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RECORDING ECOLOGICAL DEBTS IN THE NATIONAL ACCOUNTS: POSSIBILITIES OPEN BY THE DEVELOPMENT OF ECOSYSTEM CAPITAL ACCOUNTS

Jean-Louis Weber
Special Advisor on Economic-Environmental Accounting, European Environment Agency, Copenhagen
Jean-louis.weber@eea.europa.eu
Jlweber45@gmail.com

Abstract: The degradation of ecosystems' capability to deliver biomass, freshwater and natural cycles regulation or socio-cultural services is not recorded in companies' accounting books and national accounts. Therefore depreciation is not charged in the price of our consumption. Consuming ecosystem capital without paying is equivalent to create ecological debts that are transmitted to others, to our present and future generations or to those countries from which we import products produced under unsustainable conditions.

Ecosystem capital simplified accounts are currently being implemented in Europe by the European Environment Agency. Their objective is to measure the ecosystem resources that are accessible without degradation, the actual intensity of use of this accessible resource and the change in the capability of ecosystems to deliver their services over time. These accounts are based on currently available data from nature observation by satellite or and on socioeconomic statistics. They cover all ecosystems types (forests, wetlands, agricultural and urban systems, sea ...) of the European Union 27 countries. The results are aggregated by watersheds or administrative regions, but most data are collected or disaggregated according to the European standard grid of 1 km x 1 km. This geographic data management is required firstly to analyze short-term degradation of different ecosystems. In a second step, it will articulate programs of national, regional or local initiative with the assessment made at European level.

In physical accounts, measurements are made in basic units (tons, joules, m^3 or ha) and converted to a special composite currency named ECU for 'Ecosystem Capability Unit'. The price of one physical unit (e.g. 1 ton of biomass) in ECU expresses at the same time the intensity of use of the resource in terms of maximum sustainable yield and the direct and indirect impacts on ecosystem condition (e.g. contamination or biodiversity loss). Loss of ecosystem capability in ECU is a measurement of ecological debt. To territorial debt, it should be added the consumption of non-paid ecosystem capital that is embedded in international transactions. The ecological debt in ECU (and symmetrically credits when improvements are verified) could be incorporated into portfolios of financial instruments. Physical degradation or ecological debts can be recovered in a second time into euros on the basis of the costs necessary to restore ecosystems capability.

Key words: *ecosystem capability, ecosystem capability unit, ECU, ecosystem capital, ecosystem service, ecological debt, accessible resource, national accounts.*

RECORDING ECOLOGICAL DEBTS IN THE NATIONAL ACCOUNTS: POSSIBILITIES OPEN BY THE DEVELOPMENT OF ECOSYSTEM CAPITAL ACCOUNTS

'Because National Accounts are based on financial transactions, they count for nothing nature, to which we owe nothing in terms of payments, but to which we owe everything in terms of livelihoods.'
Bertrand de Jouvenel - Arcadie, 1968

1. Introduction: accounting, accountability and fairness

We can properly manage only what we measure. This is the reason why economic actors and countries keep accounting books: to record and measure accurately, fully and fairly revenues and expenses, income, profits and losses and the state of their assets and liabilities, physical, intangible and financial. Accounts' fairness is one of their essential characteristics; failure to account fairly and properly may be punished by civil, administrative and penal courts.

The fairness of a company's accounts is of high importance to business partners and banks, as it is for its employees and shareholders, to the Stock Exchange, the tax authorities and to the financial justice. The fairness of government's and national accounts is just as important. Accounting rules state clearly that business accounts' fairness is based primarily on the complete recording of revenues and costs, including the costs of capital depreciation which calculation is the subject of very stringent rules. National accounts tell the same thing when they recommend estimating the consumption of fixed capital and deduct it from gross aggregates such as Gross Domestic Product to calculate net aggregates such as Net National Income[1].

The completeness of accounting standards is however limited to transactions and assets that are subject to appropriation for the purpose of obtaining benefits. It follows that those natural assets which are not appropriated (the atmosphere, the ocean ...) and all 'unproductive' functions of appropriated natural assets are to the largest extent ignored. These functions are public goods because they provide the community with services which are 'neither exclusive nor rivals', such as good air and water quality and the ability of ecosystems to reproduce life. These functions are taken into account only when the public authority establishes their value by regulations and/or taxes or other payment schemes.

