# An experimental framework for ecosystem capital accounting in Europe

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# Foreword

The need to account for natural resources as capital, in the same way as we account for economic and financial resources, is getting more and more attention. The recently published EU Roadmap for a Resource Efficient Europe sets the policy framework for action in the coming years and decades for which robust data and indicators are needed.

In this respect, there is a contrast between the natural resources which are recorded by the System of National Accounts 2008, the basis for GDP, and other natural resources which are ignored because they are not seen as economic assets by the market. The latter is typically the case for many important ecosystem functions and services which contribute to people's wellbeing but are considered as external by the economy.

To bridge this gap, the UN Committee of Experts on Environmental-Economic Accounting decided in its June 2011 meeting to include experimental ecosystem accounts in the scope of the revision of the System of Environmental-Economic Accounts revision by 2013. In Europe, a project to test the feasibility of ecosystem capital accounts was launched by the EEA in 2010 in anticipation of such stakeholder demands.

The experimental accounts framework presented in this report builds upon the experience gained in this feasibility study. It has also benefited from the reflections which have taken place in the UN SEEA revision process as well as from the European Union GDP and Beyond initiative and TEEB, The Economics of Ecosystems and Biodiversity, process. The EEA has been actively participating in these activities and has inter-alia, produced a report on ecosystem accounting for coastal Mediterranean wetlands as well as contributed to the TEEB D1 report for National and International Policy Making.

The ecosystem accounting framework presented here is being tested in the context of an open Europe taking stock of its relations to the rest of the world. Because ecosystem accounts are deep-rooted into monitoring databases, implementation presently focuses on physical accounts. Monetary valuations, the adjustment of national accounts aggregates for income and final consumption, and the calculation of ecological debts, are foreseen in subsequent steps within the same logical framework. Although designed for European needs, most of the features proposed here have a global scope, and so can support experimentation in other regions of the world.

The progress made so far has been possible through the support of EEA partners and networks and the developments of environmental information systems in recent years. Ecosystem accounting is a module under the European Strategy for Environmental Accounting managed by Eurostat. The basis for physical accounts for Europe is the Corine land cover inventory 1990–2006 produced in collaboration with Eionet, the European Space Agency and the Joint Research Centre. EEA's own databases have been mined for computing the test accounts alongside the databases of Eurostat and the Joint Research Centre.

The EEA Management Board, Eionet and the EEA Scientific Committee have been consulted regularly and provided guidance. Last but not least, the EEA policy framework has constantly confronted stated policy requests regarding national accounts, efficient resource use or nature conservation and methodological proposals. I would like to thank all for their contributions and look forward to continuing cooperation in coming years.

*Prof. Jacqueline McGlade*

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# Executive summary


Ecosystem accounts are being developed as part of the System of Environmental-Economic Accounts which aims at supplementing the UN System of National Accounts with information on the environment and natural capital. The purpose is to broaden the scope of the variables taken into account in policy making in order to improve understanding of the interdependence and interactions between the economy and the environment. Ultimately, these ecosystem accounts will yield new indicators and aggregates expressed in physical and monetary units that will be made available to policy makers and analysts to assess the efficiency of natural resource use, the pattern of economic growth, the contribution of nature and its use within and outside the market, the short- and longer-term constraints resulting from the need to maintain living and other renewable capital, and the related benefits and costs.

At the end of 2009, the European Environment Agency launched an experimental project to implement simplified ecosystem capital accounts for Europe as a 'fast-track' initiative, based on the use of existing data and statistics. In addition to feasibility assessment, the project aims at framing ecosystem accounts and identifying which indicators and aggregates could be delivered and integrated into enlarged national accounts. Based on the project findings, an overall framework for ecosystem capital accounting has been designed. It highlights accounting balances and relationships between accounting tables and systems as well as key indicators and aggregates that describe economy-ecosystem interactions.

The indicators and aggregates include: the **ecosystem resource accessible surplus** (which shows the level of resources that can be used without jeopardising ecosystem reproduction functions); the **demand for (accessible) ecosystem services** per capita, which is a measure of ecosystem contribution to well-being; the **total ecosystem capital potential**, defined as the biomass accessible under the constraints of maintaining accessibility to water, green landscape infrastructure and biodiversity (and measured in a 'numeraire' referred to as the Ecosystem Potential Unit Equivalent); the **Ecosystem Capital Degradation** (ECD) which describes domestic ecosystem overuse; **Consumption of Ecosystem Capital** (CEC, the ecosystem capital depreciation in SNA terminology), calculated as (physical) ECD valued by remediation costs; and **the equivalent ECD embedded in imports and exports** for commodities produced in unsustainable conditions. As a next stage it is proposed to use CEC to adjust National Accounts aggregates: **CEC Adjusted Net Domestic Product or CEC Adjusted Net National Income, Final Consumption at Full Cost (including non-paid CEC), Imports and Exports at Full Cost**. Using this approach, two balance sheets of assets and liabilities are ultimately established, one in physical units, the other in terms of money. The balance sheets of financial liabilities allow, amongst other things, a record to be kept of the amount of **ecological debt** first in physical units regarding physical degradation and second in monetary units to balance the non-paid consumption of ecosystem capital. Last but not least, recording ecological debts makes it possible to keep the conventional GDP unchanged while supplementing it with appropriate adjusted aggregates.

# 1 The purpose of environmental-economic accounting

## 1.1 Environmental-economic accounts and national accounts

The purpose of environmental-economic accounting is to supplement the conventional national accounts (UN SNA 2008) with tables which inform policy makers of environmental and natural resource availability, use, depletion and degradation. Through such accounts, economic performance measured by aggregates like Gross Domestic Product, Net National Income, Final Consumption, Net Savings, Imports and Exports, Assets and Liabilities or Employment can be balanced by natural capital indicators that describe the opportunities and constraints, benefits and costs, efficiency of resource use, and externalities that arise in relation to interactions with the environment. Implementation of environmental-economic accounts has been recognised as an important step towards: sustainable development (see Agenda 21 of 1992); the measurement of economic progress (see Beyond GDP and the so-called Stiglitz-Sen-Fitoussi commission); support for green economy (UNEP) and green growth (OECD) strategies; designing resource efficiency policies (see UNEP and EC's Flagship Initiative for a resource-efficient Europe); and for biodiversity conservation (see the Aichi-Nagoya CBD's strategy of 2010). In 2007, the UN Statistical Commission mandated the UN Committee of Experts on Environmental-Economic Accounts (UNCEEA) to raise the 'Integrated System of Environmental-Economic Accounts' (SEEA 2003) up to the level of an international standard by 2012.

Although environmental-economic accounts are compiled using both physical and monetary units, the former are considered the basis of the framework in the EEA initiative.

Accounts in physical units aim primarily at supplementing conventional national accounts with data on the use and availability of natural resources. The objective is to measure the overall efficiency of the economy, first in terms of the material or energy resource input (and waste generation) necessary to produce one unit of GDP, and second to assess resource depletion. Using this approach, physical constraints can be incorporated into macro-economic analysis and support action towards **greener** growth, development and actions, both public (e.g. via taxes, regulation and planning) and private (e.g. via productivity gains, technology, contents of final consumption).

Physical units can be specific to the kind of resource recorded (tonnes, cubic meters, hectares, number of units) or common to a range of resources. In this case, a unit-equivalent needs to be found. For example, material flow accounts which are currently the main basis for resource-efficiency analysis record 'everything' in tonnes. Another solution is to use carbon or energy unit-equivalents, as in UNFCCC reporting. The Ecological Footprint Accounts propose surface area as a general unit-equivalent. These solutions are obviously incomplete (e.g. economy-wide material flow accounts commonly set aside water, considered as 'so large that they would dominate all other materials' ([1]), and land, which has no mass in itself) and limited in scope due to the specific equivalence functions used. Moreover, the qualitative aspects of the living natural resource are broadly ignored, nature being considered only as a 'mine' for resources, and so subject to depletion rather than degradation of its capability for self-renewal.

Monetary values does not ignore the qualities of assets and commodities. However, not all qualities are considered, only those which matter to economic actors in their search of profit and wealth. In the case of subsoil assets, the issue can be neglected as long they exist only as an economic resource. Considering assets with multiple functions like dynamic, biophysical systems, which can be regarded as an economic resource and a public good, market valuation does not encompass all the elements of present and future scarcity needed to assess green growth options and so frame green economy scenarios. Generally, one 'main' function is considered as productive and used to capture most of (if not all) the economic value; other functions being considered as free externalities or ignored. In the absence of external enforcement of such values (e.g. via environmental taxes or norms) market prices are incomplete and beyond market values although they are part of human wellbeing and should be included in any assessment of sustainable development.

([1]) See http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Material_flow_accounts.

The extension of national accounts to cover economic natural assets and their services (incorporated into commodities) is important but cannot deliver a sufficiently complete vision of the interaction of people and nature. For example, an enterprise holding and managing a forest will know and care about trees and timber, but much less about 'non-timber forest values', or forest water regulating functions and micro-climate effects which may be highly important for other sectors of society and for biodiversity. One reason is that the forest is privately managed for private benefits, while the other ecosystem services are mostly public goods. Another reason is that large parts of nature are out of the scope of those 'owned and managed for profit' which is the category of natural assets recorded in the SNA. For these reasons, the UNCEEA decided in June 2011 to devote volume 2 of the new SEEA to ecosystem accounts. The volume will include accounts of flows and stocks in physical units, and where relevant and consistent with SNA principles, valuations. The EEA, Eurostat and the World Bank have been asked to support the preparation of SEEA volume 2. This paper reports progress in Europe on ecosystem *capital* accounts, which express the capability of ecosystems to contribute alongside other forms of capital and to deliver services, and the responsibility of the economy regarding their good maintenance.

## 1.2 Simplified ecosystem capital accounts

The purpose of developing ecosystem capital accounts is to assess the sustainability of the economy-ecosystem interaction from the standpoint of nature, to measure the state of the ecosystems, and, when degradation is observed, to calculate the costs of avoiding damage, or of repair and compensation. These can all be regarded as measurements of ecosystem capital depreciation or 'consumption' (in the SNA sense). In such a setting, physical accounts provide a measure of the physical constraints that cannot be surpassed by the economy without causing damage to human communities and the economy itself.

At the end of 2009, the EEA launched an experimental project 'fast-track implementation of simplified ecosystem capital accounts' for Europe — 'fast-track' because of urgent and recurrent policy demands and 'simplified', because full details are not necessary at the macro level. The approach adopted is top-down, based on Europe-wide datasets and statistics but, as far as possible, data and statistics are compiled at the level of the standard European 1km² grid. The use of the grid is justified by requirements of change detection, and the flexibility needed to report in terms of different geographical units (e.g. regions, river basins, coastal zones). The approach also anticipates the forthcoming expected links with accounting applications at the national level. The test is carried out with existing data and statistics, with the aim of supplying annual updates (to meet the policy agenda) and retrospective time series. Physical accounts are being developed and computed first; the valuation of costs and benefits is still at an exploratory stage. The framework developed for SECA in Europe is an input to the current preparation of SEEA volume 2.

**The narrative behind Simplified Ecosystem Capital Accounts (SECA):** Ecosystems can be described as capital which delivers a bundle of services to people, some of which are appropriated and incorporated into products, accumulated and/or consumed. Other services are public goods of common benefit to the economy and human wellbeing. Altogether, these ecosystem services depend on ecosystem capital regeneration which is in turn influenced by ecosystem services consumption.

In the fact-track accounts three groups of ecosystem services have been considered: accessible biomass/carbon, accessible water, and accessible regulating and cultural services. *Accessible* refers to the share of the 'total' or 'available' resource which can be used without damaging ecosystem capital capacity. All three groups of services are generally produced (in variable proportions) by all ecosystems. Accessible biomass/carbon and water together make up 99 per cent of all 'provisioning services' as described in the Millennium Ecosystem Assessment (MA) or Common International Classification of Ecosystem Services (CICES) classifications of ecosystem services. Biomass/carbon and water are recorded in formal balances while regulating and cultural services are measured indirectly on the basis of ecosystem capacity to deliver them (state of landscape green infrastructure and biodiversity). For each of these groups, the amount of services which can be used must be lower than the accessible surplus, which means that in terms of sustainable development there should not be significant trade-offs between these services.

