC_ GR	MC_CR	MC_NC	
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Seagrass	Coral reefs	Other	
III. Overall access to ecosystem infrastructure functional services													
TEIP1	Opening stock of Total ecosystem infrastructure potential =NLEP1+LREP1												
AIP11	*Urban temperature in the neighbourhood*												
AIP12	*Population density in the neighbourhood*												
AIP13	*Population weighted neighbourhood urban temperature = AIP11xAIP12*												
AIP1	Population's local access to TEIP = sqrt(TEIP1xAIP13)												
AIP21	*Agriculture temperature in the neighbourhood*												
AIP22	*Agriculture biocarbon productivity*												
AIP23	*Biocarbon weighted agriculture temperature = AIP21xAIP22*												
AIP2	Population's local access to agro-ecosystems services = sqrt(AIP1xAIP23)												
AIP31	*Nature conservation areas*												
AIP3	Local access to TEIP for Nature conservation = sqrt(TEIP1xAIP31)												
AIP41	*Subbasins cumulated mean TEIP index*												
AIP42	*Subbasin population mean density*												
AIP4	Basin access to water regulating services = sqrt(AIP41xAIP42)												
AIP51	*Tourists infrastructure temperature in the neighbourhood*												
AIP52	*Tourists frequentation*												
AIP53	*Toursits weighted neighbourhood infrastructure temperature*												
AIP6	Regional access to TEIP [tourism] = sqrt(TEIP1xAIP53)												
AIP71	***International importance habitats and ecological networks***												
AIP7	Global access of nature conservation services = sqrt(TEIP1xAIP71)												

for population, pollination for agriculture); river basins (e.g. flood regulation); regional (e.g. tourism); and global (e.g. nature conservation services of global importance). For the reasons explained previously, in particular incompleteness and double counting, no total is calculated.

Because of multiple specific scales and boundaries on the ecosystem as well as on the demand side, the calculations will be based on fuzzy data, measuring values within each boundary as well as in its neighbourhood. On the ecosystem side, the total ecosystem infrastructure potential (TEIP) has been calculated in that way, on the basis of smoothed maps. On the demand side, similar maps will be produced. For each theme (population access, agriculture, nature conservation, etc.), values in the neighbourhood are calculated and combined with TEIP (using geometric average which is the square root (sqrt) of the product of the two values, also called root mean square[35]) .

Population local access to TEIP is the geometric average of TEIP and the indicator called population-weighted urban temperature. Temperature is used as a metaphor of the warming effect of a hot source on an object or person, which decreases with distance. The narrative for this indicator is that local access to TEIP increases with population as long as urban development does not reduce TEIP itself. Areas with small cities in a rather natural environment will have high scores. Low scores will be found in pristine areas (because of low local demand) and in large urbanized areas or/and intensive agriculture landscapes (because of low TEIP). The population local access to TEIP indicator is obtained by combining Urban temperature in the neighbourhood (Chapter 3, section 3.2.2[36]), calculated by smoothing the urban class of the land-cover map (which is the urban density in a grid cell), with population density in the neighbourhood, calculated from population density converted to the standard accounting grid.

The radius chosen for smoothing the maps will give an indication of the distance at which the TEIP-related services are accessible. Within cities, some NLEP can be enjoyed without moving; near cities, access to nature is easier but NLEP is low; further from the city, travelling distances are larger but NLEP is higher. The Gaussian algorithm (smoothing, filtering, blurring) commonly used in GIS packages gives a uniform picture. More advanced calculations integrate the existence of transport networks into accessibility calculations.

Population local access to agro-ecosystems services is an extension of the previous indicator of local access to TEIP. It integrates TEIP and agricultural bio-carbon in order to include access to locally produced food. Agriculture temperature in the neighbourhood is calculated (in the same way as urban areas temperature) and then combined with agriculture biocarbon productivity calculated as net ecosystem accessible carbon surplus by LCEU within SELUs. Net ecosystem accessible carbon surplus is calculated in the ecosystem carbon accounts (Chapter 4). The Biocarbon-weighted agriculture temperature is finally combined with TEIP.

Local access to TEIP for nature conservation considers the condition of protected areas. It is calculated by intersecting the TEIP grid map with boundaries of nature conservation areas. The indicator gives a sense of the quality of TEIP inside the area as well as of the influence of the temperature of the neighbouring land uses, more supporting when it consists of forests or other natural cover, or less supporting when the protected area is near a city and/or surrounded by large-scale agriculture.

Basin access to water-regulating services considers the TEIP of services provided upstream of a given grid cell. What matters is therefore not the local TEIP but the upstream cumulative TEIP. The mean cumulative TEIP index in river sub-basins is calculated in two steps. First, total TEIP is computed for each sub-basin. For a given basin 'n', total basin TEIP(n_cumul) is calculated as the sum of TEIP(n) and the TEIP of all basins upstream of n. The cumulative surface area of n, (Surf(n_cumul)), and of upstream sub-basins is calculated in the same way. The mean sub-basin cumulative TEIP index is the ratio TEIP(n_cumul)/Surf(n_cumul). The basin access to water regulating services indicator is the geometric mean of population density and mean sub-basin cumulative TEIP index. In principle, the indicator could be downscaled to the 1 km2 grid, using the population-weighted urban temperature calculated previously; however, as long as the benefits to urban settlements vary significantly because of different distances to rivers, it may be better to keep it as an average value for each sub-basin.

Regional access to TEIP [tourism] is calculated in the same way as population local access. There are, however, two differences: the first relates to the urban temperature, which is now restricted to tourist infrastructures, the second is that the tourist population is considered, not the general population.

Global access to TEIP of nature conservation services considers protected areas not in isolation, as in the indicator focused on local access to TEIP for nature conservation habitats, but in the broader context of ecological networks. The indicator is computed by overlaying the maps of internationally important habitats and ecological networks with TEIP. It gives a sense of the ecosystem potential and change of these broad ecological networks.

In the absence of maps of ecological networks, the TEIP map can be used for a first assessment and delineation in a Quick Start perspective. The TEIP formula includes landscape greenness and fragmentation, two essential variables that characterize ecological corridors. The methodology consists of overlaying the map of protected areas and the map of TEIP and finding, with expert support, the threshold TEIP value most appropriate for mapping potential corridors and disruptions.

35 *It is recommended to use the geometric average that is the square root (sqrt) of the product of the two values. It is also called "root mean square". The method is equivalent to taking the arithmetic average of the logarithms of the numbers. It gives more meaningful averages when using values of different orders of magnitude for the calculation.*

36 *It includes a presentation of the smoothing methodology (e.g. with Gaussian filters) and Box 3.08.*

Each of the seven broad services to which access is estimated in Accounting Table III will support further analysis and more detailed mapping of more specific ecosystem services. These functional accounts will in particular shift from an assessment of potential access to an effective use of these services.

7.2.4 Accounting Table IV of indices of intensity of use and ecosystem health

Accounting Table IV of indices of intensity of use and ecosystem health combines TEIP with a diagnosis of ecosystem health based mainly on species biodiversity indicators.

The importance and appropriate use of species biodiversity indicators for accounting was discussed in Section 7.1. Species biodiversity and its change are an important component of ecosystem health diagnosis, which is needed to fine-tune, confirm or challenge the assessment carried out in the TEIP accounts based on spatial data. For species, data are somewhat different, collected by sampling or from administrative sources such as reports on natural protection areas, on endangered species benefiting from special surveillance, on vulnerable natural areas, on surveys on particular species like common birds or hunted animals and fishes, or on crowd-sourcing where voluntary collection is centralized. Issues and difficulties have been examined, as well as ways to overcome them such as a combination of data analysis and expert judgement or niche ecological modelling.

Because of the large variety of conditions for data on species, it is probably premature to go into too much detail, and the first recommendation for a Quick Start is to use the best-available data. For implementation of Accounting Table IV, the following should be kept in mind:

The species indicators are expected to provide information on ecosystem health. Accounting for species abundance is not the main purpose of ecosystem accounting. Appearance or disappearance of species needs to be interpreted in terms of their importance. Reference to native species is not always appropriate as these are replaced at a fast rate, in particular in response to climate change. Ideally, one has to distinguish between the new species which are favourable to ecosystem functioning, from the ones which are detrimental, although obviously these criteria are very loose. In any case, not all exotic species can be considered as detrimental for biodiversity and ecosystem processes. Expert judgement is needed, not only statistics.

Change is the main challenge. Ideally, consistent time-series should be available. When such series exist, the sensitivity and temporal stability of the indicators need to be checked (see the current problem mentioned by IUCN regarding Red Lists, paras. 7.35 and 7.36). Expert judgement on past and future trends of a species may be more reliable than uncertain statistics. In such a case, accounts of change could be based on knowledge about a point, which can be taken as a baseline, and a slope. An example of such an approach is given Figure 7.06.

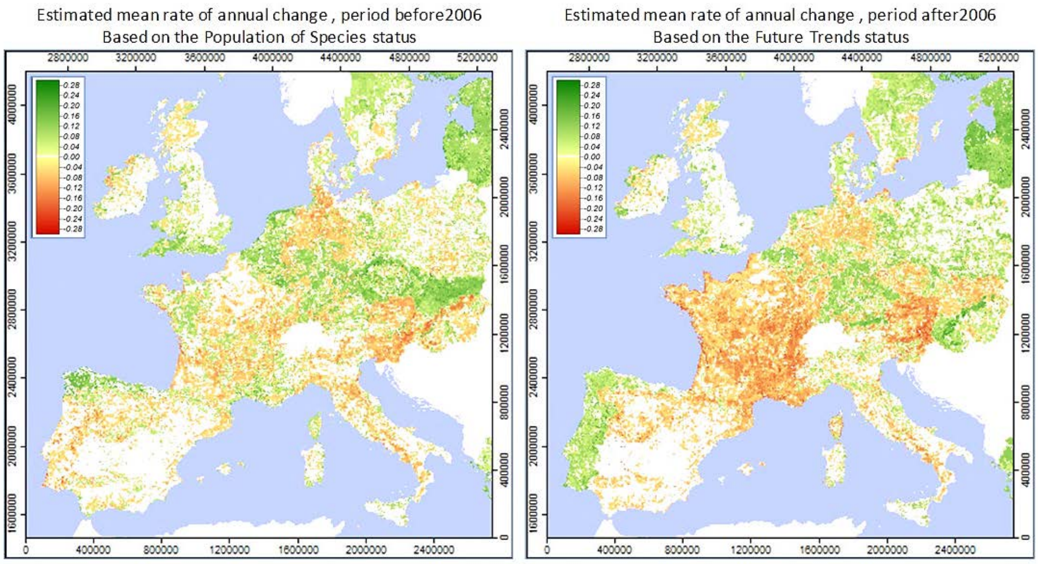
The relationship between monitored species and the geographical infrastructure used for accounting needs to be made explicit. This requirement, which is consistent with the approach to ENM, is essential for accounting as long as ecological values change in terms of extent, here given by TEIP, and condition together.

The composite species-based index requested in Accounting Table IV can be defined as a statistic or better as the result of a diagnosis. When several different indicators of the same species biodiversity are used, diagnosis methods may be preferred. Bayesian belief networks (BBN), or Bayesian networks, are tools commonly used in medicine for diagnosis, and now in ecology. They are based on decision trees and integrate the idea of compound probabilities resulting from multiple observations and decision rules. Software packages (commercial or freeware) support BBN implementation, including in a GIS environment.

The approach used by the European Environment Agency for producing species-based indicators for ecosystem capital accounting may not be appropriate for other areas since it is very specific to EU policy which requires Member States to report on a list of habitats and species of community interest (Article 17, Reporting of the Habitats Directive of 1992). It is given as an illustration of a possible general approach and of the difficulties of implementation. The methodology is presented in Annex I, *A case study: the species biodiversity change indicator used for ecosystem capital accounting at the European Environment Agency*.

Accounting Table IV of indexes of intensity of use and ecosystem health measures the annual change in ecosystem ecological integrity.

Figure 7.07 Species biodiversity change indicator used for ecosystem capital accounting at the European Environment Agency (based on the EU Habitats Directive Article 17, Reporting)



Accounting Table 7-IV of indices of intensity of use and ecosystem health

Ecosystem Accounting Unit Types		Socio-Ecological Landscape Units (SELU) / Dominant Land Cover Type (DLCT)							s/total landscape ecosystems	River System Units (RSU)/ Homogeneous Stream Reach Units (HSRU) classes					s/total river systems	Total inland ecosystems	Marine ecosystem Coastal Units (MCU)			Total inland & coastal ecosystems
		UR	LA	AM	GR	FO	NA	ND		HSR1	HSR2	HSR3	HSR4	HSR5			MC_GR	MC_CR	MC_NC	
		Urban/ developed areas	Large scale agriculture	Agriculture mosaics	Grassland	Forest cover	Other natural land cover	No dominant land cover		Large rivers, main drains	Medium rivers, main tributaries	Small rivers	Brooks, small streams	Canals			Seagrass	Coral reefs	Other	
IV. Table of indexes of intensity of use and ecosystem health																				
EIU	**Ecosystem infrastructure use intensity = TEIP2/TEIP1**																			
EIH01	Change in threatened species diversity																			
EIH02	Change in species population																			
EIH03	Change in biotopes health condition																			
EIH04	Change in species specialisation index																			
EIH05	Other indicator																			
EIH06	Other indicator																			
EIH07	*Composite index of rivers species diversity, mean value by SELU*																			
EIH08	*Index of change in rivers water quality, mean value by SELU*																			
EIH09	*Index of other rivers health change, mean value by SELU*																			
EIH	**Composite ecosystem health index**																			
EIIP	**Annual change in ecological internal unit value = AVG (EIU, EIH)**																			

The change in impact of ecosystem infrastructure use intensity is the ratio of closing to opening TEIP.

The species indices of Accounting Table IV are given as an illustration. Not all have to be compiled, and other indicators are acceptable. One good indicator validated by biodiversity experts can be enough to make a Quick Start. In every case, the meaning of the indicator selected for ecosystem health assessment has to be clearly explained. In some cases, thresholds may have to be included in the indicator definition. For example, one important property of the species specialization index is the indication of recovery capacity, which remains fair as long as it is more than 50 % but starts to decline below 50 % and is seriously compromised below 20 %.

The river composite index is derived from physico-chemical quality and biodiversity indicators calculated by rivers, and then transformed to values in km2 for integration in the overall index. The data on rivers being transferred to SELU, there is no total by RSU.

Other indicators may relate to biodiversity or to other ecosystem distress syndromes not recorded previously. It may include, for aquatic ecosystems, change in population structure, with small species replacing larger ones, or disease prevalence, which affects the capacity of ecosystems to support healthy populations, human as well as animal or vegetal[37].

The composite ecosystem health index will be established as the result of a diagnosis based on statistics and expert knowledge.