In fact, the capital that ecosystems constitute is only depreciated in accounts as for its commercial value, which generates appropriated revenue; it is not depreciated regarding the degradation of the public good. It is important to note that companies have the ability to depreciate the depletion of their own natural resources (subsoil assets, timber and under restrictive conditions, fish stocks) when they calculate their profit submitted to taxation and then distribute to shareholders.

Not such adjustment is done in the national accounts. In the System of National Accounts (SNA 2008) 'net' flows are calculated by deducting only produced 'fixed capital' depreciation (consumption) from

[1] To pay more attention to National Income than to GDP is one of the main recommendations of the Stiglitz-Sen-Fitoussi Commission Report of 2009 on the Measurement of the Economic Performance.

gross values such as GDP. Consumption of economic natural capital is disregarded although standards are defined to calculate economic depletion[2]. The human capital is ignored all the same.

As regards the ecosystem capital, financial accounting standards and national accounts come together in the same denial: no ecosystem capital depreciation for the first one, no consumption of ecosystem capital for the other. The degradation of nature's primary functions is for both standards an externality, and need not be recorded. The economy is not accountable of Nature's degradation.

2. Ecosystem capital degradation is consumption of capital which is unpaid; it is a debt

However, degrading the capability of ecosystem capital to provide services to the society via the economy or directly is consumption: a consumption of capital. This is an unpaid consumption, which by accounting measures automatically generates a debt, in all societies and at all times; in this case it is an *ecological debt*.

Such ecological debt can be considered as a liability vis-à-vis nature, but we know that it means in fact a debt either to the future generations who will have to restore what we have degraded or vis-à-vis present and future generations of countries that furnish us from their own degrading ecosystem. Recording natural capital degradation and correlated depreciation and their accounting counterpart as ecological debts is a matter of fairness and equity.

3. Two ways for measuring ecosystem capital depreciation (or consumption)

According to the current economic theory, capital depreciation (or appreciation) is the difference between assets value at two dates. Asset value can be obtained either from asset observable market prices and or by calculating the net present value of the future benefits expected from the assets. In the case of ecosystems which are for a large part out of the market, the solution is to value the many services supplied by the ecosystems, compute their NPVs and add them. The valuation should be inclusive and cover services entangled into commodities and marketed assets value as well as other 'use' and 'non-use' free services for which willingness to pay has to be revealed and 'accounting prices' estimated.

Another approach is taken in the ecosystem capital accounts developed in Europe by the EEA. It is based on the observation of ecosystems' physical degradation (quantity and quality). Depreciation (or capital consumption) is calculated then by estimating the costs necessary to remediate physical degradation, either through reduction of yields, restoration (when possible) or compensation.

The reason for this approach relate to the fact that ecosystem capital is multifunctional and delivers altogether a bundle of commodities and services which are public goods ('*privately produced public goods'*[3]). Disentangling these services is not easy task and risks of omissions as well as double counts in the final total are real. Valuing individually all the various market and non market services of an ecosystem is heavy work. There are doubt also about the theoretical possibility to aggregate altogether market prices and more subjective values of the willingness to pay for free private and/or collective ecosystem services. Lastly, the approach would be difficult to translate into statistical

[2] See SNA 2008 Chapter 20.

[3] This expression is borrowed from Graciela Chichilnisky, as well as other reflections which source can be found in (*Chichilnisky, 1994), North-South Trade and the Global Environment*.

programmes, which questions the possibility of annual updates as required to match national accounts periodicity and the needs of policy making at the macro level.

Therefore, the approach of depreciation based on physical degradation seems more robust. The state of the system, structures and functions can be assessed without going into the detail of the services provided. Valuation is limited to the change (no need to value the ecosystem themselves) and estimations can be based on the observable costs of concrete management actions of land and soil, forestry, water, rivers and catchment or even biodiversity. The overall consistency of ecosystem degradation assessment and continuous change monitoring can be supported by Earth observation by satellite programmes.

4. Accessibility to ecosystem services and sustainable use

The ecosystem is a natural resource of a particular type. Unlike subsoil resources which are not renewable and for which it is difficult to define what an excessive consumption is per se, there are intrinsic limits to ecosystem use resulting from the need to maintain their renewal capacity. Good management of subsoil assets will consider market conditions and the maximisation of the economic profit over time, increasing costs of extraction, and environmental impacts only when legal obligations demand to do so (subsoil resource being the main source of pollution and waste generation). In the case of the ecosystem capital, only one part can be used which corresponds to the surplus given by nature beyond the requirements of its own reproduction (Friend, 2004). There is a clear limit to the *accessibility* of ecosystem services, which is that it should not result in ecosystem degradation.