**The primary ecosystem service is production of biomass** which can be generated and withdrawn (by agriculture, forestry, fisheries, etc.) up to a surplus which takes into account nature's own reproductive needs. The surplus corresponds to the current 'food of biodiversity' and the maintenance of bio-carbon stocks in soil and perennial vegetation, and which is required if the ecosystem is to be self-sustaining. Production of biomass must also be compatible with the maintenance of accessible water resources (e.g. limits to irrigation) and the bundle of services supplied by the green landscape infrastructure. Similarly, water can be abstracted only up to an accessible surplus, to ensure the good functioning of the water cycle, as well as biomass production, and the needs of landscapes and biodiversity; for example, a new reservoir destroys previous ecosystem functions, over-dimensioned irrigation infrastructures create risks of agricultural shortages in years with rainfall deficit. The development of landscape services may result in the reduction, for example, of biomass production because of subsequent falling yields — which will be recorded in the carbon/biomass account.

'**Accessible**' means that not all the available resource can be used because of physical constraints (a large part of the aquifers, flood water greater than needed for reservoirs replenishment), inappropriate location or timeliness, inappropriate quality, and because part of the annual service flow has to be left to the ecosystem for its own needs. In the case of services supplied by green landscape infrastructure, accessibility is dependent on the population which can access it and the inverse of landscape artificiality (including urban areas where most of the population on Europe lives). The concept of resource accessibility is particularly important regarding the demand for ecosystem services and the definition of robust indicators with clear definitions of the limits of sustainable use. Such indicators implemented at the appropriate scale can be associated with population data, considerably increasing their usefulness for policy making.

The calculation of **Total Ecosystem Potential, Net Change in TEP and Ecosystem Capital Degradation** summarises the state of the ecosystem capital. Total inland, sea and atmosphere ecosystem potential measured in the basic balance in tonnes of carbon is weighted by a set of composite indexes which reflect the external factors that limit carbon accessibility: Ecosystem Accessible Water Surplus (EAWS), Landscape Ecosystem Potential (LEP), River Ecosystem Potential ([2]) (REP) and Ecosystem Biodiversity Rating (EBR) (which combines green infrastructure and species diversity measurements). It results in a new unit called **EPUE** for **Ecosystem Potential Unit Equivalent**. Gain in EPUE means positive effects of restoration programmes and/or natural improvement, loss means degradation by activities and/or natural disturbance. Particular attention is given to the calculation of **Ecosystem Capital Degradation (ECD)** which is the result of economic activity and will be used in a subsequent step to calculate ecosystem capital depreciation. Ecosystem capital degradation is for that purpose analysed in a special table according to the stress factors that have caused it: land-cover change, restructuring/de-structuring of landscapes and rivers, over-exploitation of biological resources, waste disposal, and pollution. It is then possible to calculate, factor by factor, the cost of restoring one unit of EPUE. Depending on the ecosystems and issues being considered, costs will reflect reductions in yields, abatement of pollution (including GHGs), and programmes such as the replanting of hedgerows and reforestation. In the accounts, cost calculations are based on observed practices not on individual preferences.

## Back to GDP

Consumption of Ecosystem Capital is similar to Consumption of Fixed Capital (CFC) and should be treated in a similar way as a deduction when shifting from Gross Domestic Product to Net Domestic Product or Net National Income. Another approach is to consider that, unlike CFC, which is included in the value of economic assets and therefore transferred to the value of commodities, *CEC is not paid*. This means that CEC is not included in the purchaser price of Final Consumption, nor in Imports and Exports. This major price distortion can be corrected by adding up the unpaid CECs to calculate Final Consumption, Imports and Exports at Full Cost. This would not require changing the conventional calculation of GDP, the CEC price adjustment being balanced by an appropriate recording of ecological debts.

The proposed way of calculating ecosystem capital degradation (or CEC) diverges from dominant economic theory which defines depreciation as a loss in asset value which is equivalent (in the absence of reliable market prices for assets, which is generally the case for natural capital) to the discounted net expected future benefits (net present value). The difficulty of the latter method at the macro scale is that it implies assessment

([2]) In the case of rivers, the potential is equivalent to exergy (or accessible energy regarding water position or potential, its concentration in various substances and other elements such as temperature or speed — see Valero, 2006), measured in energy units.

and valuation of all individual services provided by the multiple functions of ecosystems and their aggregation without double counting. There is no evidence so far that this conventional method, implemented successfully in many case studies, can be used for national accounting. The proposed approach, which combines physical degradation and restoration costs, is probably just a surrogate for the one prescribed by economic theory, but its implementation seems feasible.

# 2 The simplified framework of ecosystem capital accounts

Experimental implementation of SECA in Europe and the preliminary discussions on ecosystem accounting at the international level have clarified the design of a simplified framework of ecosystem capital accounts. It has involved defining measurement and statistical units ([3]), classifications and an accounting structure.

## 2.1 Statistical units and classifications

Unlike analytical research and modelling, accounting requires crisp units with clear borders and stable classifications for compiling data and statistics and supporting comparisons in space and time (time series). The definition of such units and their classification is an essential preliminary step when defining an accounting framework.

### *2.1.1 Statistical units*

The SNA defines basic units as legal entities entitled with complete capacity of taking any economic decision regarding production, consumption, investment, acquisition of financial assets or liabilities, etc. These 'institutional units' are typically enterprises, central or local government institutions or households. Regarding production analysis, the SNA chooses smaller units which are better correlated to particular products or groups of products, or more homogenous. They are called 'establishments'. An establishment is a part of an enterprise that is situated in a single location and which engages predominantly in one kind of economic activity.

Equivalent units need to be defined for ecosystems. Using specific statistical units for ecosystems instead of using economic or administrative units is a major step forward. In principle, ecosystems range from the microscopic level to the global. However, as ecosystem accounts are part of environmental-economic accounts, and aim at being used jointly with the SNA, priority should be given to equivalent levels for defining statistical units for ecosystems.

The scientific literature suggests that the best unit to assess ecosystems is the 'socio-ecological system (SES)' (Gallopin, 1991, Glaser, 2008). SES integrates ecosystem functions and dynamics as well as human activities and the interactions of all these. The SES is equivalent to the SNA's institutional unit. Considering the production of ecosystem services, and in particular provisioning services, SESs are more or less homogenous. A large forest is at the same time a socio-ecological system with its own behaviour and a unit of production of timber and most other ecosystem services. A small forest that is part of a mosaic landscape with agriculture, villages and natural areas is certainly a production unit for timber, but delivers other services only in conjunction with the neighbouring units; it is influenced by its environment and has less autonomy. Such units can be considered as equivalent to the establishments defined by the SNA.

Once this equivalence between SNA entities and SESs is accepted, the task is to define such entities in practice. SES and ecosystem production units are defined by their capacities to generate services, on a range of spatial scales. For the production of statistics, units need to have clear boundaries. There may be coincidences between the competency of institutional units and biophysical entities corresponding to one or other type foreseen. For example a natural reserve often covers an ecosystem, or a forest may belong to one single owner. But this is not the general case and another solution had to be found.

For inland ecosystems, the solution has been to analyse the biophysical characteristics of the landscapes. The production level can be addressed by mapping land-cover units. These are defined by their composition in terms of basic bio-physical objects or patches (e.g. grass, shrub, tree, rock and other minerals, sand, ice, snow and water), the type of use (artificial, cultivated, non-cultivated) and landscape patterns (fragmented, connected, etc.). The methodology has been developed by FAO under the name Land Cover Classification System (LCCS). In Europe, the Corine Land Cover classification

([3]) Measurement units are typically hectares, joules, cubic meters, 'ppm' or euros or $. Statistical units are the entities for which statistics are collected — or accounts computed. They are typically enterprises and their establishments, government services or households.

follows similar principles and is being translated into the LCCS3 meta-language. One important point is that LCCS and Corine can be implemented using satellite images. The units for ecosystem accounting are named Land Cover Functional Units (LCFU).

Socio-Ecological Landscape Units (SELU) are produced in turn from LCFU and other geographical dimensions such as relief, belonging to a river basin, or proximity to the sea. LCFU are agglomerated with a methodology which maps dominant land-cover types. Large forests or agricultural areas will constitute a SELU in their own right while smaller units will be part of a larger zone characterised by its dominant land cover. The Dominant Land Cover Types are then classified according to river basins and relief classes (e.g. coastal, lowland, highland, mountain). The final intersection gives the map of terrestrial SELU.

Rivers are processed separately for accounting purposes. Rivers are land-cover units of a particular type where the dynamics of the water flow is the essence. In the case of rivers, the SELU will be the river system of the sub-basin. SELUs will be decomposed into drains (main drains, secondary drains) and segments (reaches) of homogenous water discharge.

In the case of seas, a distinction is made between the coastal zone, which is described as a 'seascape' that includes seabed features (as far as possible in conjunction with the coastal landscape). 'Open sea' is mapped according to various zonings, starting with fishery management areas ([4]).

The concept of **ecosystem services** can be found in the literature as far back as 1972 (Long, 1972). It was revitalised in the 1990s (Costanza, DeGroot, Daily…) and broadly used in the Millennium Ecosystem Assessment of 2006. Ecosystem services are defined as 'the contributions that nature makes to human well-being' (MA, 2006). In the case of the provisioning services, biomass products are usually measured in tonnes of carbon and water in cubic metres. The functional services, which are very heterogeneous, are measured as attributes of spatial units and weighted when relevant by population data. Here again, the concept of accessibility helps to switch focus from ecosystem functions to human well-being. The following definition is therefore proposed for accounting: **ecosystem services are the outcome of ecosystem functions which are accessible to people**.

### 2.1.2 *Classifications*

**Draft classifications** have been established, discussed in international meetings and will be submitted by the UNCEEA to global consultation. SECA implementation is based at this stage on the classifications in use in Europe.

- **The classification of Land Cover Functional Units (LCFU)** is being prepared jointly by FAO and the EEA. It is based on the multi-purpose classification of homogenous land-cover types adopted for SEEA volume 1 and consists of the development of an application fit for classifying real landscape units which are more or less heterogeneous or mixed at the scale of SECA implementation. The documentation of LCFU will use FAO's Land Cover Classification System version 3 which has been acknowledged as a standard in the SEEA revision. It will define acceptable thresholds of heterogeneity and, in the case of mixed landscapes, the rules by which land-cover types combine to produce a new LCFU class (e.g. agriculture-nature mosaics or natural mosaics of shrubs and grassland). The forthcoming LCFU standard will easily bridge with the European Corine Land Cover classification, which is currently used for SECA. The common reference to LCCS3 will also enable the development of variants of the core LCFU at different scales and/or in particular geographical

**Table 2.1 Land-cover types (first level) in SEEA volume 1**

| | |
|---|---|
| 01 | Artificial surfaces (including urban and associated areas) |
| 02 | Herbaceous crops |
| 03 | Woody crops |
| 04 | Multiple or layered crops |
| 05 | Grassland |
| 06 | Tree covered area |
| 07 | Mangroves |
| 08 | Shrub covered area |
| 09 | Aquatic or regularly flooded shrubs and/or herbaceous vegetation |
| 10 | Sparsely vegetated natural areas |
| 11 | Terrestrial barren land |
| 12 | Permanent snow and glaciers |
| 13 | Inland water bodies |
| 14 | Coastal water bodies and inter-tidal areas |

**Source:** FAO, 2011.

([4]) More on statistical units for ecosystem accounting can be found in: *Note on Statistical Units for Ecosystems*, Alessandra Alfieri, Daniel Clarke and Ivo Havinga, United Nations Statistics Division and Jean Louis Weber, European Environmental Agency, Expert Meeting on Ecosystem Accounting, 11–13 May 2011, European Environmental Agency, Copenhagen, Denmark http://unstats.un.org/unsd/envaccounting/seearev/meetingMay2011/lod.htm.

**Table 2.2 Aggregated Corine Land Cover used in Europe for LEAC and SECA**

| | |
|---|---|
| 1 | Artificial surfaces |
| 2A | Arable land & permanent crops |
| 2B | Pastures & mosaic farmland |
| 3A | Forests and transitional woodland |
| 3B | Natural grassland, heathland, sclerophylous ([a]) vegetation |
| 3C | Open space with little or no vegetation |
| 4 | Wetlands |
| 5 | Water bodies |

**Note:** ([a]) Vegetation that flourishes in hot dry areas.

**Source:** EEA, 2006.

contexts requiring more detail, while keeping the overall classification consistency.

- **The classification of ecotones** (the zones between major ecological communities) is derived from LCFU.
- **The draft Classification of Land Cover Flows (LF)** used in SECA is derived directly from the classification defined and used in the Land and Ecosystem Accounts (LEAC) report of 2006, the data of which were updated in 2011.
- **A provisional classification of Socio-Ecological Landscape Units (SELU)** has been established for test and discussion. The version below (Table 2.4) builds upon Corine land cover and LEAC methodologies for the definition of dominant land-cover types and relief classes. The classification of rivers and rivers basins is taken from the EEA's ECRINS database.