Finally, combining change in impact of ecosystem infrastructure use intensity with the composite ecosystem health index provides a measure of the change in ecosystem ecological integrity. The calculation can be a simple average of the two indicators or can be tuned according to their relative sensitivity. The index of annual change in ecosystem ecological integrity is equivalent to an ecological price; at this stage, it is still an internal price since biomass/biocarbon and water accessibility are not reflected in its definition. In ENCA-QSP, these factors (i.e. biomass/biocarbon and water accessibility) will be incorporated into the calculation of the total ecological capability with its specific unit-equivalent, the ecosystem capability unit (ECU; Chapter 8).

37 *These illustrations come from various papers by Rapport, D.J. on ecosystem health.*

Annex I:

A case study: the species biodiversity change indicator used for ecosystem capital accounting at the European Environment Agency.

Drafted by Weber, J.-L. (EEA-SC), Spyropoulou, S. (European Environment Agency), and Ivanov, Emil D., (University of Nottingham), 2013

All Member States of the EU are required by the 1992 Habitats Directive to monitor habitat types and species considered to be of Community interest. Article 17 requires a report on species and habitats listed in the annexes of the Directive to be sent to the European Commission every six years following an agreed format. Article 17 Reporting covers the habitat types and species in the whole territory of the Member State concerned, not only those within Natura 2000 sites which are the conservation areas under EU regulation. The reporting process carried out in 2006 was supported by the European Topic Centre on Biological Diversity (ETCBD), an organization of the European Environment Agency network. Article 17 data and complete documentation are available at: http://bd.eionet.europa.eu/activities/Reporting/Article_17/Reports_2007/index_html

The best available data at the European scale for producing the biodiversity change indicators for ecosystem capital accounting at EEA were those of Art.17 2006 reporting by EU Member States.

A first try was done with species data that include 1 182 species all over Europe. Birds, which are covered by another EU Directive, are not part of Art.17.

In Article 17 Reporting, "*Conservation status was assessed using a standard methodology which was to facilitate aggregation and comparisons between Member States and biogeographical regions. Conservation status is assessed as being either 'favourable', 'unfavourable-inadequate' and 'unfavourable-bad', based on four parameters as defined in Article 1 of the Directive. The parameters for habitats are range, area, structure and functions and future prospects and for species they are range, population, habitat of species and future prospects*"[38]. Unknown status can be reported.

The conservation status of each species was specified for four variables: species range, species population, habitat of species and future prospects. The national report included breakdowns by biogeographical regions and areas of distribution for each species. On that basis, assessment results were presented in a 10 km x 10 km grid. As part of the reporting, the ETCBD established a table showing the broad ecosystem types where species were found. A look-up table between broad ecosystems and the land-cover classes used for accounting was established.

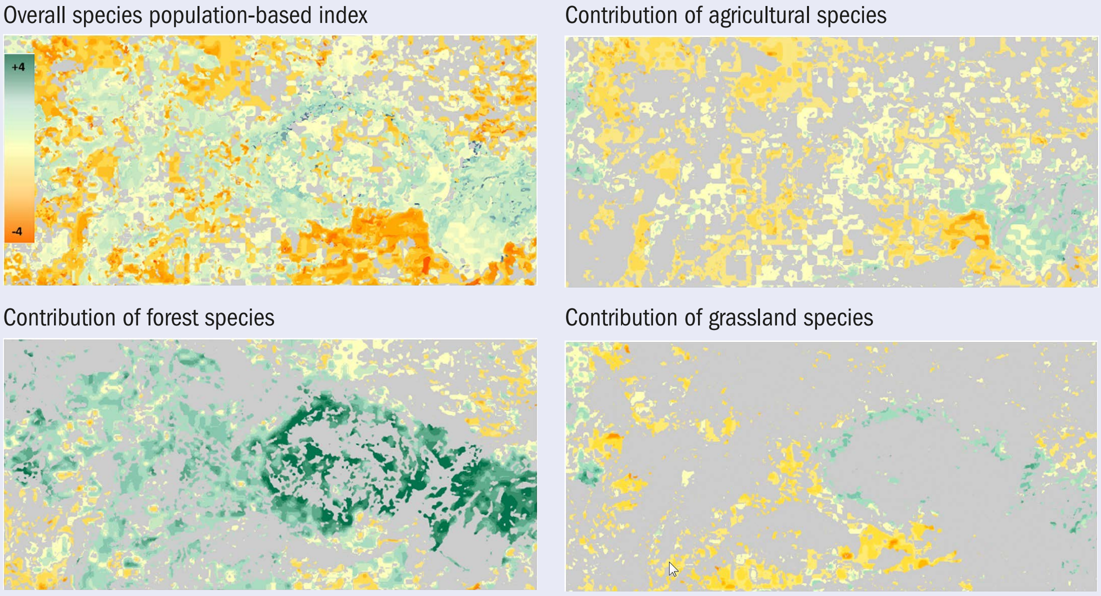
Constructing the indicator

Two conclusions were drawn from in-depth discussions with biodiversity experts in the EEA and ETCBD. The first was that Article 17 data are not data on species that can be easily and meaningfully statistically analysed but were in fact expert judgements. Since large numbers of biologists and professionals from environment agencies all over Europe worked to compile this information, it made sense to use it for accounting for ecosystem health. The second conclusion was that, of all this reporting and its processing, two variables had been better dealt with by the experts: population size and future trends. Population size status was interpreted as increasing, stable or decreasing; future prospects (or trends) were ranked as good, poor or bad. For both indicators, unknown is possible. Since only one point in time was available, 2006, changes in species biodiversity could not be assessed as the difference between two situations but as two slopes, one looking back on the basis of population assessments, the other on future prospects.

Data processing initially consisted of producing maps of preferred species habitats or broad ecosystems as classified in Article 17 reporting: forest, agriculture, grassland, shrubland, forest, wetlands and water, and coasts and marine. Maps were produced for each group on the basis of land cover. Assuming that the geographical accuracy of the species reporting was much lower than that of the Corine land-cover European map, smoothed land-cover layers were used to produce dominant land-cover types in the 1 km2 grid. Instead of using the standard DLCT established according to the majority rule, the variant with two possible dominant types was retained by setting a minimum value > 33.34 % (labelled DLCT34). The original look-up table was converted into a table of species x DLCT34. One noticeable point was that this fuzzy spatial analysis corresponds to the fact that one species may frequent several Article 17 broad habitats and that each of these broad habitats may contain several land-cover types.

38 *Article 17 Technical Report (2001-2006), downloadable from http://bd.eionet.europa.eu/activities/Reporting/Article_17/Reports_2007/index_html (accessed 14 July 2014)*

Figure 7.08 Species biodiversity change indicator used for ecosystem capital accounting at the European Environment Agency
(breakdown by broad ecosystem types)



To pair the layers on species assessments presented with a 10 km x 10 km grid, and DLCT34, a preliminary resampling of the former to the standard 1 km2 grid was carried out. The algorithm chosen was the cubic convolution[39] which gives higher values in the core of a mapped area than on its periphery. Then, statistics were computed for each Article 17 assessment status x by broad habitat type.

Compilation of the final indicator faced some statistical problems. The density of species recording varied significantly for several reasons related to natural distributions, initial designations of the list of species of EU Community interest, and the way national teams of experts interpreted the Article 17 guidelines – some focussing on hot issues, others on the whole scope. The problem of constructing statistics on heterogeneous populations is well known in statistics in the case of making averages or sampling. In both cases, the solution is to process not the numbers themselves but their natural logarithm (ln). For measurement of change, an additional advantage is that the logarithm measures the relative change (rate of change) and allows comparisons whatever the absolute values. Since the purpose of the species biodiversity index is not to assess magnitudes (which depend on natural conditions) but the way biodiversity changes, its expression as a logarithm is appropriate.

Once the geographical database was computed, final indicators were tested, initially with simple formulae. The backward- looking indicator was defined as Population Species [increase+stable-decrease] and the forward-looking indicator as Future Trends [good-poor-bad]. Other formulæ are possible (and tested), including different weightings of the components. For example, a Biodiversity Intactness Index (proposed by Scholes and others, see para 7.23) for Population Species was defined as [increase+decrease]/[increase+decrease+stable] and in a less clear way for Future Trends as [poor+bad]/[good+poor+bad] assuming that good is in some way equivalent to stable.

Unlike niche ecological modelling, the statistical analysis carried out for ecosystem capital accounting was not formal modelling, but there are similarities in the approach where observed data on species are paired with habitats in a probabilistic way.

Figure 7.07 shows estimates of annual rates of change before and after 2006. In both cases, extreme values ranged between +4 % and -4 %. As a reminder, a stock which increases by 4 % per year doubles in about 20 years. The detail by broad ecosystem or habitat type can also be displayed and provides interesting insights for interpreting the overall indexes. The following figure shows how species linked to various biotas contributed to the overall index.

39 Cubic convolution is similar to the smoothing algorithm presented in Chapter 3. Cubic convolution is a technique used for resampling raster data in which the average of the nearest cells is used to calculate the new cell value.

8. THE ECOSYSTEM CAPITAL CAPABILITY ACCOUNT

The ecosystem capital capability account aims at producing an aggregate summarizing the various changes recorded in the accounts of ecosystem carbon, ecosystem water and ecosystem ecological integrity and functional services. This aggregate measures the capacity of the ecosystems to deliver multiple services in a sustainable way. The aggregate has to reflect the real availability of each resource for use, and possible depletion or degradation, but accounting for each individual natural asset separately does not provide a full picture since they are part of systems: ecosystems. Natural assets interact with each other and what happens to one is generally of consequence to all. They also interact with human communities.

Regarding the services potentially supplied by the ecosystems, some can be appropriated, traded, and analysed using conventional market-based economic tools. Others are common or public goods which are more difficult to assess in this framework because of different value systems or because of consideration of long-term perspectives which are not all properly addressed by economic calculations: in other words ecological values should be distinguished from economic values. This distinction is clearly made in The Economics of Ecosystems and Biodiversity (TEEB) whose glossary of terms[1] states:

- **ecological value**: non-monetary assessment of ecosystem integrity, health, or resilience, all of which are important indicators to determine critical thresholds and minimum requirements for ecosystem service provision;
- **economic valuation**: the process of expressing a value for a particular good or service in a certain context (e.g. of decision-making) in monetary terms.

Nature conservation can bring short-term economic benefits, which are often neglected, but that is not the only motivation for conserving ecosystems. Other important motivations, which relate more to ecological values, include minimizing future risks to economies or humans, and the need to adapt to uncertain consequences of climate change and to secure food in the long term for an overcrowded planet. In the last resort, decisions have to be taken which will involve trade-offs between multiple options, opportunities, benefits and beneficiaries. Such decisions – at national as well as local, business or citizens levels – require comparisons between values and costs. To some extent, but not always, decision processes rely on data and, in that case, what is not measured risks not being taken into account.

1 *http://www.teebweb.org/resources/glossary-of-terms/ (accessed 14 July 2014).*

Box 8.01 Two examples of aggregation of physical indicators to support policies of resource-use efficiency and global warming mitigation

Material flow accounts build on early work by Robert Ayres[*] and have been followed by multiple attempts to document and quantify life-cycle analyses of products, aiming to produce an aggregate to measure the efficient use of products. Other pioneers include the Wuppertal Institute in Germany, the Japanese National Institute on Environmental Studies, the World Resource Institute and other experts in input-output analysis. The work was coordinated at the international level by OECD and in Europe by Eurostat. One important attempt was to define economy wide material flow accounts (EWMFA) with a common unit, the tonne. The tonne in MFA may seem to be just a technicality but, as many controversies have revealed, it is more than that. Material flow account tonnes are a general equivalent, a currency needed to account for industrial metabolism and produce aggregates to measure efficiency of resource use. Controversies continue because materials are very heterogeneous, from sand and gravel to highly toxic chemicals, harmful in very small quantities. However, MFA have delivered imperfect but useful products which have been widely used and are still in use in the context of OECD Green Growth policy and as the headline indicator of the European Flagship Initiative[**] to improve efficient use of natural resources by 2020.

Implementation of the Kyoto Protocol has been made possible by the consensus reached on the way to measure the impacts of greenhouse gases on climate and on the accountability of economic sectors with a common currency, the CO_2-equivalent. It is the "*measure that describes how much global warming a given type and amount of greenhouse gas may cause, using the functionally equivalent amount or concentration of carbon dioxide (CO_2) as the reference. The emission of 1 kg methane is equal to 21 CO_2-equivalents and the emission of 1 kg nitrous oxides is equal to 310 CO_2-equivalents*"[***]. Because of the linear relationship between carbon and CO_2 and the fact that mitigation of greenhouse gas emissions is expressed in terms of carbon (carbon trading permits, low carbon economy, etc.), and because of the opportunities for carbon sequestration in forestry, carbon has become the target when discussing global warming and climate change.

Progressive implementation of the UNFCCC process; the relationship between continuing development of the IPCC guidelines (Chapter 5) and the progressive implementation of measures in the context of the Clean Development Mechanism; the definition of agreed targets and the reporting on measures to attain them; the development of tools for carbon sequestration (REDD+); and the verification of their implementation, all rely on the common metric of CO_2-equivalent (CO_2-e or C-e). Carbon dioxide-equivalent is commonly used when speaking of carbon credits and debits which are in fact defined in relation to global warming and not to carbon reserves and depletion, as in economic balance sheets. Because of this agreement on the purpose and ways of measuring the impacts of global warming and the value given to climate stability, carbon accounting has been put in place in an incremental way, taking into account the variety of situations. In the extensive IPCC guidelines, sector- and land-based approaches are distinguished and three tiers are used for accounting and reporting: the first is based on a set of default values provided by IPCC, the second on national values and the third on real land-based monitoring.

Because the policy is based on an appropriate currency (CO_2-e or C-e), the UNFCCC values are used in other policies such as green growth, green economy and resource efficiency, together with the aggregates derived from material flow accounting and national accounts.

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* Ayres, R.U. 1978. Resources, Environment and Economics: Applications of the Materials/Energy Balance Principle. Wiley, New York. USA.