Ecosystem resource accessibility is determined firstly by the net natural flows of biological services and water, ‘net’ meaning after satisfaction of the biosphere requirements. A second accessible element is the accumulation of carbon or water done in the ecosystem: it can be used in a multi-annual perspective without depleting the ecosystem. The third element relates to ecosystems’ structures and functions which have to remain healthy in order to support the various services expected from the ecosystem. It refers to landscape integrity, biodiversity and other ecosystem health elements related for example to contamination.

To consume more than the accessible ecosystem resource is un-sustainable practice. It is just consuming as current consumption the capital which needed over time.

An additional difficulty results in the fact that ecosystem resource accessibility cannot simply be measured service by service. The use of a given service has habitually indirect effect on other services and on the system as a whole. For example, irrigation increases dramatically crops yields but it often results in the degradation of water systems and consequently of biodiversity. Ecosystem accounts must reflect the interdependency of the ecosystem components.

In the economic accounts, the solution to the aggregation issue is in the conversion of natural assets and flows into money, the general market equivalent and to aggregate them. Coming to accounts in physical units, the issue is more complex: the measurement units and equivalences must be defined prior to any aggregation. A known attempt is for example ‘economy wide’ material flow accounting (MFA) where everything is assumed to be measured in tons. In practice however, MFA aggregate ‘materials’ of very different nature on the basis of their mere weight, with no consideration to their use or properties.

De facto, the asset and supply and use tables in physical units of the SEEA Part1 cannot be aggregated in one single account. This is not simply a matter of missing common accounting unit. The issue of integrating physical accounts relates more to the equivalence between measurements than to measurement units. We can add 1 m^3 of ‘blue water’ and 1 m^3 of ‘grey water’: what will be the result? For irrigation purpose, maybe 2 m^3, for drink water, 0 m^3… In fact, the various physical accounts of the SEEA Part1 are not integrated as such. Their integration is taking place in the SNA, the system of which they are extensions which allow comparing monetary values and their physical counterpart to measure aggregates such as resource use efficiency.

On the market side, monetary values express all together quantities and qualities. On the physical side, the values revealed in the course of actual transactions need to be substituted by integrative measurements of the potential or capacity of ecosystems to deliver their multiple services.

5. Ecosystem capital: accounting for quantity(ies) and quality(ies) all together

Ecosystem capital accounts cannot be founded principally on the market based equivalence function prevailing in the SNA. Ecosystem capital and services can be marketed or free, private and/or public goods. Valuation in money of ecosystem assets and flows reflects preferences as stated by the market: existing market prices or shadow prices estimated in reference to market values. Values far from the market because they express collective preferences for ethical principles, intergenerational responsibility and the longer term future of the planet are poorly or misleadingly measured in money, if measurable at all in the economic currency. More, those ecosystem functions that the economy considers external because no payment is requested for their use are internal to the ecosystem. The economic price of a resource reflects (incomplete) production costs, normal profit and possible rents on the supply side and quality from a user perspective, on the demand side. It ignores direct effects impacts of resource excessive use as well as indirect effects on ecosystem functioning (often called ‘qualitative’) which matter as much as ‘quantitative’ resource appropriation, both being entangled.

There is therefore the need of defining a universal equivalent unit for the ecosystem, which can play the role of money in the economic system. Such *physical currency* should measure the ecosystem capital capability to deliver ecosystem services which relates altogether to their natural annual productivity and to the other aspects of their health or condition that determine the sustainability of their services.

The need of a unique currency is understood since a long time, from Georgescu-Roegen and its thermodynamic vision of the economy to Odum and the attempt to define a holistic economic and ecological system in emergy terms. Important research is continuing in this domain but has not resulted yet in methodologies transferable to the national accounts. Regarding accounting applications, there is however an exception which is the work in Spain by Naredo, Valero et al. (Valero, Naredo,) on water accounting and their successful integration of quantities and qualities using exergy measurements to measure the economic and environmental cost of water use. In his paper on ‘Costes y Cuentas del Agua: Propuestas Desde el Enfoque Ecointegrador’ (Naredo, 2003), supports the relevance of this measurement of physical costs (exergy losses) and their conversion into money on the basis of energy prices. Environmental costs are referred to social targets such as the objectives of good environmental quality of river basins included in the European Water Framework Directive. Extensive application of the methodology has been done in Spain for water accounting but no application has been done for the ecosystems in a more general way.