**Table 2.3 Provisional land-cover flow classification used in Europe for SECA**

| | |
|---|---|
| **lf1 Land development processes, urban sprawl, expansion of intensive land use** | |
| lf11 | Artificial development over agriculture |
| lf12 | Artificial development over forests |
| lf13 | Artificial development of other natural land cover |
| lf14 | Conversion from small field agriculture and pasture to broad pattern cropland |
| lf15 | Conversion from forest to agriculture |
| lf16 | Conversion from marginal land to agriculture |
| lf17 | Water body creation and management |
| **lf2 Land restoration processes** | |
| lf21 | Conversion from crops to set aside, fallow land and pasture |
| lf22 | Withdrawal of farming |
| lf23 | Forest creation, afforestation of agriculture land |
| **lf3 Rotations, natural processes and steady state** | |
| lf31 | Internal conversion of artificial surfaces |
| lf32 | Internal conversion between agriculture crop types |
| lf33 | Recent tree clearing and forest transition |
| lf34 | Forest conversions and recruitment |
| lf35 | Changes of land-cover due to natural and multiple causes |
| **lf4 No observed land-cover change** | |

**Table 2.4 Provisional classification of Socio-Ecological Landscape Units (SELU)**

| | |
|---|---|
| **1. Mountain ecosystem landscapes** | |
| 1.1 | Urban and associated developed areas |
| 1.2 | Broad pattern agriculture |
| 1.3 | Agriculture associations and mosaics |
| 1.4 | Pastures and natural grassland |
| 1.5 | Forest tree cover |
| 1.6 | Other dominant natural land cover |
| 1.7 | Composite land cover (no dominant land cover) |
| **2. Highland ecosystem landscapes** | |
| 2.1 | Urban and associated developed areas |
| 2.2 | Broad pattern agriculture |
| 2.3 | Agriculture associations and mosaics |
| 2.4 | Pastures and natural grassland |
| 2.5 | Forest tree cover |
| 2.6 | Other dominant natural land cover |
| 2.7 | Composite land cover (no dominant land cover) |
| **3. Lowland ecosystems (inland) landscapes** | |
| 3.1 | Urban and associated developed areas |
| 3.2 | Broad pattern agriculture |
| 3.3 | Agriculture associations and mosaics |
| 3.4 | Pastures and natural grassland |
| 3.5 | Forest tree cover |
| 3.6 | Other dominant natural land cover |
| 3.7 | Composite land cover (no dominant land cover) |
| **4. Coastal landscapes** | |
| 4.1 | Urban and associated developed areas |
| 4.2 | Broad pattern agriculture |
| 4.3 | Agriculture associations and mosaics |
| 4.4 | Pastures and natural grassland |
| 4.5 | Forest tree cover |
| 4.6 | Other dominant natural land cover |
| 4.7 | Composite land cover (no dominant land cover) |
| **5. River systems** | |

- **Provisional Common International Classification of Ecosystem Services (CICES)**

  In December 2008, EEA, together with UNEP and the German Federal Ministry of Environment, convened an international expert meeting on the project of a Common International Classification of Ecosystem Services (CICES). The need for such a standard results from the multiple global initiatives related to assessment and accounting of ecosystem services such as IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services), TEEB, MA follow-up, the **Eur**opean **ec**osystem **a**ssessment (Eureca!2012), many national assessments, Green Economics, PES and IPES (Payments and International Payments for Ecosystem Services), SEBI2010, the SEEA2003 revision and the European Strategy on Environmental Accounting. CICES is expected foster synergies and bring together the diverse approaches taken to quantify and value ecosystem services.

  Discussions took place at two international workshops on CICES hosted by the EEA in Copenhagen in December 2008 and 2009 and in an e-forum from November 2009 to January 2010, designed to enable a wider international audience to comment on the issues relating to the CICES concept. CICES was presented for information to the UNCEEA meeting of June 2010. The consultation is continuing.

  CICES has been cross-referenced with CPC, the UN Common Products Classification.

**Table 2.5 Provisional common international classification of ecosystem services**

| Theme | Class | Group |
|---|---|---|
| **Provisioning** | Nutrition | Terrestrial plant and animal foodstuffs |
| | | Freshwater plant and animal foodstuffs |
| | | Marine plant and animal foodstuffs |
| | | Potable water |
| | Materials | Biotic materials |
| | | Abiotic materials |
| | Energy | Renewable biofuels |
| | | Renewable abiotic energy sources |
| **Regulation and maintenance** | Regulation of wastes | Bioremediation |
| | | Dilution and sequestration |
| | Flow regulation | Air flow regulation |
| | | Water flow regulation |
| | | Mass flow regulation |
| | Regulation of physical environment | Atmospheric regulation |
| | | Water quality regulation |
| | | Pedogenesis and soil quality regulation |
| | Regulation of biotic environment | Lifecycle maintenance and habitat protection |
| | | Pest and disease control |
| | | Gene pool protection |
| **Cultural** | Symbolic | Aesthetic, Heritage |
| | | Religious and spiritual |
| | Intellectual and Experiential | Recreation and community activities |
| | | Information & knowledge |

### 2.1.3 Grids

Although not statistical units in their own right, grids must be mentioned as important features of simplified ecosystem capital accounts. In Europe, the INSPIRE Regulation defines a standard grid which is highly important when combining data from very diverse sources is needed — a constant in ecosystem accounting — or when analysis requires different scales or geographical breakdowns. In

**Figure 2.1 Simplified ecosystem capital accounting structure (SECA)**

| | Tables by ecosystem units | | Tables by economic units |
|---|---|---|---|
| Analytical and reporting units, classifications | ***Countries and biophysical geographical breakdowns or administrative regions*** | ⟵ ⟶ | ***Countries and administrative regions or biophysical geographical breakdowns*** |
| | ***Ecosystem statistical and accounting units: socio-ecological landscape units, elementary functional units (land cover, river reaches...), ecosystem assets, ecosystem service units*** | ⟵ ⟶ | **Economic statistical and accounting units: institutional units, establishments, economic assets, commodities** |
| | **[A] Land-cover stocks and flows basic account:** Gross and Net Land-Cover Change | ⟵ ⟶ | Land-use statistics |
| Basic accounts | **[B] Ecosystem Capital Carbon/biomass Account:** Net Ecosystem Carbon Balance (NECB) & Net Ecosystem Accessible Carbon Surplus (NEACS) | ⟵ ⟶ | Physical supply and use tables, and economic assets accounts. Agriculture, forestry and fishery statistics |
| | **[C] Ecosystem Capital Water Account:** Total Ecosystem Accessible Fresh Water Surplus (TEAWS) & Net Ecosystem Accessible Fresh Water Surplus (NEAWS) | ⟵ ⟶ | Physical supply and use tables & economic assets accounts Water use statistics |
| | **[D] Landscape Green Infrastructure Account:** Landscape Ecosystem Potential (LEP), Green Accessible Landscape Infrastructure (GALI) & Rivers Ecosystem Potential (REP) | | |
| | **[E] Ecosystem Capital Biodiversity Account:** Biodiversity Infrastructure Integrity (BII) & Ecosystem's Biodiversity Rating (EBR) | | |
| Ecosystem total potential | **[F1] Ecosystem Total Potential Account, Net Change & Ecosystem Capital Degradation (ECD),** in Ecosystem Potential Unit Equivalents (EPUE) | | |
| | **[F2] Account of Territorial Ecosystem Capital Degradation (TECD) by Stress Factors** (in EPUE) | | |
| | **[G] Demand and Accessibility to Ecosystem Services:** Ecosystem Carbon/biomass, Ecosystem Fresh Water, Green Infrastructure Neighbourhood Ecosystem Services (GINES) | | |
| | **[H] Ecosystem Physical Balance Sheet: Stocks and Change of Non-Financial and Financial Assets & Physical Liabilities,** in EPUE | | |
| Ecosystem depreciation | **[I] Estimation of unit costs of ecosystem capital restoration by Stress Factors** | ⟵ ⟶ | Environmental protection and management expenditure (part) |
| | **[J] Ecosystem Capital Depreciation:** Territorial Consumption of Ecosystem Capital in money | | |
| | | | **[K] Account of Ecosystem Capital Degradation & Depreciation Embedded into Imports and Exports,** in EPUE and in money |
| | **[L] Sustainable Ecosystem Services Macro-economic Benefits: Ecologically Sustainable Total Induced Value Added (ES-TIVA)** (by SELU and ISIC) | | |
| | | | **[M] Economic aggregates and additional adjustments for CEC, in money: Gross Domestic Consumption of Ecosystem Capital (GDCEC), GDCEC Adjusted Net Domestic Product, Final Consumption at Full Price (including NDCEC)** |
| | **[N] Ecosystem Monetary Balance Sheet: Stocks and Change of Ecosystem Financial Assets and Liabilities, in Euro** | | |

addition, grid data (raster) are faster to compute with GIS than vector data. The most widely-used grid for accounting purposes is 1 km x 1 km. The 0.1 km x 0.1 km (1 ha) grid can also be used, but much less data is available at this scale.

## 2.2 The accounting structure of simplified ecosystem capital accounts

Simplified ecosystem capital accounts include tables in both physical and monetary units. Some of these tables are directly connected to SEEA volume 1 tables where breakdowns are mostly presented by economic sector and are, in that way, indirectly bridged to the SNA itself (in particular regarding supply and use and input-output tables). Other tables link back directly to the SNA.

The following sections comment on the various tables one by one. The tables are presented separately in a spreadsheet with mock-up numbers aiming to facilitate ease of understanding (see Annex 2). The accounting structure is summarised in Figure 2.1.

## 2.3 The physical accounting tables

### 2.3.1 *The basic balances*

**Table [A] Land-cover stocks and flows basic account**

This account measures, in km², the land-cover stocks and changes in the ecosystem statistical units used for accounting.

**Land-cover stocks**: artificial surfaces, large to medium farm arable land and permanent crops, pastures, mosaic farmland (small farms, mixed land cover), forest cover, natural grassland, scrubland, natural mosaics, open space with little or no vegetation, wetlands and water bodies.

Elementary one-to-one land-cover changes are grouped into **land-cover flows**: land development processes, urban sprawl, land-use intensification, land restoration processes, rotations, natural processes and steady state.

Land-cover flows are **indicators of land-cover consumption** (regarding the opening year) **and new formation** (in the closing year).

Produced from satellite images, land-cover accounts can be reported at various scales, regarding various types of natural or administrative zonings and by regular grids (1 x 1 km or 0.1 km x 0.1 km). Their organisation plays a central role in organising the whole system of inland ecosystem accounts.

**Table [B] Ecosystem capital carbon/biomass account**

The ecosystem capital carbon/biomass account measures the Net Ecosystem Accessible Carbon Surplus (NEACS) in soil, vegetation and fisheries and its use.

The account records, in tonnes of carbon, the stocks available in soil, below-ground and above-ground vegetation and in water (fish). It records the flows of Net Primary Production (NPP) by natural and cultivated vegetation, and its use by crops and timber harvests. In addition to inland ecosystems, the accounts covers sea (fisheries and sea regulating capacity) and the atmosphere's climate regulation capacity which is a measure of the amount of fossil carbon accessible without increasing mean global temperature beyond the stated target of a maximum of 2 degrees Celsius.

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

- **NPP and its removal** by agriculture, forestry and fisheries, which indicates the availability of these provisioning ecosystem services;
- the **Net Ecosystem Carbon Balance (NECB)** which indicates the sustainability of carbon/ biomass use; in principle, NECB should be always greater than or equal to zero;
- **Net Ecosystem Accessible Carbon Surplus (NEACS)** which measures the share of available ecosystem production of carbon which meets the sustainability constraints of maintaining stocks in soils and vegetation (mostly in trees) and fisheries; in addition to inland and sea ecosystems, NEACS includes the fossil carbon accessible under constraint of maintenance of the atmosphere's climate regulation functions.
- The Ecosystem Accessible Carbon Surplus index summarises the sustainability of total carbon use (removal of biological carbon plus use of fossil carbon) compared to the accessible resource (NEACS). The ratio NEACS/Use should be always greater than zero.

Because of the primary character of biomass ecosystem production and the comprehensive coverage of carbon/biomass accounts, they play a central role in ecosystem capital accounts. Carbon/biomass is the primary service expected from the ecosystem, under the constraint of sustainable supply of water (for human use and the ecosystem itself) as well as sustainability of all the regulating (water regulation, assimilation of residuals, habitat regulation, pollination) and socio-cultural services which are produced.