** http://ec.europa.eu/resource-efficient-europe/ (accessed 14 July 2014)

*** Glossary, Environmental Accounts of the Netherlands 2012, Statistics Netherlands

8.1 ACCOUNTING FOR ECOLOGICAL VALUE

Accounting for ecosystems as natural capital is an attempt to bring together multiple data in a way that can be used for decision making. Ultimately, these data will express values, the values of nature that may be economic values, benefits and costs, but not only those. Other values can and should be considered and expressed in a way that makes them easy or easier to integrate into decision-making processes[2]. This need to express non-monetary values is not new or specific to ecosystems and biodiversity. In recent years, measuring the true performance of the economy has been high on the agenda and ways and means are being sought to take the human social and environmental dimensions into

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2 *Econd, Ecointegrador or Local ecological footprint tool (LEFT) ecological value calculation, are attempts to provide a solution to this critical issue. They are described in Chapter 2, Section 2.1.6 and Annexes II and III.*

account in decision processes dominated by national accounts. A recurrent difficulty in this endeavour is the contrast between the well-integrated national accounts and the scattered data on the other domains. Making lists of indicators or dashboards is a valuable attempt but their multiplicity shows that the target of rebalancing the conventional macro-economic aggregates is not being met. One reason is that collections of indicators actually express multiple values which are sometimes contradictory. There are, however, two accounting projects for which this is not the case as they have defined unit-equivalents: Material Flow Accounts and Kyoto Protocol reporting (Box 8.01).

SEEA-ENCA propose calculation of the ecological value of ecosystem capital in terms of its capability, which encompasses the multiple options offered (not necessarily particular services) and their sustainability over time. The currency proposed is the ECU, the rationale, calculation principle and use for accounting of which are presented in Chapter 2, section 2.1.6. Chapter 8 focuses on the description of the ecosystem capital capability account and the practical calculation of ECU values. Discussion of ECU is presented in Chapter 2, section 2.1.6 and Annex III.

8.2 THE ECOSYSTEM CAPITAL CAPABILITY ACCOUNT

The Ecosystem capital capability account is presented in Table 8.1 with mock-up numbers for an ecosystem unit.

The table in spreadsheet format can be downloaded from http://www.cbd.int/accounting.

Table 8.1 Ecosystem capital capability accounts for an ecosystem unit with mock-up numbers

YEAR (2)			[C] Biomass/ Carbon	[W] Water	[EIP] Ecosystem infrastructure potential	[ECC] Ecosystem Capital Capability
Accessible Ecosystem Resource and Use			t or j	m^3 or j	Weighted ha_or_km	NA
Accessible Basic Resources	EC1	Net Accessible Ecosystem Resources, year (t-1) (NEACS, NEAWS & Net Ecosystem Infrastructure Potential)	1270	1980	2331	
	EC211	*Change due to Use of Accessible Basic Resources*	90	-30	-11	NA
	EC212	*Other Change due to Natural & Multiple Causes*	-60	50	0	NA
	EC21	Total Change in Basic Resource Accessibility	30	20	-11	NA
	EC2	Net Accessible Ecosystem Resources, year (t) (NEACS, NEAWS & Net Ecosystem Infrastructure Potential)	1300	2000	2320	NA
Use of ecosystem resource	EC3	Use of ecosystem resource	1210	2030	2331	NA
Ecosystem Capability Account			ECU	ECU	ECU	ECU
Calculation of unit values in ECU	EC4	Mean ECU unit value of Accessible Resources & Ecosystem Capital Capability in year (t-1)	0,963			
	EC511	*Indexes of sustainable intensity of resource use [IF<1, = overuse, dilapidation; IF>1, accumulation]*	1,074	0,985	0,995	NA
	EC512	*Indexes of change in ecosystem health [IF<1, = deterioration; IF>1, improvement]*	0,910	0,960	0,950	NA
	EC51	Annual change in accessible resources internal unit values & change of ECU unit value	0,992	0,973	0,973	0,979
	EC5	Mean ECU unit value of Accessible Resources & Ecosystem Capital Capability in year (t)	0,943			

YEAR (2)			[C] Biomass/ Carbon	[W] Water	[EIP] Ecosystem infrastructure potential	[ECC] Ecosystem Capital Capability
Accessible Ecosystem Resource and Use			t or j	m^3 or j	Weighted ha_or_km	NA
Accessible Resources & Ecosystem Capital Capability	EC6	Net Accessible Resources & Ecosystem Capital Capability, ecological value in ECU, year (t-1)	1222,7	1906,3	2244,2	1222,7
	EC7	Net Accessible Resources & Ecosystem Capital Capability, ecological value in ECU, year (t)	1225,5	1885,4	2187,0	1225,5
	EC71	Activities' Net Accumulation of Ecosystem Capital Capability, in ECU [IF<0, = degradation; IF>0, = renewal]	0,8	-22,9	-59,2	0,8
	EC722	*Global/continental/regional processes*	1,0	1,0	1,0	1,0
	EC722	*Change caused by neighbouring/interacting ecosystems*	1,0	1,0	1,0	1,0
	EC72	Change in Ecosystem Capital Capability Due to Natural and Multiple Causes, in ECU	2,0	2,0	2,0	2,0
	EC73	Total Change in Accessible Resources & Ecosystem Capital Capability, in ECU = EC7-EC6	2,8	-20,9	-57,2	2,8
Creation of Ecological Debts & Credits	EC81 = EC71	Activities' Net Accumulation of Ecosystem Capital Capability, in ECU [IF<0, = degradation; IF>0, = renewal]	0,8	-22,9	-57,2	0,8
	EC821	*Indirect change caused, Global/continental/ regional processes*	-3,0	-2,0	-4,0	-3,0
	EC822	*Change caused to neighbouring/interacting ecosystems*	-1,0	-10,0	-15,0	-1,0
	EC82	Net Change Caused to Other Ecosystems' Capability, in ECU [degradation (-) or enhancement (+)]	-4,0	-12,0	-19,0	-4,0
	EC8	Creation of New Ecological Debts & Credits (in ECU) [direct & indirect ecosystem degradation or renewal]	-3,2	-34,9	-78,2	-3,2
	EC9	Cumulated Net Balance of Ecological Debts (-) & Credits (+) in ECU (from baseline year 0)				-16,5
Indexes						
Indexes	EC51	Annual change in accessible resources internal unit values & change of ECU unit value	0,992	0,505	0,498	0,665
	EC5	Mean ECU unit value of Accessible Resources & Ecosystem Capital Capability in year (t)	0,943			
	EC22	Index of Change in Volume of Basic Resource Accessibility = EC2/EC1	1,024	1,010	0,995	NA
	EC23	Index of Change in Ecological Value of Ecosystem Capital Capability =EC22xEC5	0,965	0,952	0,938	0,965

The table first provides a summary of Table II: Accessible Basic Resource and Table III: Use of Ecosystem Resource established for each component: ecosystem carbon, water and infrastructure potential. At this stage, ecosystem capital capability cannot be filled in since data on components are not additive. Total change in basic resource accessibility is the difference between the current and previous year (EC2-EC1). Change due to use of accessible basic resources is the difference between current accessible resource and use (EC211= EC2-EC3), and other change due to natural and multiple causes is therefore the remaining balance (EC212 = EC21-EC211).

The calculation of ECU unit values is derived directly from Table IV of indices of intensity of use and ecosystem health of the three component accounts. Table IV calculates the change in ecological internal unit values for each component of each ecosystem unit. An average of internal change indices is made to change the ECU unit value. Change in ECU unit value is then multiplied by the ECU unit value of the previous year. The unit value in ECU is now the same for the three components, which are integrated in that way.

Note that the table presented in the example is referred to as Year (2). In Year (1), which is the first year of accounting, the ECU unit value is by default 1 for all ecosystems; had a policy target for ecosystem restoration existed, the distance to target would have been incorporated in the baseline unit value which could have remained 1 only in the case of a good ecological state, or been lower, depending on the distance between the observed state and the target (e.g. 0.9 or 0.6). This implies that distance to ecosystem conservation or restoration policy targets is first expressed in ECUs.

In the next subset of the table, accessible resources are calculated in ECUs and one (ecosystem carbon) is selected to represent the overall ecosystem capital capability (ECC). The calculation is done for quantities of Year (t) at unit values of Year (t). The same calculation of accessible resource and ECC has been made for quantities of Year (t-1) at unit values of Year (t-1); subtraction of the later from the former gives total change in accessible resources and ecosystem capital capability. This approach is in some way the inverse of the usual practice in national accounting where aggregates are measured in current value (from observation of market transactions and related flows) and then deflated from changes in price to calculate volumes. In the case of ENCA-QSP, the observations are first of quantities (recorded in the various basic balances) and ecological unit values (equivalent to prices) calculated by a combination of sustainable intensity of resource use (the ratio of accessible basic resource to use of ecosystem resource) and health diagnosis. Quantities are multiplied by unit value to get the ecological value of the ecosystem, its ECC.

All these elements are calculated from the accounts of the three basic ecosystem components recorded in ENCA-QSP. The accounts themselves start with basic balances strongly based on the SEEA-CF principles and liaise through it to the SNA. Additional developments needed to shift from an economic system to an ecosystem perspective are documented with reference to well-established frameworks and data sources such as the IPCC guidelines, FAO statistics and other official statistics sources, the main land-cover classifications (such as FAO/LCCS and CORINE land cover), and data bases on biodiversity. When possible, the use of products derived from modern sources such as Earth observation by satellite has been indicated. These extensive references make accounts feasible as well as giving them some robustness and possibilities of verification.

Additional items need to be introduced in the ECC account to reflect that not all degradation or enhancement in the ecosystem is due to human activities; natural factors or perturbations have to be reflected in the account, in particular considering the calculation of ecological debts.

Other items need to reflect that each ecosystem is part of a broader one. This means that ecosystem degradation caused by anthropogenic uses – as well as enhancements, for example due to water purification – can take place in another ecosystem, a neighbouring one (e.g. a downstream river basin) or the broader ecosystems into which the accounting unit is placed, or the global ecosystem in the case of greenhouse gas emissions or degradation of seas.

Symmetrically, the degradation of the ecosystem accounting unit can be imported from another ecosystem, or result from processes taking place at broader scales.

These additional items are recorded in change in ecosystem capital capability due to natural and multiple causes and net change caused to other ecosystem's capability, in ECU (degradation [-] or enhancement [+]). In that way, the positive or negative accountability of economic sectors and corresponding ecological credits and debts can be measured fairly.

The creation of new ecological debts and credits (in ECU) corresponding to direct or indirect degradation or enhancement, and the cumulated net balance of ecological debts (-) and credits (+) in ECU from the baseline year, in the example, Year (1), constitute the conclusion of the account. They are the first part of a more comprehensive ecological balance sheet where credits and debts are presented by ecosystem as well as by economic sector, according to the SNA classification.

This concludes the first part of the ENCA-QSP. Chapter 9 introduces the next steps that consider demand for ecosystem services, including valuation of their benefits, and accountability of economic sectors for the ecosystem, including valuation of ecosystem restoration costs and compilation of a second balance-sheet of credits and debts, not in ECU but in monetary terms.

9. THE ECOSYSTEM NATURAL CAPITAL ACCOUNTS QUICK START PACKAGE AND BEYOND

The scope of ENCA-QSP as initial implementation of the SEEA-EEA does not cover all possible accounts. Priority has been given to the measurement of ecosystems in terms of physical capital, productivity and resilience, for several reasons, the first being the aim to create a comprehensive database of all ecosystems. Although schematic to start with, such a database needs a minimum knowledge of general trends, and also needs to identify hotspots and specific issues, with some idea of their contexts and interactions.

This not to say that ENCA-QSP does not contain its own operational indicators. Indeed, its core accounts allow the production, at various scales including the macro level, of indicators of resource accessibility and sustainable use, and of ecosystem health and capability to deliver services, and consequently of degradation or enhancement by human activities. On some points, where a consensus could not be reached by the SEEA-EEA editorial board, ENCA-QSP will go one step further with the aim of allowing testing of the policy relevance of ecosystem capital accounts.

Future extensions of QSP towards (more) complete ecosystem natural capital accounting can be grouped into three broad types:

- assessment of the accountability of sectors for ecosystem degradation, and production of a balance sheet of ecological credits and debts;
- calculation of restoration costs and adjustments in relation to the SNA;
- assessment and valuation of ecosystem services and derived assessments of the economic wealth of ecosystem assets.

Not all these are novel. In the case of the third, important work has been carried out in recent years in various international and national programmes and the issue is more to link specific methodologies with the ENCA-QSP infrastructure, for example the land-cover map and accounts, and core accounts.

9.1 THE BALANCE SHEET OF ECOLOGICAL CREDITS AND DEBTS.

The ENCA-QSP core accounts include calculation of ecological values in order to assess the capability of ecosystems to deliver services and their degradation or enhancement by human activities (Chapter 8). This measure of ecological value in ECUs corresponds to two main aspects of the ecosystem: an asset which can be owned, exploited and managed in the economic sense, a natural resource; and a component of the broader ecosystem, the full bundle of services delivered to the owner as well as to others, its capacity to reproduce itself and continue delivering services in the future, and everything that corresponds to public-good functions. In accounting terms, degradation of an ecosystem will have to be recorded in two ways: as a decrease in the asset in terms of its use as a resource, and as an ecological debt in terms of the broader functions its fulfils. In the first case, degradation reduces assets; in the second, since ecosystem functions do not belong exclusively to the owner, their loss may affect not only him but also the community at large, in and around the ecosystem and elsewhere, and current and future generations.

Accounting for ecological debts is important for policies that aim at preventing such debt creation or at mitigating it through the payment of compensation, directly for restoration or indirectly as part of tax systems or insurance schemes. Such policies are being considered and several are being experimented with in several countries and/or companies. One factor limiting their implementation is the availability of relevant and verifiable information. Ecosystem natural capital accounts have the potential to deliver such information, and it is important to test this now.

A balance sheet of ecological credits and debts can be established as part of ENCA. Measuring credits and debts in physical units rather than monetary terms is not new, as shown by the well-known example of carbon credits and debits implemented to support the carbon management scheme in the context of UNFCCC, following the IPCC rules and national emission trading schemes. Another example is the EU Environmental Liability Directive of 2004[1].

A schematic ecological balance sheet is presented in Table 9.01. Sub-tables are established for short-term assets and liabilities, long-term assets and liabilities, international liabilities, and the consolidated balance sheet. Columns include domestic physical assets (described in the short-term assets and liabilities sub-table), ecological credits, ecological debts and net ecological worth calculated as the difference between credits and debts. Increase and decrease of domestic physical assets are recorded as changes in credits when they are due to natural causes. Degradation due to human activity is recorded as debt creation. For ecosystem enhancement, a distinction is made between restoration of previous degradation (decrease of debts) and ecosystem creation taking place in the context of historic restoration (increase of credits).