From a different angle, an integrative methodology for measuring ecosystem health has been defined by David J. Rapport (Rapport, 1999) from the early 1980's. It is commonly called 'ecosystem distress syndrome' diagnosis and defines a small set to symptoms to observe: vigour (including metabolism, nutrient cycling, activity and productivity), organization (including substrate stability, integrity, community structures, biodiversity), resilience (including recurrence of distress situations), capacity to support healthy populations (plant, animal and human populations, considering disease prevalence and ecosystem services) and dependency from artificial external inputs (including work and energy, fertilisers, irrigation, subsidies…)[4]. The EDS diagnosis integrates an assessment of the stress factors, namely pressures from physical restructuring, overharvesting, discharge of chemicals and residuals, and introduction of exotic species. Disturbances by natural causes are recorded in addition to pressures by human activities. The EDS methodology has been used in a large number of case studies of a variety of ecosystems as the Laurentian Great Lakes, the Baltic Sea, estuaries and wetlands, deserts, or rangeland.

The pilot natural patrimony accounts produced in France include a first attempt to combine in an ecosystem accounting framework geo-statistical information and the EDS principles (CICPN, 1986, Weber, 1987). The approach was to attach a health index to land cover units. Because suitable land cover databases were not available at that time in France, ecosystem accounts were not produced. The research continued in the context of a UN Economic Commission for Europe working group (IFEN, 1995) and later on in two Eurostat projects which combined case studies in France, Germany and the United Kingdom.

In 2003, the European Environment Agency started (with Eurostat's support) the feasibility study of land and ecosystem accounts which lead to the production in 2006 of land cover accounts for 24 countries in Europe using the 'CORINE land cover' databases 1990 and 2000 (EEA, 2006)[5]. The report's title is *'Land accounts for Europe 1990-2000, Towards integrated land and ecosystem accounting'*, meaning that ecosystem accounts were the ultimate purpose of the project. The EEA approach to ecosystem accounts is detailed in (Weber, 2007). In 2009, the EEA started a pilot implementation a framework for simplified ecosystem capital accounts focusing on the calculation ecosystem capital monetary depreciation on the basis of physical degradation. Ecosystem capital physical degradation (ECD) is defined as the loss of 'Total Ecosystem Potential' (TEP) measured by

[4] Because of its simple and synthetic character, the EDS diagnosis can be implemented at a rather macroscopic scale, in a summary way, as well as in the most detailed way for specific case studies. The starting point of the EDS approach is described by D. Rapport (1999) as such: *"Given that regional ecosystems are unique and thus may differ considerably in their normal range of primary and secondary productivity, species composition, diversity, and nutrient cycling, and given that each system is exposed to unique combinations of stresses, it might be expected that patterns of response to stresses will be highly variable and unpredictable. Therefore, it is surprising to discover remarkable similarities in the response of ecosystems to stress. Stressed ecosystems are characterized by a "distress syndrome" that is indicated not only by reduced biodiversity and altered primary and secondary productivity but also by increased disease prevalence, reduced efficiency of nutrient cycling, increased dominance of exotic species, and increased dominance by smaller, short-lived opportunistic species."*

[5] The land cover accounts have been updated later on for the year 2006 and can be accessed on line via an interactive viewer (EEA, 2012).

combining six indicators reflecting ecosystem productivity and health in line with Rapport's EDS diagnosis methodology. Potential means here ecosystem capacity to deliver services, not ecosystem stocks. TEP's composite index of ecosystem capital potential is the implicit price of one unit of capital potential. As the project developed, a technical report was published by the EEA to present the complete experimental accounting framework of simplified ecosystem capital accounting in physical and monetary unit and describe the calculation of capital potential in 'ecosystem potential unit-equivalent'[6] (Weber, 2011).