Carbon/biomass use and ownership can also be detailed by economic sectors, which is done in another part of the SEEA, so-called the 'supply and use tables' and 'asset accounts'. Carbon/biomass can in that way be brought together with the SNA tables in money terms ('supply and use' and 'input-output') for hybrid analysis and modelling.

The use of biological and fossil carbon can be or is recorded in national accounts by economic sectors and commodity content (embedded carbon). Carbon/biomass accounts are therefore an essential element to broaden the scope of **resource efficiency indicators** towards integrating impacts on the ecosystem (the 'second decoupling' paradigm).

**Table [C] Ecosystem Capital Water Account**

The account measures the Total Ecosystem Accessible Fresh Water (TEAW) and the Net Ecosystem Accessible Fresh Water Surplus (NEAWS) adjusted for water stress during the vegetation growing season.

Accounts in $m^3$ are established for water stocks in terrestrial ecosystems (soil and vegetation) and water bodies (aquifers, lakes and dams, rivers). They include a distinction between total and accessible stocks, the difference being due to physical or economic constraints of abstraction, pollution or time mismatch between availability and requirements for natural or human uses.

The water flow accounts are tracked from precipitation infiltration and runoff down to the final outflow. Total available *effective* rainfall (in hydrological terms), which is available to feed the water bodies, is precipitation minus Evapo-Transpiration (ETa). ETa is subdivided into 'spontaneous' and 'induced by irrigation and other uses'. 'Spontaneous' ETa is further subdivided into 'induced by rain-fed cultivated vegetation' and 'induced by non-cultivated vegetation'. Total available effective rainfall is further analysed to take account of inaccessible water due to events like floods, wastewater disposal and dilution, additional ETa induced by irrigation, and evaporation induced by power plants cooling towers or reservoirs. Total ecosystem accessible fresh water can then be computed after appropriate adjustments to take account of water transfers between ecosystems and within or between river basins. A final adjustment is then made to reflect the timeliness of the water resource regarding vegetation requirements.

The characteristic indicators of water accounts are:

- Total available effective rainfall, calculated from a hydrological perspective (water available for runoff), before evapo-transpiration induced by irrigation and evaporation induced by other uses;
- Withdrawals of water (by ecosystems, catchments and economic sectors);
- Returns of wastewater, an additional although degraded resource and a cost regarding maintenance of ecosystem water quality. Taking into account the acceptable dilution of pollutants (maximum concentration, BOD), untreated wastewater returning to water bodies can reduce the accessibility of fresh water by several times the amount of wastewater discharged;
- Returns of water to soil due to losses in transport and irrigation;
- Total Ecosystem Accessible Water: TEAW is the accounting balancing item of stocks and flows;
- Water Stress Coefficient is an additional adjustment needed to reflect the timeliness over the year of water accessibility considering vegetation requirements, in particular during the growing period;
- Net Ecosystem Accessible Fresh Water Surplus.

The final aggregate is called **Net Ecosystem Accessible Fresh Water Surplus (NEAWS)**. It can be compared to the withdrawals of freshwater to measure the intensity of use of the water resource. The ratio Withdrawals/NEAWS should always be < 1. A lower target value is likely to be needed in order to take stock of 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 [D] Landscape green infrastructure accounts**

These accounts measure the capacity or potential of ecosystems to deliver ecosystem services in a sustainable way. Typical indicators are Landscape Ecosystem Potential (LEP), Green Accessible Landscape Infrastructure (GALI) and Rivers Ecosystem Potential (REP). They reflect the fact that sustainable provision of carbon/biomass and water has to be compatible with the good functioning of ecological infrastructure, landscapes and rivers and that access to the many ecosystem regulating and socio-cultural services is better measured in the first instance by the abundance and health of the ecosystems which deliver them to people. Ecosystem health is assessed following the principles developed by David J. Rapport in his description of the 'ecosystem distress syndrome' (Rapport 2007).

In contrast to provisioning services, regulating and cultural services cannot be harvested or abstracted and consumed. Their value in the economy is seen as an attribute of land which is not measured directly but bound up with the values of real estate and/or related goods and services. Disentangling such ecosystem services from market values has been done in many case studies for selected services. However, there is as yet no evidence that such case studies can be up-scaled to the macro level of national accounts. Service-specific accounts have been generated successfully on a one by one basis but there is no evidence that double counting when aggregating several of these services can be avoided or that the full range of ecosystem services can be covered. Simplified ecosystem capital accounts therefore start by measuring, in a holistic way, the capacity of the capital to continue to deliver any service over time. This approach does not preclude the development of local and/or service-specific accounts but offers instead a starting point and background information for such exercises.

The characteristic indicators of landscape green infrastructure accounts are:

- The Green Background Landscape (GBL) index, which weights hectares of land cover according to their 'greenness'. Because the greenness of an ecosystem service is important not only in each place but also in its neighbourhood, the calculation is based on fuzzy logic (smoothed values);

- The Mesh Effective Size (MEFF) index, which measures the partitioning effects of landscape fragmentation by urban areas and transport infrastructures. Small meshes limit good ecological functioning;

- The Stated Social Nature Value (SSNV) index, which reflects the importance of biodiversity for society as expressed in terms of landscape protection;

- **Landscape Ecosystem Potential (LEP)** a multi-criterion index which combines GBL, MEFF and SSNV;

- The Green Ecotones Index, based not on the surface area of land-cover units but on the length of their borders which concentrate higher animal and plant biodiversity. The ecotone classes are weighted according to their potential for hosting biodiversity;

- **The Green Accessible Landscape Infrastructure index (GALI)** is a composite index which combines GBL and the green ecotones indexes;

- The River Infrastructure Potential, which measures the capacity to deliver water and related services of large, medium and small rivers and brooks and streams; it is measured in a common unit named 'standard-river km' (1 srkm = 1 km x 1 $m^3$/second);

- The River Integrity Composite index, which combines indexes of water quality, river fragmentation and river green ecotones.

- **Rivers Ecosystem Potential (REP)**, a composite index combining river infrastructure potential and integrity. REP connects landscapes to water accounts.

All indexes are produced from spatial analysis and assimilated into a regular grid (typically 1 $km^2$ cells at the macro level, 1 hectare at the local level) which facilitates the detection of interactions, potentials and degradation. In a second step, elementary and/or composite indexes can be aggregated by regions, catchments etc.

**Table [E] Ecosystem Capital Biodiversity Account**

This account brings together biodiversity variables measured from the standpoints of landscape and species/biotopes. The first sub-account of **Biodiversity Infrastructure Integrity (BII)** is a continuation of Table [D] from which it is computed. It is supplemented by a second sub-account based on species and biotope monitoring which is used for producing a diagnosis of ecosystem health or distress (Rapport, 1999). Several methods can be accepted for that, the aim being to assess ecosystem health regarding biodiversity, not biodiversity per se. Finally, the **Ecosystem Biodiversity Rating (EBR)** combines landscape and species/biotope indexes.

### 2.3.2 *Synthesis tables in physical units: Total Ecosystem Capital Potential and Physical Balance Sheet (Assets and Liabilities)*

The ultimate purpose of ecosystem capital accounts is to assess whether economic use of ecosystems results in an increase and/or improvement, a steady state, or a degradation of the natural assets which together are used as economic resources, consumed by the economy as free externalities, and/or directly supply a range of free services to individuals or humankind as a whole. As the measurement of ecosystem capital on the basis of private benefits is necessarily incomplete, it can be misleading. Ecosystems are multifunctional and the core of the issue is that using one particular function or service most often results in the degradation and even elimination of one or all the others. The other possible approach is to look at the capital as a bio-physical system and assess its ability to continue to deliver its services.

As noted above, the SECA model considers three groups of services: biomass/carbon production, freshwater production and functional services. It measures, for each of them, the amount that is accessible regarding the (maximum) accessible surplus that can be used without impairing the reproduction of nature itself and the need to ensure that the use of one of these services does not degrade access to the others. For each group, it is an issue of maximisation of the resource in the presence of internal and external constraints. As the three assets and their services are not measured in additive units, one has to be chosen as the primary one. The proposal is that this should be biomass/carbon, the primary component of life, encompassing food, fibre and energy. The narrative of SECA is then as follows: **ecosystem capital is measured by the stocks of accessible biomass/carbon adjusted in the light of constraints of freshwater accessibility, maintenance of landscape and river potentials and biodiversity conservation**.

**Table [F1] Total Ecosystem Capital Potential Account**

This table presents the calculation of Net Total Ecosystem Capital Potential (NTECP) and Net Change and Territorial Ecosystem Capital Degradation (TECD). The starting point is given by table [B]. The balancing item 'Net Ecosystem Accessible Carbon Surplus' (NEACS) is taken as a surrogate measure of the gross ecosystem capital potential of inland, sea and atmosphere ecosystems. In simplified accounts it covers the accessible carbon of terrestrial ecosystems, sea (fisheries) and the atmosphere's capacity to assimilate carbon. Estimation of similar assimilation capacity should be done for the sea. River system potential also needs to be measured in a consistent way and added to the gross total potential. A possible solution is to assess the exergy (accessible energy) potential of rivers following the approach to water accounting in Spain developed by Naredo, Valero et al. (Valero, 2006). An important point is that this work starts from accounts of river stocks which are identical to the River Infrastructure Potential of Table [C] in terms of 'standard-river km' (1 srkm = 1 km x 1 $m^3$/second). The solution would be to convert 'srkm' measurements into exergy potential and then into carbon unit-equivalents.

At this stage, 'gross' means prior to integration into the calculation of the other factors that limit the accessibility of the carbon resource: access to other services and maintenance of ecosystem functions. This integration will be done by weighting the gross potential with indexes extracted from tables [C], [D] and [E]: Ecosystem Accessible Water Surplus (EAWS), Landscape Ecosystem Potential (LEP), Rivers Ecosystem Potential (REP) and Ecosystem Biodiversity Rating (EBR). Several options are available for combining the various indexes into a 'limiting factors index' to weight the gross potential, including average values or more elaborate methods e.g. Bayesian belief network decision trees. The final decision will have to take into consideration that it is more important to quantify change than to quantify stocks; sensitivity analysis will be necessary to establish the final methodology.

By weighting the initial carbon balance with the limiting factors index, we create a measurement unit of general application which we will call Ecosystem Potential Unit Equivalents (EPUE).

Within an economic territory (using the SNA definition), Net Total Ecosystem Capital Potential (NTECP) can increase or decrease. An increase reflects ecosystem improvement due to restoration programmes or spontaneous natural processes. A decrease can be the effect of natural disturbances or ecosystem degradation. Ecosystem Capital Degradation (ECD) is thus defined in a strict way as the consequence (effect, impact) of human activities.

**Table [F2] Account of Territorial Ecosystem Capital Degradation (TECD) by Stress Factors**

Table [F2] analyses TECD by stress factors.

Stress factors are: effect of land-cover change, restructuring/de-structuring of landscapes and rivers, over-exploitation of biological resources, waste disposal and pollution (including GHGs). The link to sectoral accounts is through the rows of supply and use tables detailing the generation of pollutants and emissions of residuals and the more elaborated hybrid input-output tables ([5]) (combining physical and monetary data). Other links are with land-use accounts which bridge to agriculture and forestry statistics of crop yields and farming and management practices, and with fisheries accounts and statistics.

Table [F2] is used later when calculating ecosystem capital depreciation (see tables [I] and [J]).

**Table [H] Physical Balance Sheet: Assets and Liabilities**

The Ecosystem Capital Physical Balance Sheet brings together the physical ecosystem assets (from Table [F1]) and the physical debts or liabilities that the economy contracts to future generation when degrading nature. This concept of physical liability does not exist in the SNA where both financial and non-financial assets are balanced by debts which are all recorded in the financial tables. This practice conforms to the analysis of the economic system. In ecosystem accounts, as long as some costs are not paid by the economy, it is necessary first to record the physical degradation as a liability. Then, Table [H] is supplemented with a second balance sheet in money terms. This prevents changes in natural asset value being seen as resulting in an improvement in the situation when physical degradation is not remediated or compensated.

The physical balance sheet is established in Ecosystem Potential Unit Equivalents (EPUE) — see Section 1.2.