1 *http://ec.europa.eu/environment/legal/liability/ (accessed 14 July 2014).*

Table 9.01: Example of a simplified ecological balance sheet in ECU (mock-up numbers)

	Domestic physical assets	Ecological credits	Ecological debts	Net Ecological Worth
	[a]	[b]	[c]	= [b]-[c]
I - Short term assets and liabilities				
Opening balance sheet/ short term	100	100		100
Degradation by activities	-12		12	-12
Natural losses	-9	-9		-9
Restoration from previous degradation	2		-2	2
Ecosystem creation/ enhancement	7	7		7
Natural gains	4	4		4
Net change in short term assets and liabilities	-8	2	10	-8
Closing balance sheet/ short term	**92**	**102**	**10**	**92**
II - Long term assets and liabilities				
Ecosystem restoration commitments		50	50	0
Accumulated ecological credits/ allocations		13		13
Accumulated ecological debts			35	-35
Opening balance sheet/ long term		63	85	-22
Change in ecosystem restoration commitments		0	0	0
Change in accumulated ecological credits/ allocations		8		8
Change in accumulated ecological debts			11	-11
Net change in longterm assets and liabilities		8	11	-3
Ecosystem restoration commitments		50	50	0
Accumulated ecological credits/ allocations		21		21
Accumulated ecological debts			46	-46
Closing balance sheet/ long term		71	96	-25
III - International liabilities				
Opening balance sheet/ Embedded ecosystem degradation			30	-30
Accquisition of embedded ecosystem degradation			15	-15
Compensation of embedded ecosystem degradation			-5	5
Net change in ecosystem degradation embedded in trade			10	-10
Closing balance sheet/ Embedded ecosystem degradation			40	-40
Consolidated balance sheet (I + II + III)				
Opening balance sheet	100	163	115	48
Net change	-8	10	31	-21
Closing balance sheet	**92**	**173**	**146**	**27**

The balance given in the example in Table 9.01 shows that current domestic ecosystem capital (measured in ECUs) degraded during the period covered, from 100 to 92 (-8). This change in assets will be reported as a change in net ecological worth in the balance sheet of the next accounting period. In the current table, current change (-8) adds up first to the net change in credits and debts accumulated from previous years (-3), called long-term assets and liabilities, and then to the net change in ecosystem degradation embedded in trade (-10). In total, the net ecological worth shifted during the period from 48 to 27 (a loss of 21).

Implementing an ecological balance sheet requires more than just measurement of physical assets, credits and debts: these variables need to be recorded according to the economic sectors which are responsible. General indications on how to proceed are given in a 2011 European Environment Agency technical report[2]. However, as yet there is little empirical experience in this domain.

2 *Weber, J-L. An experimental framework for ecosystem capital accounting in Europe. EEA Technical report No 13/2011 http://www.eea.europa.eu/publications/an-experimental-framework-for-ecosystem (accessed 14 July 2014).*

9.2 CALCULATION OF RESTORATION COSTS AND POSSIBLE ADJUSTMENTS IN RELATION TO THE SNA

Restoration costs are generally well known as they are part of the working data of ministries of agriculture and forestry, water agencies, and ministries of environment in the context of compensation programmes and of emerging programmes of environmental compensation or mitigation involving financial institutions. Countries including the Australia, New Zealand, UK, USA, and parts of Europe use biodiversity offsetting as an optional or mandatory (depending on the country) biodiversity conservation management tool within their planning systems. Biodiversity offsetting is also being considered by Latin American countries (Brazil, Chile, Colombia, Ecuador and Peru) and by South Africa. In France, the French Sovereign Fund (CDC), has created a branch devoted to financing actions of biodiversity compensation when required by the law[3].

3 *Caisse des Dépôts et Consignations/ CDC Biodiversité http://www.cdc-biodiversite.fr/ (accessed 14 July 2014).*

Another example is the comprehensive assessment in EU Member States of the costs of meeting the target of good environmental quality of river basins required by the Water Framework Directive. Data and statistics on restoration costs can also be found in the statistics collected for compiling the environmental protection and management expenditure accounts of the SEEA Central Framework.

Knowing ecosystem degradation by issues and by accountable economic sectors, and mean unit restorations costs, makes assessing this cost possible. As discussed in Chapter 2, since restoration costs are not part of purchase prices and therefore not paid by anyone, assessing them should lead to an adjustment of the final demand aggregate of the national account in order to calculate it at full cost: we consume more than we pay (we consume ecosystem capability). Such issues have not been discussed in the context of SEEA-EEA.

9.3 ASSESSMENT AND VALUATION OF ECOSYSTEM SERVICES AND DERIVED ASSESSMENTS OF WEALTH

Establishing an ecological balance sheet of credits and debts, and calculating restoration costs are still on the research agenda. Assessment and valuation of ecosystem services and derived assessments of wealth have a long history, going back to the early work of Constanza, Dasgupta, Mahler and others (see Bibliography). This stimulated comprehensive studies such as the Green Accounting for Indian States Project[4] created by Pavan Sukhdev, subsequently the project leader of TEEB, which produced a broad review[5] of methodologies and empirical knowledge.

The status of Section 9.3 of Chapter 9 is therefore not to indicate the way forward but to provide references to sources that can be used in national applications jointly with ENCA-QSP. Three sub-sections of Section 9.3 address separately the issues of mapping and assessing ecosystem services in physical units, valuing ecosystem services, and use of ecosystem services valuations, for example for wealth assessments.

4 *http://www.gistindia.org/monograph.html (accessed 14 July 2014).*

5 *http://www.teebweb.org/our-publications/all-publications/ (accessed 14 July 2014).*

Figure 9.01 The policy context of Action 5 and MAES*

Source: MAES 2014

* NB: the 15 % target in Figure 9.02 refers to the EU Biodiversity Strategy which states that "by 2020, ecosystems and their services are maintained and enhanced by establishing Green Infrastructure and restoring at least 15 % of degraded ecosystems" http://ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm (accessed 14 July 2014).

9.3.1 Assessing ecosystem services in physical units

It is likely that a national test of ENCA-QSP will reveal earlier work done on some ecosystem services in different contexts, including nature conservation strategies, land management, and academic research. It is also likely that the policy demand of an experiment will require the QSP test to address specific ecosystem services of particular interest. Some references to ecosystem services accounting may be therefore useful.

Hundreds of studies contain assessments of ecosystem services and cannot be quoted here[6] as there are so many. Instead, the recent report on mapping and assessment of ecosystems and their services (MAES, 2014) is proposed as an introduction and a review of a broad range of methodological and practical issues[7]. The MAES project is set in the EU in the context of the development of "*indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*" (*op. cit.*).

The earlier 2013 MAES report presents "*An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020*" which refers to SEEA and uses CICES version 4.3. MAES also refers explicitly to the CBD Aichi Target 2 of "*integrating biodiversity values in accounting systems*". "*Although Action 5 is formally associated with Target 2 of the Biodiversity Strategy it is clear that its scope goes much further than*

6 *References to studies on ecosystem services can be found on websites of UNEP, WAVES, the Millennium Ecosystem assessment and in the scientific literature on ecological economic and ecological indicators.*

7 *Three MAES working documents or reports have been published by the JRC:*

In 2011: A European assessment of the provision of ecosystem services - Towards an atlas of ecosystem services. Maes. J., Paracchini, M-L.and Zulian, G.), http://publications.jrc.ec.europa.eu/repository/handle/111111111/16103 (accessed 14 July 2014).

In 2013: An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Maes J. et. al. http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf (accessed 14 July 2014).

In 2014: Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Maes J. et al. http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/2ndMAESWorkingPaper.pdf (accessed 14 July 2014).

this and that it underpins the achievement of many of the targets and the other actions in the strategy".

MAES is steered by the JRC and co-steered by European Environment Agency. One important benefit of the close coordination is its ecosystem capital accounting context and the use of the CORINE Land-Cover inventory as common data infrastructure.

The MAES report presents results at the European scale for a large range of ecosystem services. Mapping and assessment is continuing in many European countries which have started the MAES process at the national, regional or case-study level. Pilot projects involve voluntary Member States and other stakeholders, including NGOs, and are coordinated by the JRC, the Directorate General Environment of the EC, and European Environment Agency. Six domains have begun to be explored: nature, agriculture, forest, freshwater, marine ecosystem and natural capital accounting. Services are mapped and assessed in terms of supply and demand and related to the condition of the ecosystems which deliver them.

The MAES project screens the practical feasibility of the interim CICES classification and is of high practical relevance for starting accounting for ecosystem services. Table 9.02 reproduces Table 14 of the 2014 MAES report (*op. cit.)* as an illustration of the areas covered.

Table 9.02: MAES 2014 assessment of available indicators

Ecosystem services	Leader	Indicator	Marine systems
Cultivated crops	Agro	• Area and yields of food and feed crops	• Yield • Landings • Catch per unit effort (where applicable)
Reared animals and their outputs	Agro	• Livestock	
Wild plants, algae and their outputs	Forest	• Distribution of wild berries (modelling)	
Wild animals and their outputs	Forest	• Population sizes of species of interest	
Plants and algae from in-situ aquaculture	Water		
Animals from in-situ aquaculture	Water	• Freshwater aquaculture production	
Water (Nutrition)	Water	• Water abstracted	
Biomass (Materials)	Forest Agro	• Area and yield of fibre crops • Timber production and consumption statistics	
Water (Materials)	Water	• Water abstracted	
Plant-based resources	Forest	• Fuel wood statistics	
Animal-based resources			
Animal-based energy			
(Mediation of waste, toxics and other nuisances)	Forest	• Area occupied by riparian forests • Nitrogen and Sulphur removal (Forests)	• Nutrient load to coast • Heavy metals and persistent organic pollutants deposition • Oxyrisk
Mass stabilisation and control of erosion rates	Forest Agro	• Soil erosion risk or erosion protection	• Coastal protection capacity
Buffering and attenuation of mass flows			
Hydrological cycle and water flow maintenance			
Flood protection	Fresh	• Floodplains areas (and record of annual floods) • Area of wetlands located in flood risk zones	• Coastal protection capacity
Storm protection			
Ventilation and transpiration	Agro	• Amount of biomass	
Pollination and seed dispersal	Agro	• Pollination potential	
Maintaining nursery populations and habitats		• Share of High Nature Value farmland • Ecological Status of water bodies	• Oxygen concentration • Turbidit • Species distribution • Extent of marine protected areas
Pest and disease control			
Weathering processes	Agro	• Share of organic farming • Soil organic matter content • Ph of topsoil • Cation exchange capacity	
Decomposition and fixing processes	Agro	• Area of nitrogen fixing crops	
Chemical condition of freshwaters	Water	• Chemical status	
Chemical condition of salt waters	Marine		• Nutrient load to coast • HM and POP loading • Oxyrisk
Global climate regulation by reduction of greenhouse gas concentrations	Forest	• Carbon storage and sequestration by forests	• Carbon stock • Carbon sequestration • pH; • Blue carbon • Primary production
Micro and regional climate regulation	Forest	• Forest area	
Physical and experiential interactions	Forest Agro WaterMarine	• Visitor statistics	
Intellectual and representative interactions			
Spiritual and/or emblematic			
Other cultural outputs		• Extent of protected areas	

All services at CICES class level except services in italic at CICES group level. CICES Division indicated by brackets.

Box 9.01 Some sources of publications on ecosystem services value and valuation

UNEP has important activity on ecosystem service valuation and related payments for ecosystem services (PES) in the context of the green economy approach.

UNEP DEPI's Ecosystem Services Economics Unit (ESE) has produced a series of 17 working papers downloadable at http://www.ese-valuation.org/index.php/res/publication/25-ese-working-papers-series/8-working-papers-series 17, in particular the Guidance Manual for the Valuation of Regulating Services (http://www.ese-valuation.org/guidance%20 manual%20valuation%20reg%20serv%203.pdf) and a forthcoming (2014) Guidance Manual on Valuation and Accounting of Ecosystem Services for Small Islands Developing States, drafted by Paulo A.L.D. Nunes.

UNEP TEEB is also an important resource for documentation on ecosystem services valuation, starting with the TEEB reports themselves: http://www.teebweb.org/our-publications/

Publications by the **SCBD** are less numerous but economic valuation issues are a long-standing concern, as shown by three Technical Series reports:
Pearce D. and Pearce C. 2001. The Value of Forest Ecosystems. Secretariat of the Convention on Biological Diversity Montreal, 67p. (CBD Technical Series no. 4);
De Groot, R.S., Stuip, M.A.M., Finlayson, C.M. and Davidson, N. 2006. Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services, Ramsar Technical Report No. 3/CBD Technical Series No. 27. Ramsar Convention Secretariat, Gland, Switzerland and Secretariat of the Convention on Biological Diversity, Montreal, Canada; Gallagher L., Hill C., Martin A. et al. 2013.
Valuing the biodiversity of dry and sub-humid lands. Technical Series No.71. Secretariat of the Convention on Biological Diversity, Global Mechanism of the United Nations Convention to Combat Desertification and OSLO consortium (2013).

The **Word Bank** hosts a wealth of documentation on the WAVES pages (http://www.wavespartnership.org/en/publications). In particular, the WAVES Policy and Technical Experts Committee (PTEC) presents recent projects involving ecosystem services valuation:
Ecospace: spatial modelling and accounting for ecosystem services in which specific maps are being produced for ecosystem services and ecosystem assets, in both physical and monetary units (http://www.wageningenur.nl/en/show/Ecospace-spatial-modelling-and-accounting-for-ecosystem-services.htm);
Ecosystem Values Assessment and Accounting (EVA). One of the main goals of EVA is to pilot the development of Ecosystem Accounts -- the measurement of flows of ecosystem benefits into the economy, which requires analysis, mapping and monetary valuation of ecosystem services in a way that is consistent with national accounting (http://www.wavespartnership.org/en/ecosystem-values-assessment-accounting-project-peru).

9.3.2 Valuation of ecosystem services

As indicated above, methodologies for valuing ecosystem services are well known and many studies are available. In principle, as all goods are considered as products, all provisioning services should be in the SNA, including in particular household production for own account when this consists of picking berries, collecting firewood, extracting peat or abstracting water from a well[8]. Box 9.01 only references documents on ecosystem services valuation available from international organizations. There is more literature at the country level and in the academic world[9]. Chapters 5 and 6 of SEEA-EEA present a thorough review and discussion which helps to assess the relevance and soundness of the valuation methods in the accounting framework.

8 SNA2008, op.cit., paras. 6.32 and 6.33. In practice, such recording is not always done because of statistical difficulties. In addition, as there are no transaction market prices in the case of household production for own account, conventional prices have to be used. In particular, by convention, no net return to capital is included when own-account production is undertaken by non-market producers (SNA 6.125) and in a production perspective, no trade margin is included, which makes comparisons of purchased and own-account produced consumption difficult.

9 For example, the International Society for Ecological Economics has organized many sessions on ecosystem services valuation in its biennial conferences and published many articles on the subject in its journal.

9.3.3 Aggregation and integration of the monetary value of ecosystem services

Aggregation and integration of ecosystem services in monetary values is another extension of ecosystem services accounting closely related to economic assessment and modelling. Although not part of ENCA-QSP, these approaches can benefit from it. Two broad types of work can be mentioned: economic wealth calculations, and aggregation of ecosystem services monetary value.