In 2010, Cosier and McDonald presented to the London Group on environmental accounting a proposal for 'A Common Currency for Building Environmental (Ecosystem) Accounts' (Cosier and McDonald, 2010). The proposal is based on the Australian experience of "the 'Accounting for Nature' (WGCS[7], 2008) model which creates a common unit of account for all environmental assets and indicators of ecosystem health, irrespective of the unit of measurement. It does this by using the science of reference condition benchmarks." As in the European approach the reference is David J. Rapport' measurement of ecosystem health, named here 'condition'. The common currency is called '*Econd*'; it refers to the condition of ecosystem stocks, change in stocks being analysed as 'flows'.

Although differences exist between the two approaches (see next section), the objectives are very similar: define a common unit of measurement for all ecosystems at all scales so that aggregations are possible and comparisons with the economic values straightforward. Without such ecosystem currency, no authentic ecosystem accounts are possible.

6. ECU, a single currency to account for ecosystem capital degradation/development and ecological new debts/new credits

The single currency needed to account for ecosystem capital degradation/development and ecological new debts/new credits must have several properties. It has to be:

- Able to capture the effects of resource use intensity on the overall ecosystem state and capability. Clearly connected to the basic accounts of ecosystem resources, stocks, supply and use.
- Able to capture all change in ecosystem condition, resulting directly from resource use and indirectly from other anthropogenic causes.
- Able to measure the accessible ecosystem resource which is the resource which can be used without degrading the ecosystem.
- Based on best scientific knowledge and monitoring technology.
- Transparent and verifiable: as long as the ECU is based on a convention, it has to be transparent and verifiable so that it can be trusted and used by all with maximum confidence.

[6] In this 2011 EEA report, the acronym is EPUE. It was decided to change it for clarity reasons. There is an ambiguity in the term potential which is often employed in the literature as 'absolute potential' of biodiversity or biomass production when in the rationale of the accounts is to record the actual potential. So we propose to replace 'potential' by 'capability' and shorten the acronym which will become ECU for Ecosystem Capability Unit.

[7] Wentworth Group of Concerned Scientists, 2008

A measurement in ECU will tell in one single number what the capability of a given ecosystem regarding all provisioning (biomass and water), regulating and socio-cultural services is.

The ECU value of an ecosystem's capability should not result from strong assumptions about the equivalence between stocks and flows of biomass, water, ecosystem infrastructures and biodiversity. For that purpose, each service component of the ecosystem is firstly measured per se. Only dimensionless indexes of degradation or improvement are combined on the basis that the development of one service must be adjusted of the consequences on the others.

The ECU values are calculated regarding the complete ecosystem: basic stocks and flows, ecosystem condition. However, as long as ecosystem intensity of use relates only to the accessible resource, ECU values apply only to it.

The accessible resource is made of several elements:

- Material resources (biomass and water):
  - The net natural flow which is the natural input (precipitation, gross primary production…) minus all natural outputs (evapotranspiration, plants and animal respiration, natural runoff out of the ecosystem boundaries, soil erosion…) (+)
  - The returns after resource abstraction or harvest in the same place or transferred form another place (+)
  - The accumulation of resource in the previous accounting periods (in reservoirs, forest plantations…) (+)
  - The limiting factors of use resulting from timeliness, quality, difficulty of use (e.g. most part of flood water…), leakages from human activity (e.g. evapotranspiration generated by irrigation), recurrent risks of shortages… (-)
- Ecosystem structures and functions (landscapes, river systems, coastal systems…):
  - Ecosystem surface expressed in landscape potential or capacity with characteristic attributes including integrity, biotope quality and biodiversity
  - River potential expressed in standard river kilometres (srkm) with characteristic attributes including integrity, biotope quality and biodiversity
  - Coastal and sea zones with characteristic attributes including integrity, biotope quality and biodiversity

The price in ECU combines two types of indexes:

- Indexes of resource use impacts:
  - for material resource (biomass and water):
    - accessible resource is made of net flows and previous accumulation
    - index: effective use in basic units/accessible resource
  - for systemic services supplied by ecosystem structures and functions:
    - accessible resource is made of the condition of the ecosystem stock
    - index: change in composition and integrity of landscapes (and the equivalent for rivers and the sea)
- Indexes of ecosystem condition
    - Qualitative variables not directly related to resource use (because of dispersion, side effects, synergies, time lags…)

- Index: composite index combining observations of biodiversity, contamination, health of populations, dependency

The two indexes can be expressed in a scale of 0 to 100 or more and added up to calculate the elementary implicit price of a given resource. 100 is a conventional baseline. The mean value of the various elementary implicit resource prices is the price in ECU.