It presents:

- physical ecosystem *assets* accounts where the opening balance is the initial Net Total Ecosystem Capital Potential; Change in Ecosystem Potential Due to Economic Activities, Other Change in Potential of Ecosystem Capital make Net Change in Physical Ecosystem Assets leading to the closing balance (the resulting NTECP);
- physical *liabilities* accounts include, as the opening balance, NTECP plus international national and private Ecosystem Restoration Targets (recovery from historical damage, compliance with conventions/regulations) endorsed by society. Changes are due to Territorial Ecosystem Capital Degradation (TECD), Ecosystem Capital Degradation in 'consumed imports', and, in the opposite direction, reduction of physical liabilities by ecosystem restoration programmes and spontaneous natural improvement of ecosystems, reduction of physical liabilities by acquisition of EPUE (mitigation/compensation), and reduction in physical liabilities by swaps and debt consolidation. Opening balance sheet plus Net change in physical liabilities makes the Closing balance sheet item for physical liabilities.

**Table [G] Demand for and Accessibility to Ecosystem Services**

Table [G] details the demand for and accessibility to Carbon/Biomass, Fresh Water, and Green Infrastructure Neighbourhood Ecosystem Services (GINES). The tables are presented by ecosystem type and include population data in order to calculate accessible ecosystem services per capita. Accessible Carbon/Biomass and Accessible Fresh Water were presented in Tables [B] and [C] respectively. When referring to local or gridded population data, the indicators represent accessibility in the place (ecosystem or grid-cell) or in the neighbourhood when using fuzzy datasets (e.g. data smoothed over a radius of 5 km) ([6]).

([5]) Known in Europe under the acronym of NAMEA.
([6]) See EEA, 2006.

Green Infrastructure Neighbourhood Ecosystem Services (GINES) is derived from Tables [D] and [E]. It is an over-arching indicator which assumes a direct relationship between ecosystem health and the availability of regulating and cultural ecosystem services. Its calculation takes into account the fact that landscape artificial intensity reduces the supply of green infrastructure services and, at the same time, increases the number of potential beneficiaries (because of neighbourhood or easier access by transport infrastructures). Not surprisingly, medium-size human settlements will be the best performers regarding accessible GINES.

GINES are not only interesting per se. As long as they can be computed by Socio-Ecological Landscape Units and/or grid-cells and reported by river basins and administrative units, GINES can be balanced with other variables in trade-off analysis. The first of these are Accessible Carbon/biomass and Accessible Fresh Water as well as Net Total Ecosystem Capital Potential and Territorial Ecosystem Capital Degradation.

## 2.4 The monetary accounting tables

Monetary accounts for ecosystem capital and services will be developed on top of physical accounts. As noted by the UNCEEA in June 2011, not all possible valuation methods are relevant to national accounting, only those that are compatible with the SNA rules.

Compatibility with the SNA excludes some methods frequently used in cost-benefit analysis (typically 'contingent valuation') because of different definition of value itself (based on observable transaction prices in the SNA, on willingness to pay in CBA) and of up-scaling and aggregation issues (Weber, 2011a). It does not, however, exclude the estimation of important economic variables in the absence of directly observable transactions. This is the case for 'government services' which are valued by the total of production costs (but exclude any operating surplus), the production of food products for own use (value using the basic price in farms, not at purchaser price of similar products), etc.

One particularly interesting variable which has to be estimated is Consumption of Fixed Capital (CFC), the equivalent in SNA to capital depreciation in business financial accounting. CFC is the accounting item which makes the difference between the Product and Income concepts. According to the International Accounting Board standard, capital depreciation *must* be subtracted when calculating a company's profit. The point is that consumption of ecosystem capital is not subtracted in the same way, because it is considered as an externality, a cost to be borne by society, not by those responsible for the ecosystem degradation. It is an unpaid cost which biases the estimation of growth and progress given by the conventional national accounts aggregates: Net Domestic Product or National Income — which are overestimated, and Final Consumption (and Imports) — which are underestimated, leading to the well-known distortions of consumption patterns and international trade (Chichilnisky, 1994).

Paying for ecosystem capital depreciation is however an idea at work in several areas:

- A prime example is the Clean Development Mechanism of the Convention on Climate Change which is based on accounting for carbon and $CO_2$. The target of 'maximum temperature increase of 2 degrees' refers to degradation of the atmosphere ecosystem. The cost of keeping below this target is 'ecosystem capital consumption'.

- Reducing Emissions from Deforestation and forest Degradation (REDD) was originally framed as payments for a particular ecosystem service (carbon sequestration by forests) and has moved to REDD+, which considers ecosystem capital degradation more holistically (to avoid biological and other leakages).

- Another example is given by the European Environmental Liability Directive of 2004 and the shift in the Polluter Pays Principle from pressures towards ecosystem impacts. The remediation costs of these impacts are ecosystem capital consumption.

- A similar approach has been taken in the European Water Framework Directive with the over-arching targets of 'good environmental quality of the river basins' (to be quantified and for which costs of remediation measures have to be estimated by Member States) and 'full recovery of costs' in water pricing.

- Wetlands Mitigation Banking in USA is another example where 'accounts' are established for 'ecosystem service areas' defined as 'the designated geographic area in which a bank can reasonably be expected to provide appropriate compensation for unavoidable impacts to wetlands.' The 'determination of credits' in a 'wetland bank' is based on accounts of physical characteristics and capacity to deliver services which 'include acreage, category type, and/or function'. The need for credits for mitigating damage is assessed by a certification process based on a symmetric accounting of the amount to be replaced regarding expected damages. This is the basis of a market mechanism where credit values are established.

- Other examples can be found in timber certification mechanisms and last but not least in the expanding 'fair trade' market voluntarily supported by more and more consumers. We should pay the real price of what we consume.

Till now, integrating unpaid costs into retrospective national accounts has been rejected by national accountants on the grounds that it would implicitly modify the prices-consumption structure which has led to a particular GDP amount. We cannot re-write the past (which is observed by statisticians) and such adjustments should be envisaged only for modelling the future (Bosch, Brouwer, Radermacher et al.,1997; or Vanoli, 2005).

While it is certainly not possible to modify the past as recorded in national accounts, there is a solution for taking stock of unpaid consumption which is to record it as a debt. For that purpose, monetary accounts for ecosystem capital include a detailed financial balance sheet.

**[I] Estimation of unit costs of ecosystem capital restoration by stress factors**

The estimation follows the structure of Table [F2] of physical degradation by stress factors. In Table [I], unitary costs per EPUE are derived from analysis of real expenditures or costs of restoration programmes. Such work relies on the expertise of environmental agencies, water agencies, agronomists, foresters, etc, doing such calculations in their daily work. Estimates of unitary costs have to be carried out by ecosystem types/issues/regions.

**[J] Territorial Ecosystem Capital Depreciation**

Table [J] presents the estimation of **Territorial Consumption of Ecosystem Capital (TCEC)** in money. TCEC is calculated as degradation in EPUE multiplied by unitary remediation costs by ecosystem types/issues/regions.

**[K] Accounts of Ecosystem Capital Degradation & Depreciation Embedded in Imports & Exports**

The accounts of the SNA are compiled for resident institutional units grouped into institutional sectors and subsectors. Together these describe the Domestic rather than National (used for qualifying Income) or Territorial economy (which applies to the physical world). An institutional unit is resident in a country when it has a centre of economic interest in the territory of that country. Resident units may have temporary activities in the rest of the world, and may import and export commodities. In terms of ecosystem capital degradation, this means that the territorial approach should be broadened to take account of the effects of the domestic economy on the rest of the world, in particular from the use of natural resources and the degradation that this may generate in the producing country. This can be due to uneven level of environmental protection or uneven robustness of property systems (Chichilnisky, 1994) which results in flows of ecosystem capital consumption embedded in international trade (Koellner, 2011). These embedded flows must be measured and valued in an appropriate way, which is the purpose of Table [K]. Virtual or embedded land in 'consumed imports' (Van der Sleen, in Koellner, 2011) is recorded first as data infrastructure, then as ecosystem capital degradation embedded in imports of agriculture, forest, and fishery products and carbon embedded in the production of all imported products. Ecosystem capital degradation embedded in imports (in EPUE) is then converted into 'unpaid ecosystem depreciation' in 'consumed imports' in money terms. At this stage, remediation costs should be estimated on the basis of prices in the importing country.

**[L] Sustainable Macro-economic Benefits from Ecosystem Services**

The macro approach chosen for simplified ecosystem capital accounts in Europe results in a service-by-service assessment of selected benefits. Ad hoc calculations can be well supported by the physical accounts presented above. Some of these can be done for specific services and integrated into the SECA framework. We propose to start with provisioning services, following recent experiences in Zanzibar (Lange & Jiddawi, 2009) and for the Mediterranean Sea (Plan Bleu, 2010). The methodology currently tested at the EEA ([7])

([7]) Acosta, J., Pedersen, O. G. and Weber, J.-L., 'Ecologically Sustainable Total Induced Value Added', draft, EEA and European Topic Centre on Sustainable Consumption and Production (ETC-SCP), Copenhagen, 2011.

is called 'hypothetical extraction' of value-added from input-output tables (I-OT). The I-OT are those compiled for Europe by Eurostat for 1995 to 2005. The first result expected is the Total Induced Value Added of key sectors, starting with agriculture and the food industry, followed by forestry, fisheries and water management. In a second step, TIVA is planned to be adjusted with an index of ecosystem capital degradation for the respective sectors, leading to **Ecologically Sustainable Total Induced Value Added (ES-TIVA).** Note that the ES-TIVA for the various sectors cannot be added together without double counting.

### [M] Economic aggregates and additional adjustments for Consumption of Ecosystem Capital (CEC)

Table [M] takes over the conventional SNA aggregates and the Consumption of Fixed Capital. It appends the summary of ecosystem capital calculation: Territorial Consumption of Ecosystem Capital plus Ecosystem Capital Depreciation virtually embedded in imports equals **Gross Domestic Consumption of Ecosystem Capital (GDCEC)**. GDCEC minus Ecosystem Capital Depreciation virtually embedded in exports equals Net Domestic Consumption of Ecosystem Capital.

Finally, Table [M] proposes additional macroeconomic aggregates adjusted for ecosystem depreciation. They are **GDCEC Adjusted Net Domestic Product or National Income, Final Consumption at Full Price** (which includes NDCEC)**, Imports at Full Price and Export at Full Price.**

### [N] Monetary Balance Sheet: Assets and Liabilities

Table [N] is the Monetary Balance Sheet of ecosystem Assets and Liabilities. To a large extent, Table [N] mirrors Table [H], the Physical Balance Sheet. The two separate balance sheets are necessary as long as SECA does not postulate that ecosystem capital degradation can automatically be compensated by an expenditure. Instead, SECA considers remediation costs as an estimate (in the way Fixed Capital Consumption is an estimate) of the amount which should be reinvested in the next period to repair the observed degradation. If degradation persists despite restoration action, a new Consumption of Fixed capital will be calculated accordingly. The relative evolution of physical and monetary liabilities, in the territory and in the rest of the world, is likely to become an important assessment variable ([8]).

On the asset side, one must note that no calculation of total ecosystem capital potential monetary value is foreseen. The remediation costs represent the costs of restoring the ecosystem, which at some moment will be a natural process. Using remediation costs to calculate the value of the ecosystems themselves would be seriously misleading since it would imply that nature is produced by human activity — when it is at best a co-production. The only costs recorded are the market value of economic ecosystem assets and the financial assets which can be accumulated as a consequence of ecosystem improvement.

### Conclusion

This paper is followed by annexes with details of the various tables described briefly above. One version is **a mock-up table** in which real, estimated and invented numbers have been used. This does not matter at this stage as long as it is appreciated that the numbers are there to enable understanding of the way the various accounting items relate to each other and are used to synthesis tables and aggregates. Simulated numbers are being progressively replaced by real ones, in the course of the fast-track implementation of the Simplified Ecosystem Capital Accounts in Europe. Not all details are currently there (it is still a simplified framework) and there is room for improvement. However, the present sketch gives a vision of possible accounts of the ecosystem in its co-evolution ([9]) with the economy.

The ecosystem capital accounting framework of Table 6 integrates physical and monetary tables. Physical tables integrate basic quantitative balances and qualitative indexes of ecosystem health and ecosystem services accessibility. Basic quantitative balances compiled by ecosystem type can be mirrored with the physical supply and use tables and economic assets accounts detailed by economic sectors in SEEA volume 1. In that way

([8]) It can be envisaged that ecological debts exported/imported with non-sustainable products are recorded by a special international institution. They would be recorded twice, in physical and in monetary units. Payments by the debtor would be made to this institution which would repay the creditor in proportion to the effective remediation of ecological damages.