Wealth calculations are well established – WAVES stands for Wealth Assessment and Valuation of Ecosystem Services – and publications are accessible (9.23). At the micro level, wealth calculations are an important part of cost benefit analysis (CBA) where projects are compared according to expected future benefits. *"In CBA, benefits and costs are expressed in monetary terms, and are adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their net present value."*[10]

Wealth calculations at the national or global level have been undertaken in order to assess and compare the total wealth of nations as well as the relative shares of its components: produced capital, human capital and natural capital[11]. Two important publications are :

- *The Changing Wealth of Nations*, 2011, World Bank[12];
- *Inclusive Wealth Report* (IWR), 2012, IHDP, UNU and UNEP[13].

Aggregation of ecosystem services in monetary terms has been the subject of long discussions, initially complicated by the idea of adjusting GDP or comparing the total value of ecosystem services with GDP. The aim is not to reopen these discussions here, but to suggest that the idea of comparisons with GDP is periodically revisited. Again, such research on ecosystem services valuation can benefit from the existence of ecosystem accounts in physical units that aim at providing a common infrastructure for the widest possible range of applications. Two recent examples of attempts to aggregate ecosystem services are given in Box 9.02. Their contexts, and to some extent their purpose, are very different, but they have in common the aim of calculating the final value of ecosystem services and making these calculations operational inputs to policy making. They are gross ecological product (GEP) experiment in China, with International Union for Conservation of Nature (IUCN) support, and the approach to experimental ecosystem accounting in Victoria State, Australia.

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10 Source: Wikipedia

11 Note that total or inclusive wealth assessment implies the idea of substitutability between forms of capital and results in weak sustainability assessments – weak from the point of view of the ecosystems whose value can be replaced by man-made capital. ENCA ecological value relies on the idea of the maintenance of the ecosystem total capability which refers implicitly to the strong sustainability paradigm – where ecosystems are considered as a critical capital which has to be kept for its own sake.

12 http://www.worldbank.org/en/topic/environment/publication/changing-wealth-of-nations (accessed 14 July 2014)

13 http://ihdp.unu.edu/docs/Publications/Secretariat/Reports/SDMs/IWR%20SDM%20Low%20Resolution.pdf

Box 9.02 Two examples of approaches to ecosystem services aggregation

GEP in China

Gross Ecosystem Product (GEP), is a project of the Chinese Government supported by IUCN. It "*aims to develop specific indicators to measure the total economic value of all ecosystem products and services that nature provides for human well-being. The GEP is seen as supportive of China's new Eco-Civilization initiative, established as top priority in the Report to the 18th National Congress of the Communist Party of China (CPC).*" The project, to be conducted in Kubuqi, Inner Mongolia, the seventh largest desert in China, will develop and test an evaluation framework for GEP and identify practical policy, technical, and institutional arrangements for establishing a GEP accounting system.

"*GEP counts natural ecosystems as a source of output, rather than simply as a cost. If we consider ecological civilization has four pillars: economic, social, environmental, nature ecosystem, values and morals, then GEP would be a ground breaking accounting system for nature's ecosystem. It could be connected with the world's leading green economic accounting systems such as SEEA, and act as an effective indicator system for ecological civilization*".

Zhang Xinsheng, IUCN President and Secretary-General of Eco-Forum Global

http://www.iucn.org/zh/china/?12537/1/IUCN-China-takes-lead-in-measuring-the-true-value-of-nature.

The GEP approach starts by first "*measuring ecosystem goods and services in biophysical values. The primary task is determining the quantity of the provisioning, regulating and cultural services at a given time period.*" In a second step, ecosystem services are valued according to different valuation methods, including the use of shadow price and consumer surplus estimates. "*The main alternative market methods for determining the price can be categorized as the expenditure method, market price method, opportunity method, and travel cost method.*"

Note that in GEP accounting, attention is paid to the measurement of intermediate flows (internal to or between ecosystems) in order to come to the equivalent of the value added in the SNA, where intermediate consumption is subtracted from sales. This willingness to measure actual final flows in GEP meets similar concerns in the experimental ecosystem accounts produced in 2013 for Victoria State, Australia.

Victorian ecosystem accounts

"*Applying the Victorian environmental markets approach to ecosystem accounting uses a bottom-up methodology by (i) quantifying all intra-ecosystem flows using a measure of asset condition; (ii) quantifying the volume of inter-ecosystem flows as a function of the asset condition and its context in the landscape; and (iii) quantifying the volume of ecosystem services as a function of the inter-ecosystem flows and a measure of significance representing an anthropocentric preference for the flows. In contrast, the SEEA-EEA advises the use of a top-down approach whereby only the ecosystem services are quantified and measurements of the intra- and inter-ecosystem flows are not required. The bottom-up approach has the advantage of collating data along a chain of causes and effects which might be overlooked in the top-down approach. Mapping this chain may be particularly important in order to assess the ecosystem-wide implications of specific decisions. For example, the loss of a forest may have consequences on stream water quality which may in turn affect the downstream estuary, impacting fish stocks. To understand fully the changes (in this case the fish stocks) and to enable effective intervention, it is necessary to understand the whole system. The bottom-up approach makes it possible to model and monitor cumulative chains of complex processes across the whole system.*"

Eigenraam, M., Chua, J. and Hasker, J. 2013. Environmental-Economic Accounting: Victorian Experimental Ecosystem Accounts, Version 1.0. Department of Sustainability and Environment, State of Victoria

http://unstats.un.org/unsd/envaccounting/londongroup/meeting19/LG19_16_5.pdf.

CONCLUSION

Ecosystem accounting is not a substitute for science, rather it is a way of bringing together the best available knowledge and presenting it in a form that may help decision makers. It is a way of bringing together and summarising often scattered information in a logical and transparent manner.

The development of ecosystem capital accounts is hampered by the state of our understanding of nature, natural systems and society, as well as by access to the data that does exist. This is not specific to the domain, climate change monitoring and national accounting face similar difficulties – although a longer tradition of developing socio-economic statistics results in more robust information in the latter case.

In practical terms, missing data has to be estimated with models, so that policy makers can have evidence that they can handle and interpret, alongside the usual macro-economic aggregates and social statistics.

As there is some urgency in incorporating ecosystems and biodiversity values into decision-making processes, as required by the CBD Aichi Target 2, and SDG Goal 15 proposed by the United Nations General Assembly Open Working Group, scientific issues and uncertainties can no longer be an argument for not producing ecosystem accounts now. Progress will only come by doing tests with what is available, rather than waiting for better scientific information, data and statistics – although these are highly desirable. This is the approach that has been adopted by the UN Statistical Commission for the SEEA Experimental Ecosystem Accounts, and although the first accounts in pioneer countries will certainly be imperfect, the experience gained from producing them will be the basis for further improvements.

The knowledge gap is, however, a strong argument for transparent methodologies and meta-data. The ambition to support evidence-based policy making puts great responsibility on the accountant. First, stakeholders, themselves, should be able to estimate the uncertainties resulting from scientific and data issues. Second, they should be fully aware of the underlying assumptions of the ecosystem accounting framework which, as for any model, cannot be neutral.

The ENCA framework is primarily a statistical one. It aims, in particular, to facilitate access to a wide range of data and statistics for ecosystem accounting, as well as for modelling or doing different types of analysis. One important aspect of accounting methodologies is that they contain systematic cross-checks, an important way of assessing data quality, and particularly important in the frequent cases of different data sources proposing different numbers for the same topics.

Another property of ENCA is the focus on change, particularly the measurement of degradation, which requires the establishment of time series, which are, themselves, a useful tool to assess data consistency and likelihood. The ENCA framework is not neutral in itself as priority is given to the measurement of ecological, opposed to economic, values based on ecosystem performance and resilience assessment. Ecosystem maintenance and restoration costs are, however, essential economic variables in ENCA – other frameworks favour an ecosystem services approach and monetary valuation of benefits.

Although ENCA is open to the broadest range of applications, including ecosystem services accounting, its rationale is to start with core accounts of ecosystem capital, which is the purpose of the QSP.

The roadmap for implementing ENCA-QSP has been presented in 5 steps:

1. collection of reference geographical datasets and creation of a database of ecosystem accounting units (EAUs);
2. collection of basic datasets: monitoring data and statistics;
3. production of core accounts, measure total ecosystem capability, assess degradation or enhancement;
4. functional analysis of ecosystem capital and services in physical units;
5. functional analysis of ecosystem capital and services in monetary units: measurement of unpaid degradation costs; valuation of ecosystem services.

Steps 1 to 3 correspond to the QSP. Steps 4 and 5 are additional developments.

Data availability will determine the detail and accuracy of the first generation of accounts. The accounting tables will probably have to be simplified in practice, which means that all details will not be recorded at a preliminary stage. This simplification will be done according to specific conditions which will vary from country to country, and/or ecosystem to ecosystem.

Data collection has to be envisaged for the project and beyond. Institutional cooperation between environment agencies, statistical offices, various ministries and the research sector should lead, in the short term, to work-sharing agreements and a steering committee; and, in the medium term, to the creation of a shared environmental information system to provide annual updates.

Policy priorities may result in various focuses on particular zones, for example costal zones, a region or a natural park, or particular ecosystems such as forests or agro-systems. More complete accounts may be done in such cases, as it can be expected that the policy interest has lead to the multiplication of studies and therefore of data which can be used for a test. Nonetheless, it is recommended that ENCA is always started with core accounts. These can be done in a lighter, simpler way than might needed for priority area accounts, but it is necessary to provide a view of the whole geographical context: the coastal zone and hinterland, forests and surrounding agriculture or urban areas, terrestrial ecosystems and the rivers which connect them, etc.

Managing data constraints and policy priorities will finally result in a tiered approach, similar in some degree to that proposed by IPCC in which Tier 1 is a calculation based on global default values, Tier 2 on national ones and Tier 3 corresponding to actual monitoring – MAES follows the same rationale. In the case of ENCA, the tiers could correspond to the use of databases of international organisations, products derived from satellites images, national statistics and indicators, and *in situ* monitoring data.

With such an approach, ENCA-QSP accounts can be produced quickly, deliver invaluable information to policy makers, help frame a future system in which ecosystem and biodiversity values are incorporated into accounts and contribute to the tests required for improving the SEEA-EEA.

ACRONYMS

ABS	Australian Bureau of Statistics
AFOLU	Agriculture, forestry and other land use
ANCA	Advancing natural capital accounting
AR	Autotrophic respiration
BDOT	Banque de Données de l'Occupation des Terres (Burkina Faso)
BII	Biodiversity intactness index
BOD	Biological oxygen demand
CBA	Cost benefit analysis
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CEC	Consumption of ecosystem capital
CFC	Consumption of fixed capital
CI	Conservation International
CICES	Common International Classification of Ecosystem Services
CLC	CORINE Land Cover
CO2	Carbon dioxide
CO2e	Carbon dioxide equivalent
CORILIS	CORINE lissé (smoothed CORINE).
CORINE	Co-Ordination de l'Information sur l'Environnement
CPF	Collaborative Partnership on Forests
CPN	Comptes du patrimoine naturel
DEM	Digital elevation model
DLCT	Dominant land-cover type
DLT	Dominant landscape type
DMC	Direct material consumption
DMI	Direct material input
DPSIR	Drivers, pressures, state, impacts responses
EAU	Ecosystem accounting unit
EC	European Commission
ECA	Ecosystem capital accounts or accounting
ECC	Ecosystem capital capability
ECMWF	European Centre for Medium-Range Weather Forecasts
ECRINS	European catchments and rivers network system
Econd	Ecosystem condition unit (WGCS)
ECU	Ecosystem capability unit
EDS	Ecosystem distress syndrome
EEA	European Environment Agency
EEZ	Exclusive economic zone
EGGS	Environmental goods and services sector
ELD	Environmental Liability Directive (EU, 2004)
EMBRAPA	Brazilian public enterprise for agricultural research
ENCA	Ecosystem natural capital accounts or accounting
E N C A - QSP	Ecosystem Natural Capital Accounts Quick Start Package
ENM	Ecological niche modelling
E-RISC	Environmental risk integration in sovereign credit analysis
ESA	European Space Agency
Eta or ETA	Actual evapotranspiration (ETActual)
EU	European Union
EVA	Ecosystem values assessment and accounting
EVI	Enhanced vegetation index
EW-MFA	Economy wide material flow accounts

FAO	Food and Agriculture Organization of the United Nations
fAPAR	Fraction of absorbed photosynthetically active radiation
FDES	Framework for the Development of Environmental Statistics
FRA	Forest resource assessment (see also FAO)
GBIF	Global Biodiversity Information Facility
GBLI	Green Background Landscape Index
GCP	Global Carbon Project
GDP	Gross domestic product
GEO/GEOSS	Group on Earth Observations/Global Earth Observation System of Systems
GEP	Gross ecosystem product
GFC	Global forest cover
GHG	Greenhouse gas
GIS	Geographical information system
GJ	Gigajoule
GLCN	Global Land Cover Network
GPM	Global precipitation monitoring
GPP	Gross primary production
GTOS	Global Terrestrial Observing System
HANPP	Human appropriation of net primary production
HANTS	Harmonic ANalysis of Time Series
HARFW	Human appropriation of renewable freshwater
HWSD	Harmonized World Soil Database
HR	Heterotrophic respiration
HSRU	Homogeneous stream reach unit
IASB	International Accounting Standards Board
IBGE	Instituto Brasileiro de Geografia e Estatística/Brazilian Institute of Geography and Statistics
ICZM	Integrated coastal zone management
IFRS	International Financial Reporting Standards
IGBP	International Geosphere-Biosphere Programme
IHDP	International Human Development Programme
IKI	Институт Космических Исследований/Space Research Institute of the Russian Academy of Sciences
INCAS	Indonesian National Carbon Accounting System
IIASA	International Institute for Applied Systems Analysis
IOC/COI	Indian Ocean Commission/ Commission de l'Océan Indien
I-OT	Input-output table
IPCC	Intergovernmental Panel on Climate Change
IRWS	International Recommendations for Water Statistics
IT	Information technology
IUCN	International Union for Conservation of Nature
JAXA	Japan Aerospace Exploration Agency
JRC	Joint Research Centre
LAGMA	Locally adaptive global mapping algorithm
LCCS	Land cover classification system
LCEU	Land-cover ecosystem unit
LCML	Land cover meta language
LEAC	Land and ecosystem accounting
LEFT	Local ecological footprinting tool
LULUCF	Land use, land-use change and forestry
MA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystem and their Services
MAUP	Modifiable area unit problem
MCU	Marine coastal unit or marine ecosystem coastal unit
MDGs	Millennium Development Goals
Meff	Effective mesh size
MFA	Material flow accounting or material flows analysis
MODIS	Moderate Resolution Imaging Spectroradiometer