The value in ECU of the ecosystem capability expresses the quantity of resource of a given quality, in the same way monetary values express quantities of given qualities; in the first case, the quality is ecological, related to ecosystem health while in the second case the quality relates to the economic use of the resource.

Because prices in ECU integrate intensity of resource use and other ecosystem condition indicators, a change in price of the accessible resource in ECU will capture the degradation or oppositely the development of the ecosystem capability to deliver services in a sustainable way.

For example, in the example on Table 1, three ecosystem services are considered: biomass/carbon provision (food, fibre, energy…), freshwater provision and the bundle of systemic services (regulating and socio-cultural…) measured indirectly by the good condition of the ecosystem structures and functions. The basic accounts in quantities tell that there is accumulation of biomass for 25 tons, an excessive use of accessible water of 50 m^3 and a net consumption of landscape potential of 120 hectares. This is typically the situation where grassland starts to be cultivated with irrigation or fast growing forest planted on shrub area for carbon sequestration. The account in ECU tells that the accessible resource of biomass/carbon went from 108407 down to 105549. The difference of -2859 is change in total ecosystem capability; it is the measurement of the ecosystem capital degradation during the period.

Two difficulties need to be fixed to come to that point.

As it is not possible to add up carbon and water and hectares (or other components), even though they are converted into ECU, a choice has to be made of a pivot account. In theory, all options are possible as long as the account is general enough. The specific stress indexes of the other components will be reflected on its own value in ECU. The choice done for the first ecosystem capital accounts in Europe is to take biomass/carbon as surrogate of the ecosystem capital capability.

The second difficulty is to choose a bottom-line for accounting.

In the case of the Australian '*Econd*', the reference condition is the situation at the time of colonisation, supposed to represent a maximum potential to which the value 100 is given.

Another possibility when such reference is not easily accessible is to make the distinction between two different targets: on the one hand the annual maintenance of the capital recommended in international standards and on the other hand the restoration targets decided by the society as they are expressed in approved programmes, regulations, or conventions. In this perspective, the current accounts of ecosystem capability can be established using any year to fix the bottom line, independently of any judgement on ecosystems nature and condition at that date. It means that only changes will be accounted in full, which is enough regarding the purpose of measuring ecosystem degradation and new ecological debts.

Of course, the objectives of restoration must be accounted as well. While the effects of these programmes will be recorded in the current accounts as gains of ECU, the corresponding targets will be quantified, converted in ECU and recorded as debts in the ecosystem capital balance sheet.

7. From ecosystem capital degradation in ECU to ecosystem capital consumption (depreciation) in money and to valuation of ecosystem services.

Three important accounts are not presented on Table 1 [8]: degradation by stress factors, degradation by economic sectors, ecosystem capital consumption (or depreciation in business accounting terms) in money units.

The first account is the breakdown of ecosystem capital degradation 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.

The account of degradation by stress factors is important for several reasons. Firstly, accounts of ecosystem capital degradation by stress factors connect core accounts and the various indicators commonly used in environmental policies and reporting. These environmental indicators are presented according to the so-called DPSIR[9] framework, of which they correspond to D and P.

Secondly, this analysis is a step for assigning ecosystem capital degradation and ecological debts to the economic sectors which are accountable. The outcome is another table in ECU which can be used jointly with conventional national accounts of production and consumption (combined accounts, Input-Output analysis).

Thirdly, measuring degradation by stress factors is a step to estimate remediation costs (reduction of yields and/or restoration works) on the basis of the actual costs (cost of works, opportunity costs…) as they can be estimated by the economic actors in charge of ecosystem management and planning in the various sectors: farmers and agronomists, foresters, water agencies, nature conservation agencies, land and urban planning agencies… The total of remediation costs is an estimation of ecosystem capital depreciation (financial accounts) or ecosystem capital consumption (then equivalent in national accounting). As long as it is not covered by any allowance, Ecosystem Capital Consumption generates an ecological debt in money, the counterpart of the physical debts described previously.