([9]) To quote Norgaard, 1994.

they can be connected to the monetary Supply and Use Tables (S-UT) and natural assets accounts of SNA 2008 itself. Ecosystem capital accounts are mainly built up from geo-referenced data so they are genuinely top-down, connected to the local scales as much as to the macro level. A large part of the accounts can be reported by regions or river basins. Ecosystem capital accounts measure resource stocks and flows, factors limiting use, and the accessible resource surplus, and compare it with resource use computed from statistics. They measure ecosystem degradation, remediation costs and the accumulation of ecological debts which may result from cumulative degradation both in the country and abroad in trade-partner countries. All these elements are particularly important for monitoring progress towards green economy and assessing green growth. In particular they broaden the scope of the resource efficiency indicators based on material flow analysis: the flows can now cycle between ecosystems, and opportunities, quantitative and qualitative constraints and risks can be taken into account. Assessment of progress or degradation of well-being is no longer restricted to market variables.

The issue of how to handle subsoil assets, coal, oil and minerals remains. They are the 'dead services' of ecosystems dead for hundreds of millions of years. They are not being renewed on any significant time scale that people can influence. Their depletion is primarily an economic issue. The way to integrate them into the picture in a way consistent with the physical/money approach of ecosystem degradation could be to follow El Serafy's 'user cost' method (El Serafy, 1992). This aims at measuring the share of the economic benefit from resource exploitation which should be reinvested in another asset in order to maintain the resource flow at a constant level. Another method for measuring economic asset depletion is proposed with variants by the SNA and SEEA volume 1; this should give similar results when prices are not too volatile. The two approaches however do not reflect the fact that, having alleviated the pressure on ecosystems at the beginning of the industrial revolution, subsoil energy and minerals have become by far the most important source of pollution and poisoning of ecosystems. A weak approach to sustainability of the ecosystem issue (i.e. maintain income, not the environment) is hence very debatable. It is an open question whether to expand the ecosystem capital accounting approach to fossil resources, on the basis of ecosystem assimilation capacity which finally determines their accessibility ([10]).

([10]) It would follow the pioneer work of Naredo and Valero (Valero, 2006).

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# Annex 1 List of tables and accounting items

**List of tables and accounting items as labelled in the mock-up tables of Simplified Ecosystem Capital Accounts (supplied as MS Excel worksheet). Where they are based on real data, the mock-up numbers refer in principle to ~1995 and ~2005**

## Headings

### Ecosystem classes

| Inland ecosystem landscapes | | | | | | | | Sub-total inland eco-systems | Sea | | | | Atmo-sphere | Grand total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dominant urban landscape | Dominant agri-culture/ cropland | Dominant agri-culture/ mixed landscape | Domi-nant forested landscape | Other domi-nant natural land-scape | Compos-ite land-scape | **Sub-total Land** | River systems | | Fisheries (EEZ, all fishing areas) | Inter-national fishing areas | **Total Fisheries** | Regula-tion potential | Regula-tion potential | |

### And/or ISIC classes

## Rows (part 1): Accounts in physical units

### [A] Land-cover stocks and flows basic account

**A1 Total EU-27 1990, km²**

- a11 Artificial surfaces
- a12 Large to medium field arable land & shrub crops
- a13 Pastures & mosaic farmland (small fields)
- a14 Forests cover
- a15 Natural grassland, shrubs
- a16 Open space with little or no vegetation
- a17 Wetlands
- a18 Water bodies

**A2 Land cover change, total flows 1990–2006, km² [lcf1+lcf2+lcf3]**

- a21 lf1 Land development processes, urban sprawl, land use intensification
  - a211 lf11 Artificial development over agriculture
  - a212 lf12 Artificial development over forests
  - a213 lf13 Artificial development of other natural land cover
  - a214 lf14 Conversion from small fields agriculture and pasture to broad pattern cropland
  - a215 lf15 Conversion from forest to agriculture
  - a216 lf16 Conversion from marginal land to agriculture
  - a217 lf17 Water bodies creation and management

- a22 lf2 Land restoration processes
  - a221 lf21 Conversion from crops to set aside, fallow land and pasture
  - a222 lf22 Withdrawal of farming
  - a223 lf23 Forest creation, afforestation of agriculture land

a23 lf3 Rotations, natural processes and steady state
- a231 lf31 Internal conversion of artificial surfaces
- a232 lf32 Internal conversion between agriculture crop types
- a233 lf33 Recent tree clearing and forest transition
- a234 lf34 Forests conversions and recruitment
- a235 lf35 Changes of land cover due to natural and multiple causes

A3 lf4 No observed land cover change [A1-A2]

A4 lf5 Change of dominant landscape type [A5-A1]

**A5 Total EU-27 2006, km$^2$ (as A1)**

**[B] Ecosystem Capital Carbon/biomass Account: Net Ecosystem Carbon Balance (NECB) & Net Ecosystem Accessible Carbon Surplus (NEACS)**

**Stock accounts**

B1 Stock t1 (~1995), $10^6$ tonnes of C
- b11 Stock t1 (~1995), $10^6$ tonnes of C/Soil
- b12 Stock t1 (~1995), $10^6$ tonnes of C/trees & shrubs

B2 Stock t10 (~ 2005), $10^6$ tonnes of C
- b21 Stock t10 (~2005), $10^6$ tonnes of C/soil
- b22 Stock t10 (~2005), $10^6$ tonnes of C/trees & shrubs

B3 Change t10-t1, $10^6$ tonnes of C
- b31 Change t10-t1, $10^6$ tonnes of C/soil
- b32 Change t10-t1, $10^6$ tonnes of C/trees & shrub
- *b33 Mean annual C increase %*

B4 Mean annual carbon/biomass account and NECB
- b41 GPP $10^6$ tonnes of C
- b42 Rp = Respiration by Plants
- b43 NPP $10^6$ tonnes of C
- b44 Rh = Respiration by Heterotrophs and Decomposers
- b45 NEP $10^6$ tonnes of C
- b46 Leakages of carbon/biomass
  - b46a Leakages to water bodies/erosion, DOC
  - b46b Leakages to the atmosphere/fires, VOC
- b47 NEP Surplus $10^6$ tonnes of C [b45-b46] (NB: includes effects of LUC)
- b48 Net removals
  - b481 Net removal/crops
    - b481a total harvest
    - b481b leftovers, returns
  - b482 Net removal/grazing
    - b482a total grazing
    - b482b animal excretion return to pasture
  - b483 Net removal/timber
    - b483a total harvest
    - b483b leftovers, returns
  - b484 Net removal/fish
    - b484a total catches
    - b484b leftovers, returns
  - b485 Removal/extraction of soil, peat
  - b486 Organic fertilisation

b49 mean NECB (~1995–~2005), $10^6$ tonnes of C, [b47-b481-b482-b483-b484-b485+b486]
- b491 mean NECB (~1995–~2005), $10^6$ tonnes of C_soil
- b492 mean NECB (~1995–~2005), $10^6$ tonnes of C_trees & shrubs

**Net Ecosystem Accessible Carbon Surplus**

B5 Carbon stress coefficient t1 (~1995) ([b81+b82)/100)
- b51 A = Total area% WHERE NECB_Soil < or = 0
- b52 B = area% of SELU WHERE NECB_Trees & shrubs < NEP surplus

B6 Carbon stress coefficient t10 (~2005)
- b61 A = Total area% WHERE NECB_Soil < or = 0
- b62 B = area% of SELU WHERE NECB_Trees & shrubs < NEP surplus

B7 Net Ecosystem Accessible Carbon Surplus: NEACS t1 (~1995), weighted $10^6$ tonnes of C [proxy b47*B8]

B8 Net Ecosystem Accessible Carbon Surplus: NEACS t10 (~2005), weighted $10^6$ tonnes of C [proxy b47*B9]

*B8-B7 Change in NEACS*

B9 Use of biological carbon (removals) t1 (~1995), weighted $10^6$ tonnes of C [b481+b482+b483-b484]

B10 Use of biological carbon (removals) t10 (~2005), weighted $10^6$ tonnes of C [b481+b482+b483-b484]

B11 Use of fossil carbon, t1 (~1995), $10^6$ tonnes

B12 Use of fossil carbon, t1 (~2005), $10^6$ tonnes

*B13 Ecosystem Accessible Carbon Surplus index t1 (~1995), [B7/B9*100)] [NB should be > 100]*

*B14 Ecosystem Accessible Carbon Surplus index t10 (~2005), [B8/B10*100)] [NB should be > 100]*

**[C] Ecosystem Capital Water Account: Total and Net Ecosystem Accessible Water Surplus (TEAWS and NEAWS)**

**Water stock accounts**

C1 Water stock t1 (~1995) $10^6$ $m^3$
- c11 Aquifers
  - c111 of which aquifers accessible water stock
- c12 Soil water
  - c121 of which soil accessible water stock
- c13 Rivers
  - c131 of which rivers accessible water stock
- c14 Lakes and dams
  - c141 of which lakes and dams accessible water stock

C2 Water stock t10 (~ 2005) $10^6$ $m^3$ (as C1)

C3 Annual water flows account $10^6$ $m^3$
- c31 Precipitation
- c32 Spontaneous real evapotranspiration
  - c32a of which real evapotranspiration induced by rainfed cultivated vegetation
  - c32b of which real evapotranspiration induced by non-cultivated vegetation

c31-c32 s/t Total available effective rainfall
c33 Net spontaneous internal and external transfers
c34 s/t Total available effective rainfall after spontaneous transfers
- c34a of which Inaccessible runoff (flood…)
- c34b of which reserved runoff/dillution of pollution, biological needs
- c34c of which net transfers of pollution as additional reserved runoff/dilution of pollution
- c34d of which additional Evapotranspiration induced by irrigation and other uses

c35 Accessible ecosystem water flow [c34-c341-c342-c343-c344]
c36 Withdrawals of water
- c361 Withdrawals of fresh water (abstraction, diversion to electricity turbine, net storage in reservoirs)
- c362 Withdrawals of sea water

c37 Net transport of water (artificial transfers by mains and canals, conveyance to WWTP…)
c38 Urban runoff inflow
c39 Returns of waste water
- c391 Returns of water/waste water to water bodies incl. urban runoff outflow
- c392 Returns of water/waste water to the sea

c40 Returns of water to soil/losses in transport
c41 Return of water to soil/Irrigation
c42 Evapotranspiration induced by irrigation and other uses
c43 Net runoff (external inflows — final outflows)

**Net Ecosystem Accessible Water Surplus**

C5 Total Ecosystem Accessible Water t1 (~1995) [c12+c14+c16+c18+c35+c37+c391-c38+c40+c41]

C6 Total Ecosystem Accessible Water t10 (~2005) [c22+c24++c26+c28+c35+c37+c391-c38+c40+c41]

C6-C5 Change in total accessible water [C6-55]

C7 Water stress coefficient t1 (~1995), [mean+stdv number of dry days over 30 years/dry days during growing season t1]

C8 Water stress coefficient t10 (~2005), [mean+stdv number of dry days over 30 years/dry days during growing season t10]

C9 Net Ecosystem Accessible Fresh Water Surplus t1 (~1995), [C5*(1-C7)] $10^6$ weighted $m^3$

C10 Net Ecosystem Accessible Fresh Water Surplus t10 (~2005) [C6*(1-C8)], $10^6$ weighted $m^3$

*C10-C9 Change in Net Ecosystem Accessible Fresh Water Surplus [C10-C9]*

C11 Withdrawals of fresh water t1 (~1995) $10^6$ weighted $m^3$

C12 Withdrawals of fresh water t10 (~2005) $10^6$ weighted $m^3$

*C13 Ecosystem Accessible Water Surplus index t1 (~1995), [((C11-C9)/C9))*100]*

*C14 Ecosystem Accessible Water Surplus index t10 (~2005), [((C12-C10)/C10))*100]*

**[D] Landscape green infrastructure accounts: Landscape Ecosystem Potential (LEP), Green Accessible Landscape Infrastructure (GALI) & Rivers Ecosystem Potential (REP)**

**Landscape Ecosystem Potential**

D1 Green Background Landscape Index 2000, 5 km smoothing, $10^3$ points-km$^2$, 0–100 scale
- d11 Mean GBL_P per km$^2$
- d12 GBLI change 1990–2006
- d13 Mean change

D2 Effective Mesh Size index (ln MEFF), $10^3$ points-km$^2$, 0–100 scale
- d21 Mean MEFF_P per km$^2$