MRV	Measurement, reporting and verification
MSA	Mean Species Abundance index
MU	Mauritius
NAMWA	National accounting matrix including water accounts
NASA	National Aeronautics and Space Administration
NCA	Natural capital accounting
NDP	Net domestic product
NDVI	Normalized Difference Vegetation Index
NEACS	Net ecosystem accessible carbon surplus
NEAWS	Net ecosystem accessible water surplus
NECB	Net ecosystem carbon balance
NEP	Net ecosystem production
NEWB	Net ecosystem water balance
NFMS	National forest monitoring system
NFMS	National forest monitoring system
NGO	Non-governmental organization
NI	Nature Index
NLEP	Net landscape ecosystem potential
NPP	Net primary production
NREP	Net river ecosystem potential
NRSCC	National Remote Sensing Center of China
OECD	Organisation for Economic Co-operation and Development
OLAP	Online analytical processing
PSU	Primary statistical unit
PSUT	Physical supply and use table
QA/QC	Quality assurance/Quality control
QSP	Quick Start Package
RECAP	REgional Carbon Cycle Assessment and Processes of the GCP
REDD+	Reducing emissions from deforestation and forest degradation
RSU	River system unit
SCBD	Secretariat of the Convention on Biological Diversity
SDGs	Sustainable Development Goals
SEEA	System of Environmental-Economic Accounting
SEEA-CF	SEEA-Central Framework
SEEA-EEA	SEEA-Experimental Ecosystem Accounting
SEEA-W	SEEA-Water
SELU	Socio-ecological landscape unit
SES	Socio-ecological system
SLF	Small linear landscape features
SM	Statistics Mauritius
SNA	System of national accounts
SPOT	Satellite Pour l'Observation de la Terre
SRKM	Standardized river kilometre
SRMU	Standardized river measurement unit
SRU	System river unit (see SRKM or SRMU)
SUT	Supply and use table
TEEB	The Economics of Ecosystems and Biodiversity
TEIP	Total ecosystem infrastructure potential
TER	Total ecosystem respiration
TNWR	Total natural renewable water resources
TRMM	Tropical Rainfall Measuring Mission
TUEW	Total use of ecosystem water
UNCEEA	United Nations Committee of Experts on Environmental-Economic Accounting
UNEP	United Nations Environment Programme
UNEP-DEPI	UNEP Division of Environmental Policy Implementation
UNFCCC	United Nations Framework Convention on Climate Change
UNSC	United Nations Statistical Commission
UNSD	United Nations Statistical Division

UNU	United Nations University
VA	Value added
VCF	Vegetation continuous fields (MODIS)
VOC	Volatile organic compound
CH4	Methane
WAA	Water Account Australia
WAVES	Wealth Assessment and Ecosystem Valuation of Ecosystem Services
WB	World Bank
WCMC	United Nations Environment Programme's World Conservation Monitoring Centre
WGCS	Wentworth Group of Concerned Scientists

GLOSSARY OF TERMS USED IN THE ENCA QSP MANUAL

Accessible resource is the amount of a resource that is accessible for uses in a sustainable way. It is not the stock itself nor the total stock plus inflow. Accessibility takes into account the part of the resource that is needed by the ecosystem for its own renewal and that only a surplus is sustainably exploitable. The accessibility of resources that are not depletable by extraction is measured indirectly, in terms of the integrity and health of the systems which generate them. Accessible resource is calculated by adjustment of the "available resource" from all the elements which limit its use: respect of sustainable yields to avoid depletion, timeliness, distance, affordable economic costs of operation, respect of environmental norms and other legal constraints. ***See Available resource; Exploitable water resource; Chapters 5, 6, 7.***

Actual evapotranspiration (ETa or ETA): *see Evapotranspiration (Actual).*

Appropriation refers to the measure of total human intervention into the ecosystem. This intervention is broader than resource extraction or consumption as it takes into account unused but appropriated resources such as the roots of harvested plants (and all leftovers) and the water resource needed to dilute pollution down to acceptable levels (grey water). Total appropriation has been calculated for NPP and Fresh Water. ENCA refers to consumption instead of appropriation. ***See Grey water; HANPP; Water appropriation; Chapters 5, 6.***

Aquifer: *"an aquifer is defined as a geological formation where all the void spaces are filled with water (saturated). The formation must be permeable enough to yield economic quantities of water"* FAO-AQUASTAT]. ***See Chapters 3, 6.***

Asset: *"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. It is a means of carrying forward value from one accounting period to another"* [SNA 2008, 3.5] and [SEEA]. All assets in the SNA are economic assets, including (economic) natural resources. ***See Economic asset; Ecosystem asset; Natural asset***.

Available water: *"that part of water resources that is available for use. The concept is ambiguous, and depends on whether it refers to water available for immediate use or freshwater resources available for future development. In either case, access to the water would have a cost"* [FAO-AQUASTAT]. ***See Accessible resource; Exploitable water resource.***

Balancing item: an account balancing item is the difference between the totals of resources and uses. *"The balancing items typically encapsulate the net result of the activities covered by the account in question and are therefore economic constructs of considerable interest and analytical significance. Examples of balancing items include value added, disposable income and saving"* [SNA 2008, 1.14]. In ENCA, each table has its balancing item such as net formation of land cover or net ecosystem carbon balance. ***See Introduction, Chapter 1, 2.***

Basic spatial unit (BSU): *"a basic spatial unit (BSU) is a small area. Ideally, BSU are formed by delineating tessellations (small areas e.g, 1 km^2), typically by overlaying a grid on a map of the relevant territory; but they may also be land parcels delineated by a cadastre or using remote sensing pixels. BSU are the smallest unit in the model used to define areas for the purposes of ecosystem accounting. They can be aggregated to form land cover/ecosystem functional units (LCEU) and ecosystem accounting units (EAU)"* [SEEA]. In ENCA, BSUs are regular grid cells. ***See Chapter 3.***

Biocarbon: *"biocarbon refers to carbon stored in the biosphere, in living and dead biomass and soils (including peat)"* [SEEA]. In ENCA, ecosystem carbon is made of biocarbon and carbon in the atmosphere system. ***See Ecosystem carbon; Peat; Chapter 5.***

Biodiversity: *"biodiversity is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within species, between species and ecosystems"* [Convention on Biological Diversity (2003), Article 2, Use of Terms]. ***See Chapters 2 and 7.***

Blue water: *"the water in the lakes, rivers and aquifers. Blue water occurs in two different forms: surface runoff in surface water bodies and renewable groundwater runoff in the aquifers"* [FAO-AQUASTAT]. ***See Chapters 2 and 6.***

Capability (of an ecosystem): the capability of an ecosystem is its overall potential to deliver any service in a sustainable way without reducing the potential for other services. It relates to the maintenance of futures options without knowing which will be future users' preferences. Capability encompasses the sustainable use of ecosystem components or assets and risks of depletion as well as the more comprehensive risk of degradation of structures and functions. Future access to intangible services is included in capability measurements even though these services cannot be depleted, only degraded. Capability combines quantitative measurements of the accessible resources with indexes of sustainable use and of ecosystem health (integrity, resilience, etc.). The unit of account of ecosystem capability is the ECU. ***See Accessible resource; Capacity; Ecological unit value; Ecosystem capability unit; ECU; Chapter 2 and 8.***

Capacity is the potential of an ecosystem to deliver one or the other particular service. It can be defined as the total available resource or more restrictively as the resource which is accessible only without depletion. Capacities are measured service by service while capability refers to the overall ecosystem potential to deliver its bundle of services. ***See Accessible resource; Capability.***

Carbon sequestration: *"the process of increasing the carbon content of a reservoir other than the atmosphere"* [MA2005; TEEB]. In ENCA, the distinction is made between gross carbon sequestration, which is the difference between gross primary production and total ecosystem respiration (recorded as net ecosystem production), and net carbon sequestration after harvest and other withdrawals (recorded as net ecosystem carbon balance). The net ecosystem carbon balance corresponds to the measurement of carbon sequestration in IPCC. ***See Chapter 5.***

Catchment: ***see River basin.***

CICES: provisional Common International Classification of Ecosystem Services. ***See Chapter 9.***

Climate change: *"a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods"* [UNFCCC].

CO2-equivalents (CO_2-e or CO2eq): *"measure that describes how much global warming a given type and amount of greenhouse gas may cause, using the functionally equivalent amount or concentration of carbon dioxide (CO2) as the reference. The emission of 1 kg methane is equal to 21 CO2-equivalents and the emission of 1 kg nitrous oxides is equal to 310 CO2-equivalents"* [CBS-NL]. CO2-e is the unit-equivalent (unit of account) used for the Kyoto Protocol implementation. ***See Chapters 2, 5, 8.***

Consumption of fixed capital (CFC): *"CFC reflects the decline in the value of the fixed assets of enterprises, governments and owners of dwellings in the household sector. Decline in value is due to normal wear and tear, foreseeable ageing (obsolescence) and a normal rate of accidental damage. Unforeseen obsolescence, major catastrophes and the depletion of natural resources, however, are not included." [SNA2008] "Consumption of fixed capital does not, therefore, cover the depletion or degradation of natural assets such as land, mineral or other deposits, coal, oil, or natural gas (...)"* [SNA2008, 6.241]. ***See Chapters 2, 9***.

Consumptive water use: *"The part of water withdrawn from its source for use in a specific sector (e.g. for agricultural, industrial or municipal purposes) that will not become available for reuse because of evaporation, transpiration, incorporation into products, drainage directly to the sea or evaporation areas, or removal in other ways from freshwater resources. It is opposed to non-consumptive water use"* [FAO-AQUASTAT]. ***See Chapter 6.***

Cost-benefit analysis: *"a technique designed to determine the feasibility of a project or plan by quantifying its costs and benefits"* [MA2005; TEEB]. ***See Chapter 9.***

Cultivated biological resources: *"cover animal resources yielding repeat products and tree, crop and plant resources yielding repeat products whose natural growth and regeneration is under the direct control, responsibility and management of an institutional unit"* [SEEA]. In the 2008 SNA, cultivated biological resource is distinguished from non-cultivated biological resource in the context of the establishment of rules for recording natural growth as either production (annual output or work-in-progress) or formation if fixed capital [SNA2008, 10.88; 10.182]. In the SEEA-EEA, cultivated biological resources are not provisioning ecosystem services. In ENCA, both cultivated and non-cultivated biological resources are part of ecosystem output. ***See Natural resources; Chapter 2.***

Cultural ecosystem services: *"the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values"* [MA2005; TEEB]. ***See Chapter 7, 9***.

Decoupling: "*decoupling occurs when the growth rate of an environmental pressure is less than that of its economic driving force (e.g. GDP) over a given period. Decoupling can be either absolute or relative. Absolute decoupling is said to occur when the environmentally relevant variable is stable or decreasing while the economic driving force is growing. Decoupling is said to be relative when the growth rate of the environmentally relevant variable is positive, but less than the growth rate of the economic variable*" [CBS-NL]. In present resource efficiency assessments, decoupling is generally expressed as the ratio of material flows to GDP. ***See Chapter 2.***

Deforestation: "*is the decrease in the stock of forest and other wooded land due to the complete loss of tree cover and transfer of forest land to other uses (as agricultural land, land under buildings, roads, etc.) or to no identifiable use*" [SEEA]. This definition of deforestation borrowed to FAO is equally followed in ENCA where it is distinguished from loss of forest cover. ***See Chapter 4***.

Degradation: "*considers changes in the capacity of environmental assets to deliver a broad range of ecosystem services and the extent to which this capacity may be reduced through the action of economic units, including households*" [SEEA]. In ENCA, degradation is the loss of ecosystem capital capability measured in ECU, of which human activities are responsible. ***See Chapters 2, 8.***

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]. In ENCA, depletion is measured for each basic ecosystem resource as the difference between accessible resource and total use. ***See Chapters 2, 8.***

Dilution factor: *"the number of times that a polluted effluent volume has to be diluted with ambient water in order to arrive at the maximum acceptable concentration level"* [Water Footprint]. ***See Accessible resource; Exploitable water resource; Chapter 6.***

Direct material input (DMI): *"measures the direct input of materials for use in an economy, in other words, all materials which are of economic value and are used in production and consumption activities (excluding water flows). DMI can be calculated as domestic (used) extraction plus imports. The relation of domestic material consumption (DMC) to DMI indicates to what extent inputs of material resources are used for own domestic consumption or are exported to be consumed in other economies"* [EuroStat]. ***See Chapters 5, 6.***

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]. ***See Chapter 9.***

Disturbed ecosystems: *"ecosystems that have been altered as a result of anthropogenic activities or natural disasters"* [TEEB]. ***See Ecosystem integrity.***

Domestic material consumption (DMC): *"Domestic material consumption in kg, defined as extraction plus imports minus exports"* [EuroStat]. ***See Chapters 5, 6.***

Ecological infrastructure: "*any area which delivers services such as freshwater, micro climate regulation, recreation, etc, to a large proximate population, usually cities. This is sometimes referred to as green infrastructure*" [TEEB]. ***See Chapter 2, 7.***

Ecological value: "non-monetary assessment of ecosystem integrity, health, or resilience, all of which are important indicators to determine critical thresholds and minimum requirements for ecosystem service provision" [TEEB]. ***See Economic valuation; Chapters 2, 9.***

Ecological unit value is the ecological value of one unit of accessible resource; it is measured in ECU, the standard unit of account used in ENCA for measuring ecosystem capability. In economics, unit value is the weighted mean price of a given quantity. In ENCA, ecological unit value is calculated by ecosystem accounting unit; its role is equivalent to a mean ecological price. ***See Capability; Ecological value; Ecosystem capability unit; ECU; Chapters 2, 8.***

Econd: *"an Econd is an accredited measure, metric or model between 0 and 100 that reflects the health of an environmental asset or an ecosystem indicator based on a reference condition benchmark"* (WGCS Australia). There are similarities between Econd and ECU, the main difference being the reference condition benchmark. While Econd refers to an undisturbed condition, ECU refers relative change and approved policy targets. The unit of account used in ENCA is ECU. ***See ECU; Equivalent Unit; Chapters 2, 7.***

Economic asset: ***See Asset***

Economic growth: "the change in volume of gross domestic product (GDP) with respect to the previous year in market prices" [CBS-NL]. ***See Gross domestic product; Value Added; Chapters 2, 9.***

Economic territory is *"the area under effective control of a single government. It includes the land area of a country including islands, airspace, territorial waters and territorial enclaves in the rest of the world. Economic territory excludes territorial enclaves of other countries and international organisations located in the reference country"* [SEEA]. ***See Chapters 2, 3.***

Economic valuation: *"the process of expressing a value for a particular good or service in a certain context (e.g. of decision-making) in monetary terms"* [TEEB]. ***See Ecological value; Chapters 2, 9.***