[8] For more complete presentation, see (Weber, 2011)
[9] Driving forces/Pressure/State/Impact/Response

Table 1 Simplified Ecosystem Capital Accounts with 3 services (mock-up numbers)

				C	W	L	TEC
				Biomass/ Carbon	Water	Landscape/ Biodiversity	**Total Ecosystem Capability**
			UNITS	**t or j // ECU**	m3 or j // ECU	ha*bdv // ECU	**ECU**
Basic Accounts							
Opening Resource Stocks	**OS(t)**	**Opening Resource Stocks (t1), basic quantities and units**	= CS(t-1)	5025	950	2380	*NA*
Basic Supply and Use, Change in Stocks and Resource Depletion	A	Net primary inputs and transfers & formation of landscape potential, basic quantities and units	= data input	1100	2000	130	*NA*
	B	Use of ecosystem material resources & consumption of landscape potential, basic quantities and units	= data input	1075	2050	250	*NA*
	C	Net accumulation of resources, basic quantities and units (IF<0, = economic resource depletion)	= A-B	25	-50	-120	*NA*
	D	Other change in stocks due to natural disturbances, basic quantities and units	= data input	0	0	0	*NA*
	E	Net change in basic stocks, basic quantities and units (IF<0, = total resource depletion)	= C+D = CS(t)-OS(t)	25	-50	-120	*NA*
Closing Resource Stocks	**CS(t)**	**Closing Resource Stocks (t1), basic quantities and units**	= OS(t)+E	5050	900	2260	*NA*
Ecosystem Capability Accounts							
Opening TEC price in ECU	*P(t-1)*	*Mean price of ecosystem capital capability, in ECU, Year (t-1)*	*P(t-1)*	*101.33*	*94.56*	*93.20*	***96.36***
Opening Ecosystem Capability, in constant ECU	*Fa*	*Change (t-1) in accessible ecosystem stock (previous net accumulation), in ECU at P(t-1) prices*	*Fa = [CS(t-1)-OS(t-1)]*P(t-1)*	***2409***	*-4818*	*-9095*	***2409***
	Fb	*Accessible ecosystem flow in ECU at P(t-1) prices*	*Fb = A*P(t-1)*	***105998***	*192724*	*NA*	***105998***
	F	**Accessible ecosystem resources & landscape potential & Total Ecosystem Capability in constant ECU at P(t-1) prices**	***F = Fa+Fb***	**108407**	*187906*	*220247*	***108407***
Indexes of ecosystem stress and TEC price in ECU	*Pa*	*Indexes of resource use impacts (at t-1 resource price) [IF <1, overuse, dilapidation]*	*Pa(C,W) = F/B; Pa(L) = CS(t)/F*	*100.84*	*91.66*	*94.96*	***NA***
	Pb	*Indexes of ecosystem condition [IF <1, impoverishment]*	*data input = index*	*99.00*	*97.00*	*98.00*	***NA***
	P(t)	***Combined indexes of ecosystem stress (implicit prices) & overall price in ECU of Total Ecosystem Capability***	***P(C,W,L) = (Pa+Pb)-100 & P(TEC) = CWL average***	*99.84*	*88.66*	*92.96*	***93.82***
Closing TEC & Net Accumulation of Ecosystem Capital in current ECU	**G**	***Accessible ecosystem resources & Total Ecosystem Capital Capability, in ECU at P(t) prices***	*G = F*(P(t)/P(t-1))*	***105549***	*182951*	*214440*	***105549***
	H	***Change in Ecosystem Capital Capability***	*H = I+J = G-F*	***-2859***	*-4955*	*-5808*	***-2859***
	I	Change in ecosystem capability due to natural disturbances, in ECU at P(t) price	*I = D*P(t)*	***0***	*0*	*0*	***0***
	J	***Net Accumulation of Ecosystem Capital in ECU, at P(t) price [IF<0, = degradation; IF>0, = development]***	*J = H-I*	***-2859***	*-4955*	*-5808*	***-2859***

Table 1 presents the accounts of the second year of a series. In the first year, the opening price in ECU is 100 by convention. In this account, accessible biomass/carbon is chosen as the surrogate of the total ecosystem capability.