D3 Stated Social Nature Value index (Naturilis), $10^3$ points-km$^2$, 0–100 scale
- d31 Mean NAT_P per km$^2$

D4 Landscape Ecosystem Potential (LEP = f(GBLI, Naturlis, ln MEFF)) t1 (~1995), $10^3$ points-km$^2$, 0–100 scale
- d41 Mean LEP_P per km$^2$

D5 Landscape Ecosystem Potential (LEP = f(GBLI, Naturlis, ln MEFF)) t2 (~2005), $10^3$ points-km$^2$, 0–100 scale
- d51 Mean LEP_P per km$^2$

D6 Net change in LEP ($10^3$ LEP_P) (D6=D5-D4)
- d61 Mean annual net change in LEP
- d62 Mean annual losses in LEP
- d63 Mean annual gains in LEP

D7 Mean Landscape Ecosystem Potential (LEP) by km$^2$, t1 (~1995), 0–100 scale

D8 Mean Landscape Ecosystem Potential (LEP) by km$^2$, t10 (~2005), 0–100 scale

**Green Accessible Landscape Infrastructure**

D9 Green Ecotones Index (GEI)

D10 Green ecotones index, GEI t1 (~1995), $10^3$ GE_P points

D11 Green ecotones index, GEI t10 (~ 2005), $10^3$ GE_P points

*D11-D10 Change in GEI*

D12 Mean GEI t1 (~1995)/points by km$^2$

D13 Mean GEI t10 (~ 2005)/points by km$^2$

D14 GALI = Green Accessible Landscape Infrastructure Index (SQRT GBLI*GEI), t1 (~1995)
- d141 Mean GALI per km$^2$, t1 (~1995)

D15 GALI = Green Accessible Landscape Infrastructure Index (SQRT GBLI*GEI), t1 (~2005)
- d151 Mean GALI per km$^2$, t1 (~2005)

**Rivers Ecosystem Potential**

D00 River infrastructure in km

D16 River infrastructure potential in $10^3$ Standard-River-Kilometer (1 srkm = 1 km*1m$^3$/second)
- d161 Large rivers
- d162 Medium rivers
- d163 Small rivers
- d164 Brooks, streams

D17 River integrity composite index, mean value t1 (~1995) [(d171+d172+d173)/3]
- d171 Water quality
- d172 Fragmentation
- d173 Rivers green ecotones

D18 River integrity composite index, mean value t10 (~2005) [(d181+d182+d183)/3]
- d181 Water quality
- d182 Fragmentation
- d183 Rivers green ecotones

D19 Rivers Ecosystem Potential (REP) t1 (~1995), weighted $10^3$ srkm

D20 Rivers Ecosystem Potential (REP) t10 (~2005), weighted $10^3$ srkm

*D16 = D20-D19 Change in REP*

*D21 Mean Rivers Ecosystem Potential (REP) t1 (~1995)/points by km$^2$*

*D22 Mean Rivers Ecosystem Potential (REP) t10 (~2005)/points by km$^2$*

**[E] Ecosystem Capital Biodiversity Account: Biodiversity Infrastructure Integrity (BII) & Ecosystem's Biodiversity Rating (EBR)**

**Biodiversity Infrastructure Integrity Index**

E1 BII = GEI weighted LEP & GEI weighted REP, t1 (~1995) [(SQRT D4*D10)] & [(SQRT D19*D10)]

E2 BII = GEI weighted LEP & GEI weighted REP, t10 (~2005) [(SQRT D6*D11) & [(SQRT D20*D11)]

*E2-E3 Change in BIII*

*E2-3 % Change in BIII %*

E4 Mean Biodiversity Infrastructure Integrity index (BII) by km$^2$, t1 (~1995)

E5 Mean Biodiversity Infrastructure Integrity index (BII) by km$^2$, t10 (~2005)

**Species/biotopes diagnosis**

E5 Species/biotopes diagnosis index, SBD t1 (~1995), 0–100

E6 Species/biotopes diagnosis index, SBD t10 (~2005), 0–100

E6-E5 Change in species/biotopes diagnosis index

**Ecosystem's Biodiversity Rating**

E11 Mean Ecosystem Biodiversity Rating (EBR) t1 (~1995), weighted km² [SQRT E4*E6]

E12 Mean Ecosystem Biodiversity Rating (EBR) t10 (~2005), weighted km² [SQRT E5*E7]

**[F1] Total Ecosystem Potential Account**

**Total Ecosystem Potential (TEP) & Net Change, Territorial Ecosystem Capital Degradation (TECD)**

**Gross Inland, Sea and Atmosphere Ecosystem Potential (NEACS & REP)**

F1 = B7+D19 Gross Inland, Sea and Atmosphere Ecosystem Potential (NEACS & REP) t1 (~1995)

F2 = B8+D20 Gross Inland, Sea and Atmosphere Ecosystem Potential (NEACS & REP) t10 (~2005)

*(F2-F1)/10 Mean net annual change in NEACS_REP [(B8D11-B7D10)/10]*

**Limiting factors to C access: access to other services and maintenance of ecosystem functions**

C13 Ecosystem Accessible Water Surplus (EAWS) index t1 (~1995), [((C11-C9)/C9))*100]

D7 Mean Landscape Ecosystem Potential (LEP) by km², t1 (~1995), 0–100 scale

D21 Mean Rivers Ecosystem Potential (REP) t1 (~1995)/points by km²

E11 Mean Ecosystem Biodiversity Rating (EBR) t1 (~1995), weighted km² [SQRT E4*E6]

C14 Ecosystem Accessible Water Surplus (EAWS) index t10 (~2005), [((C12-C10)/C10))*100]

D8 Mean Landscape Ecosystem Potential (LEP) by km², t10 (~2005), 0–100 scale

D22 Mean Rivers Ecosystem Potential (REP) t10 (~2005)/points by km²

E12 Mean Ecosystem Biodiversity Rating (EBR) t10 (~2005), weighted km² [SQRT E5*E7]

*F3 Mean limiting factors index t1 [(C13+D7+E11)/3] & [(D21+E11)/2]*

*F4 Mean limiting factors index t10 [(C14+D8+E12)/3] & [(D22+E12)/2]*

*F4-F3 Relative change % = functional gain (+) or loss (–), 0 to 100 scale*

**Net total ecosystem capital potential [NTECP] & Ecosystem capital degradation [ECD], in Ecosystem Potential Unit Equivalents [1 EPUE = 1 NEACS Unit * functional coefficient]**

F5 Net Total Ecosystem Capital Potential t1 (~1995), in $10^3$ EPUE [bottomline F5 = F1]

F6 Net Total Ecosystem Capital Potential t10 (~2005), in $10^3$ EPUE [F6= (F2*(1-((F4-F3)/F3))]

*F6-F5 NTECP Change in EPUE (–) or (+), period t1t10 (~1995–~2005), in $10^3$ EPUE*

*F6-F5 annual Mean Annual NTECP Change in EPUE (–) or (+), period t1t10 (~1995–~2005) , in $10^3$ EPUE*

*F6-F5% Mean Annual NTECP Change in EPUE (–) or (+), period t1t10 (~1995–~2005)*

F7 Ecosystem improvement, period t1t10 (~1995–~2005) , in $10^3$ EPUE
- f71 Effect of Ecosystem restoration programme, mean annual amount period t1t10 (~1995–~2005), in $10^3$ EPUE
- f72 Ecosystem spontaneous natural improvement, mean annual amount period t1t10 (~1995–~2005), in $10^3$ EPUE

F8 Ecosystem degradation & natural disturbance, 10 years period t1t10 (~1995–~2005), in $10^3$ EPUE
- f81 Ecosystem degradation & natural disturbance, mean annual amount, period t1t10 (~1995–~2005), in $10^3$ EPUE
- f82 Effect of natural disturbances, mean annual amount period t1t10 (~1995–~2005), in $10^3$ EPUE

F9 Ecosystem Capital Degradation (ECD), mean annual amount ~1995–~2005, in $10^3$ EPUE [F8-F10]

*F9% Mean annual ECD/TEP %, period t1t10 (~1995–~2005)*

**[F2] Account of territorial ecosystem capital degradation (TECD) by stress factors (in EPUE)**

F9 Territorial Ecosystem Capital Degradation (TECD)
- f91 Effect of land cover change
  - f911 Urban and infrastructures development over agriculture
  - f912 Conversion of pasture/grassland to cropland
  - f913 Deforestation (forest land uptake by agriculture or urban sprawl)
  - f914 Other shift to more artificial or intensive land cover type
- f92 Restructuring/destructuring of landscapes and rivers
- f93 Overexploitation of biological resources
  - f931 Agriculture overharvesting and over grazing
  - f932 Clearing of forest beyond mean NEP
  - f933 Overfishing
  - f934 Overhunting
- f94 Waste disposal, pollution
  - f941 Pollution/Use of chemicals in agriculture, forestry
  - f942 Pollution/Waste dumping
  - f943 Water pollution
  - f944 Air pollution
  - f945 Emission of GHGs

**[G] Demand and Accessibility to Ecosystem Services: Ecosystem Carbon/Biomass, Ecosystem Fresh Water, Green Infrastructure Neighbourhood Ecosystem Services (GINES)**

A1 Total EU-27 1990, $km^2$
- a11 1 — Artificial surfaces, urban land cover EU-27, 1990 (~1995), $km^2$
  - *a111 Mean C1 per $km^2$, ~1995, %*

A3 Total EU-27 2006, $km^2$
- a31 1 — Artificial surfaces, urban land cover EU-27, 2006 (~2005), $km^2$
  - *a311 Mean C1 per $km^2$, ~2005, %*

G1 Population 2000 (source: Eurostat+Pop_to_CLC_v5)
- g11 Population 1995 — estimated at 0.98 of 2000
- g12 Population 2005 — estimated at 1.02 of 2000

G2 Net Accessible Ecosystem Carbon
- g21 Net Accessible Ecosystem Carbon per capita 1995 (tonnes) [g21 = B7/g11]
- g22 Net Accessible Ecosystem Carbon per capita 2005 (tonnes) [g22 =B8/g11]

G3 Net Accessible Ecosystem Fresh Water
- g31 Net Ecosystem Accessible Fresh Water per capita 1995 ($m^3$) [g31 = C9/g11]
- g32 Net Ecosystem Accessible Fresh Water per capita 2005 ($m^3$) [g32 = C10/g12]

G4 Accessible landscape services/Green Infrastructure Neighbourhood Ecosystem Services (GINES)
- G41= D14 GALI = Green Accessible Landscape Infrastructure Index (SQRT GBLI*GEI), t1 (~1995)
  - g411= d141 Mean GALI per $km^2$, t1 (~1995)
- G42= D15 GALI = Green Accessible Infrastructure Landscape Index (SQRT GBLI*GEI), t1 (~2005)
  - g421= d151 Mean GALI per $km^2$, t1 (~2005)
- G43 Demand of GINES_5km (= SQRT GALI * a11 Artificial) ~1995
  - g431 Mean GINES_5km demand per $km^2$ ALL
  - g432 Mean GINES_5km demand per $km^2$ C1 Artificial
- G44 Demand of GINES_5km (= SQRT GALI * a11 Artificial) ~2005
  - g441 Mean GINES_5km demand per $km^2$ ALL
  - g442 Mean GINES_5km demand per $km^2$ C1 Artificial
- *G45 Mean accessibility of GINES_5km (GALI/a11 Artificial) t1 ~1995*
- *G46 Mean accessibility of GINES_5km (GALI/a31 Artificial) t1 ~2005*
- G47 Accessible GINES/landscape services (G47 = (G43*G45)*g11), $10^6$ points
- G48 Accessible GINES/landscape services (G48 = (G44*G46)*g12), $10^6$ points

**[H] Physical Balance Sheet: Assets and Liabilities**

**Physical Assets [in EPUE]**

H1=F5 Opening Balance Sheet: Net Total Ecosystem Capital Potential, in $10^3$ EPUE [bottomline F5 = F1]
- H11=F5 Non-financial ecosystem assets
  - H111 Land ecosystems
  - H112 River ecosystems
  - H113 Sea
  - H114 Atmosphere
- H12 Financial ecosystem assets (in $10^3$ EPUE)

**Change in Total Ecosystem Potential & Ecosystem capital degradation**

H2 Change in Ecosystem Potential Due to Economic Activities
- f71 Effect of Ecosystem restoration programme, in $10^3$ EPUE
- F9 Territorial Ecosystem Capital Degradation (TECD), in $10^3$ EPUE [F9=F8-F10]