Ecosystem Accounting Unit (EAU): *"ecosystem accounting units (EAU) are large, mutually exclusive, spatial areas delineated on the basis of the purpose of accounting. Generally, they will reflect a landscape perspective. Factors considered in their delineation include administrative boundaries, environmental management areas, socio-ecological systems and large scale natural features (e.g. river basins)"* [SEEA]. In ENCA-QSP, EAUs are SELUs, MCUs and RSUs. Inland EAUs are grouped by river sub-basins. ***See Chapters 2, 3, 4.***

Ecosystem assets: *"ecosystem assets are spatial areas containing a combination of biotic and abiotic components and other characteristics that function together. [...] In different contexts and discussions, each of these components and other characteristics may be considered assets in their own right (for example in the SEEA Central Framework many individual components are considered individual environmental assets). However, for ecosystem accounting purposes, the focus is on the functioning system as the asset"* [SEEA]. In ENCA, asset is used in the 2008 SNA sense, i.e. economic natural asset; ecosystems are called units (SELU, LCEU, RSU, HSR, MCU, etc.) and their components are resources. ***See Assets; Natural assets; Chapter 2.***

Ecosystem assets and ecosystem capital: Various project of testing the SEEA-EEA are named ENCA, ECA, ANCA, where C stands for capital. In the SEEA, "*the term ecosystem assets has been adopted rather than ecosystem capital as the word assets is more aligned with the terminology employed by the SNA and also conveys better the intention for ecosystem accounting to encompass measurement in both monetary and physical terms. In general however, the terms ecosystem assets and ecosystem capital may be considered synonymous*" [SEEA]. ***See Chapter 2.***

Ecosystem capability unit (ECU) is the unit of account (or equivalent unit) used in ENCA to measure ecosystems ecological value. ***See Ecological unit value; Internal ecological unit value; Unit-equivalents; Chapters 2, 8, 9.***

Ecosystem capital is a sub-system of the natural capital made of the stock of natural and modified ecosystems that yields a flow of ecosystem goods and services imperative for survival and well-being. Furthermore, it is the basis for all human economic activity. It includes air, water, living organisms and all formations of the Earth's biosphere. It does not include subsoil assets except aquifers when they exchange with surface water. However, the release of extracted fossil resource into the environment is recorded in ecosystem capital accounts as it alter ecosystem functioning. Ecosystem capital is one of the pillars of sustainable development together with economic, social and human capitals. In ENCA, the ecosystem capital is measured only in physical units and ECU; its maintenance and restoration costs are measured in physical units and in money. ***See Chapters 1, 2, 8, 9.***

Ecosystem capital capability (or ecosystem capability) is the overall aptitude of ecosystems to deliver services now and in the future without degrading their potential for renewal. Ecosystem capability reflects its overall performance regarding biocarbon, water and intangible services depending on ecosystem integrity and good functioning. Ecosystem capital capability is measured in a common unit of account (equivalent unit) called ECU. ***See Chapters 2, 8, 9.***

Ecosystem carbon includes the biocarbon of land and ocean ecosystems, produced by all ecosystems by photosynthesis, stored in living and dead material (including in soil and peat), transferred along the food chain, and used by human activities and returned. It includes as well all the carbon stored in the atmosphere whatever its origin, respiration and other natural processes and combustion biocarbon or fossil energy. ***See Biocarbon; Chapter 5.***

Ecosystem characteristics: *"ecosystem characteristics relate to the ongoing operation of the ecosystem and its location. Key characteristics of the operation of an ecosystem are its structure, composition, processes and functions. Key characteristics of the location of an ecosystem are its extent, configuration, landscape forms, and climate and associated seasonal patterns"* [SEEA]. ***See Ecosystem condition.***

Ecosystem condition: *"ecosystem condition reflects the overall quality of an ecosystem asset, in terms of its characteristics"* [SEEA]. In ENCA, condition is synonymous to health. ***See Ecosystem characteristics; Chapter 2.***

Ecosystem degradation: is *"a persistent reduction in the capacity to provide ecosystem services"* [MA2005; TEEB]. In SEEA-EEA and ENCA, degradation is the effect of human activities; alteration by natural processes and disasters is recorded separately. In ENCA, ecosystem degradation is measured as a loss of ecosystem capital capability. ***See Chapters 2, 8.***

Ecosystem enhancement: "*ecosystem enhancement is the increase and/or improvement in an ecosystem asset that is due to economic and other human activity*" [SEEA]. In ENCA, accumulation of ecosystem capability is recorded as enhancement when it results from human activities, natural improvements being recorded separately. ***See Chapter 2.***

Ecosystem extent: *"ecosystem extent refers to the size of an ecosystem asset, commonly in terms of spatial area"* [SEEA]. In ENCA, extent is one dimension of the quantity of an ecosystem (generally surface or length), others being volume, mass or in the case of rivers, quantity of SRMUs. ***See Chapter 2***.

Ecosystem function: *"a subset of the interactions between ecosystem structure and processes that underpin the capacity of an ecosystem to provide goods and services"* [TEEB]. ***See Chapter 2***.

Ecosystem health: *"a state or condition of an ecosystem that expresses attributes of biodiversity within normal ranges, relative to its ecological stage of development. Ecosystem health depends inter alias on ecosystem resilience and resistance"* [TEEB]. A metaphor which supports the principle of diagnoses based on the observation of symptoms of structural and functional organization, vigour, resilience, autonomy from artificial inputs or capacity to support healthy populations. ***See Chapter 7.***

Ecosystem integrity: *"implies completeness or wholeness and infers capability in an ecosystem to maintain all its components as well as functional relationships when disturbed"* [TEEB]. ***See Chapter 7***.

Ecosystem natural capital accounts (ENCA): the ecosystem approach to natural capital accounting. ENCA is an application and extension of SEEA-EEA. The ENCA-QSP focuses on accounts in physical units.

Ecosystem services: *"the direct and indirect contributions of ecosystems to human wellbeing. The concept "ecosystem goods and services" is synonymous with ecosystem services"* [TEEB]. *"Ecosystem services are the contributions of ecosystems to benefits used in economic and other human activity. […] Ecosystem services are defined only when a contribution to a benefit is established. Consequently, the definition of ecosystem services excludes the set of flows commonly referred to as supporting or intermediate services"* [SEEA]. In ENCA, ecosystem services are addressed in the core accounts as three bundles of services related to provisioning services (ecosystem carbon and ecosystem water) and regulating and socio-cultural services taken together. Detailed accounting of ecosystem services (in physical units and in money) is foreseen in functional accounts. ***See Chapters 2, 9.***

Ecosystems: *"ecosystems are a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit"* [Convention on Biological Diversity (2003), Article 2, Use of Terms]. The CBD ecosystem approach *"recognizes that humans, with their cultural diversity, are an integral component of ecosystems"*. In the SEEA-EEA, "*ecosystems may be identified at different spatial scales and are commonly nested and overlapping. Consequently, for accounting purposes, ecosystem assets are defined through the delineation of specific and mutually exclusive spatial areas*". In ENCA, in addition to areas, linear ecosystems for which area is not appropriate measurement are recorded as well; it includes rivers and ecotones. ***See in particular Chapters 2, 3***.

ECU: ***see Ecosystem capability unit***

Eddy tower: *"The eddy covariance (also known as eddy correlation and eddy flux) technique is a key atmospheric measurement technique to measure and calculate vertical turbulent fluxes within atmospheric boundary layers. […] It is a statistical method used in meteorology and other applications (micrometeorology, oceanography, hydrology, agricultural sciences, industrial and regulatory applications, etc.) to determine exchange rates of trace gases over natural ecosystems, agricultural fields, and to quantify gas emissions rates from other land and water areas. It is particularly frequently used to estimate momentum, heat, water vapour, carbon dioxide and methane fluxes"* (Wikipedia). The FLUXNET global network of *in situ* measurement of greenhouse gas fluxes collects data from eddy towers. ***See Chapter 5.***

Environmental assets: *"environmental assets are the naturally occurring living and non-living components of the Earth, together constituting the bio-physical environment, which may provide benefits to humanity"* [SEEA]. Ecosystem assets are included in environmental assets. ***See Ecosystem assets; Natural assets***.

Environmental goods and services sector (EGSS) *"consists of producers of all environmental goods and services, including environmental specific services, environmental sole-purpose products, adapted goods and environmental technologies"* [SEEA]. In general, EGSS relate to the maintenance and restoration of ecosystem functions, not to the production of ecosystem service based commodities. ***See Environmental protection activities; Environmental services; Chapter 9***.

Environmental protection activities *"are those activities whose primary purpose is the prevention, reduction and elimination of pollution and other forms of degradation of the environment"* [SEEA]. ***See Environmental goods and services; Environmental services; Chapter 9***.

Environmental services: *"industry that is occupied with collection and treatment of wastewater and waste and the clean-up of soil (NACE 37, 38 and 39). Environmental services are part of the Environmental goods and service sector. [CBS-NL] The sector includes producers of technologies, goods and services that measure, control, restore, prevent, treat, minimise, research and sensitise environmental damages to air, water and soil as well as resource depletion"* [CBS-NL]. ***See Environmental goods and services; Environmental protection activities; Chapter 9***.

Equivalent units (or units of account) are used to measure things which have common characteristics as well as differences in order to compare and aggregate meaningful statistics. The definition of an equivalent unit is based on the choice of a characteristic or function which captures an equal value (*equi-valence*). For example, livestock is commonly measured in livestock units defined in terms of grazing equivalent of one adult cow. Equivalent units can be established by selection of one common simple dimension (e.g. tonnes in the case of material flow accounts used for decoupling assessments or m3 in SEEA-W accounting) or by defining composite units with more complex conversion rules (e.g. Econd, CO2-e or SRMU). In ENCA, the common accounting unit necessary both for integrating ecosystem accounts and for delivering headline aggregated indicators is the ecosystem capability unit (ECU). ***See Chapters 2, 8.***

European Environment Agency (EEA): The European Union (EU) body dedicated to providing sound and independent information on the environment. As EEA membership is also open to countries that are not European Union Member States, it has 33 member countries: the 28 EU Member States and Iceland, Liechtenstein, Norway, Switzerland and Turkey.

Eutrophication: *"excessive enrichment of waters with nutrients and the associated adverse biological effects"* [CBS-NL]. ***See Chapters 5, 6.***

Evapotranspiration (actual): *"actual evapotranspiration (ETa or ETA) represents the actual rate of water uptake by the plant, which is determined by the level of available water in the soil and combines simultaneously both evaporative losses from the soil surface and transpiration from the plant surface"* [FAO-AQUASTAT]. ***See Evapotranspiration (potential)***

Evapotranspiration (potential): ETP is the *"maximum quantity of water capable of being lost, as water vapour, in a given climate, by a continuous stretch of vegetation covering the whole ground and well supplied with water. It thus includes evaporation from the soil and transpiration from the vegetation from a specific region at a given time interval"* [FAO-AQUASTAT]. ETP is a concept used for modelling, not accounting. ***See Evapotranspiration (actual).***

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 Nation Convention on the Law of the Sea of 10 December 1982"* [SEEA]. ***See Chapters 2, 3.***

Exploitable groundwater flow: *"the average flow that is available with an occurrence of 90 percent of the time, and economically/environmentally viable to extract"* [FAO-AQUASTAT]. ***See Accessible resource.***

Exploitable irregular surface water resources *"are equivalent to the variable component of water resources (e.g. floods). It includes the seasonal and inter-annual variations, i.e. seasonal flow or flow during wet years. It is the flow that needs to be regulated"* [FAO-AQUASTAT]. ***See Accessible resource.***

Exploitable regular renewable surface water: *"the annual average quantity of surface water that is available with an occurrence of 90 percent of the time. In practice, it is equivalent to the low water flow of a river. It is the resource that is offered for withdrawal or diversion with a regular flow"* [FAO-AQUASTAT]. ***See Accessible resource.***

Exploitable water resources (Total EWR) *"(also called manageable water resources or water development potential) are considered to be available for development, taking into consideration factors such as: the economic and environmental feasibility of storing floodwater behind dams, extracting groundwater, the physical possibility of storing water that naturally flows out to the sea, and minimum flow requirements (navigation, environmental services, aquatic life, etc). Methods to assess exploitable water resources vary from country to country"* [FAO-AQUASTAT]. In ENCA, accessible resource includes exploitable resource plus secondary resource from water returns. ***See Accessible resource.***

Externality: *"a consequence of an action that affects someone other than the agent undertaking that action and for which the agent is neither compensated nor penalized through the markets. Externalities can be positive or negative"* [MA2005; TEEB]. ***See Chapter 9.***

Functional redundancy: "a characteristic of ecosystems in which more than one species in the system can carry out a particular process. Redundancy may be total or partial – that is, a species may not be able to completely replace the other species or it may compensate only some of the processes in which the other species are involved" [MA2005; TEEB]. ***See Biodiversity; Ecosystem integrity; Chapter 7.***

Green growth: green growth is about fostering economic growth and development while ensuring that the quality and quantity of natural assets can continue to provide the environmental services on which our well-being relies. It is also about fostering investment, competition and innovation which will underpin sustained growth and give rise to new economic opportunities (OECD definition) [CBS-NL]. ***See Chapter 1.***

Green water: *"that fraction of rainfall that is stored in the soil and available for the growth of plants.* [FAO-AQUASTAT] *"The precipitation on land that does not run off or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil or vegetation. Eventually, this part of precipitation evaporates or transpires through plants. Green water can be made productive for crop growth (although not all green water can be taken up by crops, because there will always be evaporation from the soil and because not all periods of the year or areas are suitable for crop growth)"* [Water Footprint]. ***See Chapters 2, 6.***

Grey water: *"the volume of freshwater that is required to assimilate the load of pollutants based on natural background concentrations and existing ambient water quality standards. It is calculated as the volume of water that is required to dilute pollutants to such an extent that the quality of the water remains above agreed water quality standards"* [Water Footprint]. In ENCA, grey water is not added to water use but it is subtracted from water available resource to calculate water accessible resource. The ENCA treatment is analogous to FAO/AQUASTAT's deduction of minimum flow requirements when calculating exploitable water resource. ***See Accessible resource; Water exploitable resource; Water footprint; Chapter 6.***

Greenhouse gases: *"gases in the atmosphere that absorb and emit radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. The most important greenhouse gases are carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), HFKs, PFKs and SF6."* [CBS-NL] ***See Climate Change; CO2-e; Chapter 5.***

Gross domestic product (GDP): *"an aggregate measure of production, equal to the sum of the gross value added of all resident institutional units (i.e. industries) engaged in production, plus any taxes, and minus any subsidies, on products not included in the value of their outputs. Gross value added is the difference between output and intermediate consumption"* [Eurostat]. ***See Chapters 1, 9.***

Groundwater: ***see Aquifer.***

Habitat service (natural): *"the importance of ecosystems to provide living space for resident and migratory species (thus maintaining the gene pool and nursery service)"* [TEEB]. In SEEA-EEA, habitat services are included in regulating services. ***See Regulating services.***

Household: "a group of persons who share the same living accommodation, who pool some or all of their income and wealth and who consume certain types of goods and services collectively, mainly housing and food" [SEEA]. ***See Chapter 9.***

Human well-being: a context-and situation-dependent state, comprising basic material for a good life, freedom and choice, health and bodily well-being, good social relations, security, peace of mind, and spiritual experience. [MA2005; TEEB]. ***See Chapters 1, 9.***

Industry: *"in the context of national accounts, an industry consists of a group of establishments engaged in the same, or similar, kinds of activity"* [Eurostat]. An establishment is an enterprise, or part of an enterprise, that is situated in a single location. Industries include producers of government services. Industries are sometimes called branches. In the SNA terminology, economic sectors group whole institutional units such as enterprises (often made of several establishments having different activities) or government institutions. However, it may happen that sector is used as a synonymous of industry. The international classification of industry is ISIC.

Inland water system: *"comprises surface water (rivers, lakes, artificial reservoirs, snow, ice, glaciers), groundwater and soil water within the territory of reference"* [SEEA]. ENCA uses the same categories but defines soil as soil and vegetation which facilitates the presentation of water accounts by land ecosystem units (LCEU and SELU). ***See Chapter 7.***

Institutional unit: *"an economic entity that is capable, in its own right, of owning assets, incurring liabilities and engaging in economic activities and in transactions with other entities"* [SEEA] ***See Industry.***

Intermediate consumption: *"consists of the value of the goods and services consumed as inputs by a process of production, excluding fixed assets whose consumption is recorded as consumption of fixed capital"* [SEEA]. ***See Value added.***

Internal ecological unit value (or price)**:** an equivalent unit calculated for each component of an ecosystem (ecosystem carbon or water or infrastructure based functional services) by averaging its sustainable use index and its health index. Internal means that the effects of one component on the two others are not taken into accounts at this stage. They will be integrating when calculating the ECU price. ***See ECU; Equivalent unit.***

Inventories: "*produced assets that consist of goods and services, which came into existence in the current period or in an earlier period, and that are held for sale, use in production or other use at a later date*" [SEEA]. ***See Chapter 2.***

ISIC: International Standard Industrial Classification of All Economic Activities used in national accounting. NACE is the European version of ISIC.

Kriging: *"Kriging is a group of geostatistical techniques to interpolate the value of a random field (e.g., the elevation, z, of the landscape as a function of the geographic location) at an unobserved location from observations of its value at nearby locations"* (Wikipedia). ***See Chapter 3, 5.***

Land cover: "*land cover corresponds to a (bio)physical description of the Earth's surface. It is that which overlays or currently covers the ground. This description enables various biophysical categories to be distinguished – basically, areas of vegetation (trees, bushes, fields, lawns), bare soil, hard surfaces (rocks, buildings) and wet areas and bodies of water (watercourses, wetlands)"* [EEA]. In ENCA, LCEUs includes the bottom of marine coastal units. ***See Chapters 3, 4.***

Land cover ecosystem unit (LCEU): *"a land cover/ecosystem functional unit (LCEU) is defined, in most terrestrial areas, by areas satisfying a pre-determined set of factors relating to the characteristics of an ecosystem*" [SEEA]. In ENCA, LCEUs includes the bottom of marine coastal units. ***See Chapters 3, 4***.

Land use: *"corresponds to the socio-economic description (functional dimension) of areas: areas used for residential, industrial or commercial purposes, for farming or forestry, for recreational or conservation purposes, etc. Links with land cover are possible; it may be possible to infer land use from land cover and conversely. But situations are often complicated and the link is not so evident. Contrary to land cover, land use is difficult to observe. For example, it is often difficult to decide if grasslands are used or not for agricultural purposes. Distinctions between land use and land cover and their definition have impacts on the development of classification systems, data collection and information systems in general"* [EEA]. ***See Chapters 3, 4.***

Marine coastal units (MCU): ecosystem accounting units (EAU) for marine coastal ecosystems. Their bottom is generally mapped in land cover ecosystem units reflecting vegetation (seagrass) and other bio-physical cover. ***See Ecosystem accounting unit; Land cover / ecosystem functional Unit; Chapters 3, 4.***

Mineral and energy resources: *"known deposits of oil resources, natural gas resources, coal and peat resources, non-metallic minerals and metallic minerals*" [SEEA]. Peat is a resource generated by wetland ecosystems. In ENCA, peat formation, extraction and stocks are recorded in the ecosystem carbon account. ***See Chapter 5.***

Mitigation or restoration costs: *"the cost of mitigating the effects of the loss of ecosystem services or the cost of getting those services restored"* [TEEB]. In ENCA, the estimated restoration cost corresponds to an unpaid expenditure that the economic agent has to pay because of ecosystem degradation. This unpaid cost is a consumption of ecosystem capital that has to be covered by actual restoration expenditure. In ENCA, restoration costs consider the whole set of ecosystem functions, not one or the other ecosystem services. ***See Chapters 2; 9.***

Monetary valuation: ***see Economic valuation; Chapter 9***.

Natural capital: for the Millennium Ecosystem Assessment and TEEB, natural capital is "*an economic metaphor for the limited stocks of physical and biological resources found on Earth*". In the SEEA: *"the term natural capital is not defined in SEEA Experimental Ecosystem Accounting. Commonly, natural capital is used to refer to all types of environmental assets as defined in the SEEA-CF. Used in this way natural capital has a broader scope than ecosystem assets as defined in SEEA-EEA since it includes mineral and energy resources*" [SEEA]. In the EU MAES programme, natural capital is equivalent to ecosystem capital. ***See Ecosystem assets; Ecosystem capital; Chapters 1, 2.***

Natural patrimony: natural patrimony is the whole set of natural assets inherited from our ancestors that we use for present benefits and that we must transmit to the future generations. It has three functions irreducible one to one another, economic, ecological and socio-cultural. Natural patrimony accounts (*Les comptes du patrimoine naturel*, in French,) define three types of accounts, for components (the basic resources), economic sectors (the national accounts sectors) and ecozones (land cover units and complex ecosystems). Accounts in physical units are addressed first; monetary valuation however is part of the framework. ***See Chapter 1.***

Natural resource: the SNA defines natural resource with the purpose of making a distinction of what is naturally occurring from what is production output – and has therefore to be recorded as value added in GDP (for example, agricultural harvest). This distinction is needed for defining an economy's boundaries but does not mean that the physical processes involved are exclusive one to another. Instead, SNA2008 insists that "[natural] *Growth is not to be construed as a purely natural process that lies outside the production boundary. Many processes of production exploit natural forces for economic purposes, for example, hydroelectric plants exploit rivers and gravity to produce electricity*" [SNA2008, 6.136]. The SEEA-CF and SEEA-EEA interpret the SNA conventions in a restrictive way and exclude managed and cultivated biological resource from ecosystem services as long as they belong to the realm of economy. ENCA instead records all natural resource flows and stocks generated by ecosystem structures and processes (including photosynthesis), directly used or embodied into economic products or assets, considering that in the case of agriculture or managed forests, there is a joint economy – ecosystem outcome. ***See Asset; Ecosystem asset; Chapters 1, 2.***

Peat: "*a heterogeneous mixture of more or less decomposed plant (humus) material that has accumulated in a water-saturated environment and in the absence of oxygen*" [PEAT]. In ENCA, peat is included into ecosystem carbon. ***See Biocarbon; Ecosystem carbon; Chapter 5.***

Potential evapotranspiration (ETP): ***see Evapotranspiration (Potential)***

Productivity (biomass): "*rate of biomass produced by an ecosystem, generally expressed as biomass produced per unit of time per unit of surface or volume. Net primary productivity is defined as the energy fixed by plants minus their respiration*" [MA2005; TEEB]. ***See Chapter 5.***

Provisioning services: "*Provisioning services reflect contributions to the benefits produced by or in the ecosystem, for example a fish, or a plant with pharmaceutical properties. The associated benefits may be provided in agricultural systems, as well as within semi-natural and natural ecosystems*" [SEEA]. In SEEA-EEA, provisioning ecosystem services exclude the outcome of agriculture and managed forestry. In ENCA all the joint production economy-nature achieved in managed or cultivated ecosystems is recorded as ecosystem provisioning service. ***See Natural resources; Chapter 2.***

Public good: "*a good or service in which the benefit received by any one party does not diminish the availability of the benefits to others, and where access to the good cannot be restricted*" [MA2005; TEEB]. See Chapter 2.

Recreational services: ***see Cultural services.***

Regulating services: "*regulating services result from the capacity of ecosystems to regulate climate, hydrological and bio-chemical cycles, Earth surface processes, and a variety of biological processes. Regulating services are also commonly referred to as regulation and maintenance services. In the context of the definition of ecosystem services used in SEEA-EEA these two terms are synonymous*" [SEEA]. ***See Chapters 7, 9.***

Replacement cost: "*the costs incurred by replacing ecosystem services with artificial technologies*" [TEEB]. ***See chapters 2, 9.***

Residence: "*the residence of each institutional unit is in the context of national accounts the economic territory with which it has the strongest connection, in other words, its centre of predominant economic interest*" [Eurostat]. In IPCC, greenhouse gas emissions are referred to the territory where it takes place, not to the residence of the emitters. SEEA-EEA and ENCA define ecosystems on a territorial basis. ***See Chapters 2, 5.***

Resilience: "*the ability of an ecosystem to recover from disturbance without human intervention*" [TEEB]. ***See Chapters 2, 7.***

Resistance: "*the ability of an ecosystem to withstand or tolerate disturbance and stay within certain boundary conditions, or states, without human intervention*" [TEEB]. ***See Chapters 2, 7.***

Responses: "*human actions, including policies, strategies, and interventions, to address specific issues, needs, opportunities, or problems. In the context of ecosystem management, responses may be of legal, technical, institutional, economic, and behavioural nature and may operate at various spatial and time scales*" [MA2005; TEEB]. ***See Chapter 1.***

Return flow/water: *"the part of the water withdrawn for an agricultural, industrial or domestic purpose that returns to the groundwater or surface water in the same catchment as where it was abstracted. This water can potentially be withdrawn and used again"* [Water Footprint]. ***See Chapter 6.***

Return flows comprise the part of ecosystem carbon and water withdrawals sent back to the environment as harvest leftovers, losses in distribution or use, or as treated or untreated residuals or waste. ***See Accessible resource; Ecosystem carbon; Chapter 6.***

River basin: the geographical area drained by a river and its tributaries. It is characterized by all runoff being conveyed to the same outlet. It is also called catchment, drainage basin, or watershed. River sub-basin boundaries are integrated in the definition of SELUs***. See Chapters 2, 3, 6.***

River system unit (RSU): RSU are ecosystem accounting units. They are defined as the hydrological network contained in a river basin or sub-basin and used for ecosystem accounting. RSU are composed of homogenous stream reaches (HSR). ***See Chapters 2, 3, 6.***

Sectors: in the SNA group institutional units by main activities. The expression is commonly used as synonymous to economic activities in general although activities can relate in national accounting to either institutional units or establishments. ***See Industry.***

Socio-ecological landscape unit (SELU): SELU are ecosystem accounting units. They are the representation of terrestrial socio-ecological system and are classified according to dominant landscape type and other geographical criteria. ***See Ecosystem accounting unit; Chapters 2, 3, 4.***

Socio-ecological system: *"an ecosystem, the management of this ecosystem by actors and organizations, and the rules, social norms, and conventions underlying this management"* [MA2005; TEEB]. ***See Socio-ecological landscape unit (SELU); Chapters 2, 3, 4.***

Species diversity: "*biodiversity at the species level, often combining aspects of species richness, their relative abundance and their dissimilarity*" [MA2005; TEEB]. ***See Biodiversity; Chapter 7.***

Standard river measurement unit (SRMU): used to quantify with a common equivalent unit rivers and streams of different size. SRMU is defined as 1 km x 1m3 x 1 second-1. Synonymous expressions are standardized river kilometres (SRKm) or standard river units (SRU). ***See Unit equivalent; Chapters 2, 3, 6.***

Substitutability: *"the extent to which human-made capital can be substituted for natural capital (or vice versa)"* [TEEB]. ***See Chapters 2, 9.***

Supporting services: *"ecosystem services that are necessary for the maintenance of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat"* [MA2005; TEEB].

Surface water: *"comprises all water that flows over or is stored on the ground surface regardless of its salinity levels. Surface water includes water in artificial reservoirs, lakes, rivers and streams, snow and ice and glaciers."* [SEEA]. ***See Chapter 6***.

Sustainability: a characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs [MA2005; TEEB]. ***See Chapter 1, 2, 9.***

Sustainable yield: *"the surplus or excess of animals or plants that may be removed from a population without affecting the capacity of the population to regenerate itself"* [SEEA]. Also called maximum sustainable yield. ***See Chapter 2.***

Urban runoff: "*that portion of precipitation on urban areas that does not naturally evaporate or percolate into the ground, but flows via overland flow, underflow, or channels, or is piped into a defined surface water channel or a constructed infiltration facility*" [SEEA]. ***See Chapter 6***.

Valuation: "*the process of expressing a value for a particular good or service in a certain context (e.g. of decision-making) usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on)"* [MA2005; TEEB]. ***See Ecological value; Chapters 1, 2, 9.***

Value added: *"gross value added (GVA) at market prices is output at market prices minus intermediate consumption at purchaser prices; it is a balancing item of the national accounts' production account. For a country, the sum of GVAs makes GDP"* [EuroStat]. ***See Gross domestic product; Intermediate consumption; Chapters 2, 9.***

Vulnerability: *"exposure to contingencies and stress, and the difficulty in coping with them. Three major dimensions of vulnerability are involved: exposure to stresses, perturbations, and shocks; the sensitivity of people, places, ecosystems, and species to the stress or perturbation, including their capacity to anticipate and cope with the stress; and the resilience of the exposed people, places, ecosystems, and species in terms of their capacity to absorb shocks and perturbations while maintaining function"* [MA2005; TEEB]. See Chapters 1, 2, 7.

Water appropriation: *"a term used in the context of water footprint assessment to refer to both the consumption of freshwater for human activities (green and blue water footprint) and the pollution of freshwater by human activities (grey water footprint)"* [Water Footprint]. ***See Appropriation; HAFWR; Chapter 6.***

Water stress: *"the symptoms of water scarcity or shortage, e.g. widespread, frequent and serious restrictions on use, growing conflict between users and competition for water, declining standards of reliability and service, harvest failures and food insecurity"* [FAO-AQUASTAT]. **See Chapter 6.**

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