H3 Other Change in Potential of Ecosystem Capital
- f72 Ecosystem spontaneous natural improvement, in $10^3$ EPUE
- f82 Effect of natural disturbances, in $10^3$ EPUE

H4 Net Change in Physical Ecosystem Assets NTECP (–) or (+) [L5 = f71+f72-F9-F8]
- H41 Net change in non-financial ecosystem assets
  - h411 Land ecosystems
  - h412 River ecosystems
  - h413 Sea
  - h414 Atmosphere
- H42 Net acquisition of new ecosystem physical assets (Ecosystem improvement, ECD embedded into exports)

H5=F6 Closing Balance Sheet: Total Ecosystem Potential, in $10^3$ EPUE [H5=(F2*(1-((F4-F3)/F3))]
(detail as H1)

**Physical Liabilities [in EPUE]**

H6 Opening Balance Sheet Total Ecosystem Potential, in $10^3$ EPUE [bottomline F5 = F1]

H7 Ecosystem restoration targets (recovery from historical damages, compliance to conventions/ regulations)
- h71 National targets
- h72 International targets
- h73 Private targets
- h74 Change in ecosystem restoration targets

H8 Acquisition of new physical liabilities

- h81=F9 Territorial Ecosystem Capital Degradation (TECD), in $10^3$ EPUE [F9=F8-F10] of t-1

K2 Ecosystem capital degradation in 'consumed imports', agriculture & forest, in EPUE

K3 Ecosystem capital degradation in 'consumed imports', fisheries, in EPUE

K4 Ecosystem capital degradation in 'consumed imports', atmosphere $CO_2$-e potential, in EPUE

H9 Reduction of physical liabilities
- h91=f71 Reduction of physical liabilities by ecosystem restoration programmes
- h92=f72 Ecosystem spontaneous natural improvement, in $10^3$ EPUE
- h93 Reduction of physical liabilities by acquisition of EPUE (mitigation/compensation)
- h94 Reduction of physical liabilities by swaps and debts consolidation

H10 Net change in physical liabilities (=h74+H8-H9)

H11 Closing Balance Sheet, in $10^3$ EPUE

## Rows (part 2): Accounts in money

**[I] Estimation of unit costs of ecosystem capital restoration by stress factors**

**f91 & j11 Effect of land cover change**
- f911 & j111 Urban and infrastructures development over agriculture ==> compensation
- f912 & j112 Conversion of pasture/grassland to cropland ==> set aside, loss of crop revenue
- f913 & j113 Deforestation (forest land uptake by agriculture or urban sprawl) ==> reforestation
- f914 & j114 Other shift to more artificial or intensive land cover type ==> compensation

**f92 & j12 Restructuring/destructuring of landscapes and rivers ==> plantation of hedgerows**

**f93 & j13 Overexploitation of biological resources**
- f931 & j131 Agriculture overharvesting and over grazing ==> yield abatement, organic fertilisation, change of crop
- f932 & j132 Clearing of forest beyond mean NEP ==> yield abatement
- f933 & j133 Overfishing ==> yield abatement
- f934 & j134 Overhunting

**f94 & f14** **Waste disposal, pollution ==> yield abatement**

- f941 & j141 Pollution/Use of chemicals in agriculture, forestry ==> yield abatement less cost of chemicals
- f943 & j142 Water pollution ==> cost of abatement programmes
- f942 & j143 Pollution/Waste dumping ==> cost of restoration programmes
- f944 & j144 Air pollution ==> cost of abatement programmes
- f945 & j145 Emission of GHGs ==> investments in clean technologies

**[J] Ecosystem Capital Depreciation: Estimation of Territorial Consumption of Ecosystem Capital in $10^6$ Euro**

J1 Territorial Consumption of Ecosystem Capital, mean annual value period t1t10 in $10^6$ Euro
- j11 Effect of land cover change
  - j111 Urban and infrastructures development over agriculture
  - j112 Conversion of pasture/grassland to cropland
  - j113 Deforestation (forest land uptake by agriculture or urban sprawl)
  - j114 Other shift to more artificial or intensive land cover type
- j12 Restructuring/destructuring of landscapes and rivers
- j13 Overexploitation of biological resources
  - j131 Agriculture overharvesting and over grazing
  - j132 Clearing of forest beyond mean NEP
  - j133 Overfishing
  - j134 Overhunting
- f14 Waste disposal, pollution
  - j141 Pollution/Use of chemicals in agriculture, forestry
  - j142 Water pollution
  - j143 Pollution/Waste dumping
  - j144 Air pollution
  - j145 Emission of GHGs

**[K] Account of Ecosystem Capital Degradation & Depreciation Embedded into Imports & Exports, in EPUE & $10^6$ Euro**

K1 Virtual or embedded land in 'consumed imports', agriculture, $km^2$
K2 Ecosystem capital degradation in 'consumed imports', agriculture & forest, in EPUE
K3 Ecosystem capital degradation in 'consumed imports', fisheries, in EPUE
K4 Ecosystem capital degradation in 'consumed imports', atmosphere $CO_2$-e potential, in EPUE
K5 Unpaid ecosystem depreciation/'consumed imports', agriculture & forest, at EU mean price
K6 Unpaid ecosystem depreciation/'consumed imports', fisheries potential
K7 Unpaid ecosystem depreciation/'consumed imports', $CO_2$-e potential
K8 Ecosystem capital depreciation virtually embedded into imports (total)
K9 Ecosystem capital depreciation virtually embedded into exports (total)

**[L] Sustainable Ecosystem Services Macro-economic Benefits:**

**Ecologically Sustainable Total Induced Value Added (ES-TIVA), in $10^6$ Euro (by sectors/ISIC)**

L1 Primary production, basic price
L2 Value added of primary production
L3 Subsidies to primary production
L4 Ecosystem capital degradation resulting from economic exploitation %
L5 Total value added induced by primary production of agriculture products
L6 Ecologically Sustainable TIVA/ (sustainable TIVA)/agriculture products
L7 Total value added induced by primary production of forestry products
L8 Ecologically Sustainable TIVA/ (sustainable TIVA)/forestry products

L9 Total value added induced by primary production of fishing products
L10 Ecologically Sustainable TIVA/ (sustainable TIVA)/fishing products
L11 Total value added induced by primary production of fresh water supply
L12 Ecologically Sustainable TIVA/ (sustainable TIVA)/water supply

**[M] Economic aggregates and additional adjustments for CEC, $10^6$ current Euro, EU-27**

*M01 GDP*
*M02 Final Consumption*
*M03 Imports CIF*
*M04 Exports FOB*
*M05 Consumption of Fixed Capital*

**Consumption of Ecosystem Capital**

M1 Territorial Consumption of Ecosystem Capital (TCEC) (M1=J1)
- m11=J1/land Territorial Consumption of Ecosystem Capital, in $10^6$ Euro — Inland ecosystems
- m12=J1/fish. Territorial Consumption of Ecosystem Capital, in $10^6$ Euro — Sea/fisheries
- m13=J1/clim Territorial Consumption of Ecosystem Capital, $10^6$ Euro — Atmosphere/climate

K8 Ecosystem capital depreciation virtually embedded into imports (total)
M2 Gross Domestic Consumption of Ecosystem Capital (GDCEC) (M2=M1+L8)
M3 Net Domestic Consumption of Ecosystem Capital (M2=M1+L8-L9)

**Adjusted national accounts aggregates**

M06 (Conventional) Net Domestic Product (M06=M01-M05)
- *m06% % Conventional Net Domestic Product/GDP*

M4 GDCEC Adjusted Net Domestic Product (M4=M01+M2)
- *M4% % GDCEC Adjusted Net Domestic Product/GDP*

M5 Final Consumption at Full Price (M5=M02+M3)
- *M5% % Final Consumption at Full Price/FC Purchaser Price*

K10 Imports at Full Price
- *K10 % % Imports at Full Price/Imports CI*

K11 Export at Full Price
- *K11 % % Exports at Full Price/Export FOB*

**[N] Monetary Balance Sheet: Assets and Liabilities**

**Monetary Assets [in $10^6$ Euro]**

N1 Ecosystem Potential Opening Balance Sheet, in 10 Euro — Non Relevant (NR)
- n11 Market value of ecosystem economic non-financial assets, $10^6$ Euro (from SEEA vol.1)
- n12 Financial ecosystem assets, $10^6$ Euro
- n13 Market value of ecosystem public good assets, in $10^6$ Euro — Non Relevant (NR)

N2 Change in Ecosystem Potential Due to Economic Activities
- n21 (+) Effect of ecosystem restoration programmes, in $10^6$ Euro (N21= f71 in EPUE*Unit price)
  - n211 Effect of Ecosystem restoration programmes, in $10^6$ Euro — Inland ecosystems
  - n212 Effect of Ecosystem restoration programmes, in $10^6$ Euro — Fisheries
  - n213 Effect of Ecosystem restoration programmes, in $10^6$ Euro — Atmosphere/climate
- n22 (–) Territorial Consumption of Ecosystem Capital (TCEC) (n71=M1=J1)
  - n221 Territorial Consumption of Ecosystem Capital, in $10^6$ Euro — Inland ecosystems
  - n222 Territorial Consumption of Ecosystem Capital, in $10^6$ Euro — Sea/fisheries
  - n223 Territorial Consumption of Ecosystem Capital, $10^6$ Euro — Atmosphere/climate

N3 Counterpart of Other Change in Volume of Ecosystem Capital
- n31 (+) Ecosystem spontaneous natural improvement, in $10^6$ Euro (n31= f72 in EPUE*Unit price)
- n32 (–) Effect of natural disturbances, in $10^6$ Euro (n32= f82 in EPUE*Unit price)

N4 Net Monetary Change in Ecosystem Assets (–) or (+)
- n41 Net Monetary Change in non-financial Ecosystem Assets [N4=n21+n31-n22-n32]
  - n411 Land ecosystems
  - n412 River ecosystems
  - n413 Sea
  - n414 Atmosphere
- n42 Net Acquisition of New ecosystem Financial Assets

**N5 Ecosystem Potential Closing Balance Sheet, in 10 Euro — Non Relevant (NR) (detail as N1)**

**Financial Liabilities [in $10^6$ Euro]**

N6 Opening Balance Sheet
- n61 Distance to ecosystem restoration targets (historical damages, conventions/regulations)
  - n611 National targets/cost of programmes in $10^6$ Euro
  - n612 International targets/cost of programmes in $10^6$ Euro
  - n613 Private targets/cost of programmes in $10^6$ Euro
- n64 Change in ecosystem restoration targets
- n65 Revaluation of programmes cost

N7 Acquisition of New Other Financial Liabilities
- n71 (+) Territorial Consumption of Ecosystem Capital (TCEC) (n71=M1=J1)
  - n711 Territorial Consumption of Ecosystem Capital, in $10^6$ Euro — Inland ecosystems
  - n712 Territorial Consumption of Ecosystem Capital, in $10^6$ Euro — Sea/fisheries
  - n713 Territorial Consumption of Ecosystem Capital, $10^6$ Euro — Atmosphere/climate
- n72 (+) Ecosystem capital depreciation virtually embedded into imports (total)
  - n721 Ecosystem capital depreciation embedded in 'consumed imports', agriculture & forest, in EPUE
  - n722 Ecosystem capital depreciation embedded in 'consumed imports', fisheries, in EPUE
  - n723 Ecosystem capital depreciation embedded in 'consumed imports', atmosphere $CO_2$-e potential, in EPUE

H8 Reduction of Financial liabilities
- h81=n21 (–) Reduction of financial liabilities by ecosystem restoration programmes, in $10^6$ Euro (N21= f71 in EPUE*Unit price)
  - h811 Effect of Ecosystem restoration programmes, in $10^6$ Euro — Inland ecosystems
  - h812 Effect of Ecosystem restoration programmes, in $10^6$ Euro — Fisheries
  - h813 Effect of Ecosystem restoration programmes, in $10^6$ Euro — Atmosphere/climate
- h82=n31 (–) Ecosystem spontaneous natural improvement, in $10^6$ Euro (n31 = f72 in EPUE*Unit price)
- h83 (–) Reduction of Financial liabilities by acquisition of EPUE (mitigation/compensation)
- h84 (–) Reduction of Financial liabilities by swaps and debts consolidation

H9 Net change in Financial liabilities (= h64+H7-H8)

H10 Closing Balance Sheet

# Annex 2 Mock-up accounts

The mock-up accounts can be downloaded from

> **http://eea.eionet.europa.eu/Public/irc/eionet-circle/leac/library?l=/cube/ecosystem_23sept2011xls/_EN_1.0_&a=d**.

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