8. Ecological debts in money and macro-economic aggregates' adjustment

Beyond its intrinsic interest, recording consumption of ecosystem capital (CEC) as ecological debt in money solves a recurrent problem when adjusting national accounts aggregates. One of the main objections to GDP adjustment or more precisely of Net Domestic Product or Net National Income is that the price changes introduced by the adjustment lead necessarily to changes in the quantities traded, hence in the whole price system. Therefore the adjustment cannot be simply marginal but would modify the entire economic equilibrium that has governed the determination of the aggregate. The adjustment would be neither more nor less than to rewrite the past. Therefore, adjustments of aggregates should be considered as modelling (not accounting) and used in forward looking assessments, not for accounting. Recording consumption of ecosystem capital as debt drops the objection: debts are calculated at the end of the year and have effects in the following accounting period. It is therefore possible to calculate in addition to the conventional GDP, NDP and Net Income adjusted from territorial and imported consumption of ecosystem capital.

Another type of adjustment of equal interest relates to commodities' price and consumption. The purchaser price used by the national accounts to record transactions does not include the consumption of ecosystem capital, simply because is not paid by anyone. From ecosystem capital accounts in money, an aggregate called *'Final Consumption at Full Price'* can be computed. It adds CEC to the traditional Final Consumption, both territorial CEC and CEC embedded in Imports (minus the CEC embedded in exports, and therefore not consumed in the country).

The adjustment of these aggregates, calculated from integrated ecosystem accounts, establishes a formal accounting relationship between the national accounts based on official statistics and natural phenomena monitoring databases.

9. Ecological debts and international trade

To the debt created on the national territory is also added a debt embedded into imports, in the case when the production conditions in the supplying country lead to degrade their ecosystem (e.g. to provide low price products). The ecosystem capital degradation embedded into imports and exports is in fact an unpaid transfer in capital, not recorded by the national accounts. As for the ecological debt incurred in the territory, the debt embedded in imports is recorded twice, in physical units (ECU) and in monetary units (Euros).

Recording ecosystem capital degradation embedded into imports and exports has similarities and differences with footprint accounting. In both cases, accounts of virtual land use and/or virtual flows (water, carbon) are the starting point. The difference is that it is not the quantity of use which is the key indicator but the impact that this use generate on the ecosystem of the supplier country. Therefore, in the cases when production doesn't generate ecosystem degradation in the exporting country because of good accessible resource management, there will be no recording in ecosystem accounts, while footprint accounts will record the total 'biocapacity' (Ecological Footprint) or water (Water Footprint) embedded into trade. In terms of implicit policy targets, footprint accounting advocates for use diminution while ecosystem capital accounting promotes sustainable use of accessible resource and the recording of debts when the target is not met.

10. Possible use of ecological debts and credits measured in ECU as financial instruments

Financial instruments, credits and debts are based on rights and obligations which are expressed in money, because money is generally considered as capable of extinguishing most debts. This is not always the case: for example, debts to the society can be extinguished by paying a fine or by imprisonment. Very often, financial assets and debts are the mere counterpart of physical assets. This is for example the case of mortgages or, at a higher level of commodities like silver or gold when they where the guarantee of national currencies.

At the international level, the 'gold-exchange' standard put in place after Bretton Woods was based on the theoretical convertibility of the US dollar into gold. Even though the natural capital was not an issue for the SNA1953 discussions, concerns were raised at the time on the volatility of primary commodity prices in the absence of an objective standard (e.g. gold) in the international monetary system. Gold de facto de-monetisation resulted from the quasi exclusive use of the US$ (and from 1969 of a 'basket' of strong currencies (Special Drawing Rights)). It created significant policy and economic issues for commodity-exporting countries, in particular, developing countries. The so-called Mendès-France proposal[10] at that time was to balance the financial standard based on a basket of currencies with another 'basket' made of 25 primary commodities, including oil and food. The main purpose of this proposal was to support the industrial development of the Third-World, with respect to trade distortions but not resource growing scarcity. It is interesting to note that similar issues are re-surfacing today in the midst of the current financial and economic crises, where global imbalances are leading creditor and debtor nations to consider differently the roles of reserve currencies versus currency baskets versus other baskets such as commodities. Today, ecosystems should be part of the monetary 'basket' in addition to the 1950-60s primary commodities.

In the ecosystem capital accounts, ecological debt is recorded twice, in first instance in physical currency (ECU) and in a second step in monetary units. This means that the extinction (by voluntary payment) of a monetary debt does not necessarily extinguish the physical debt (for example, if restoration costs have been poorly estimated). In the same way, debtors would endure ecological taxes or penalties based on ecosystem capital degradation as long as debts in ECU are not extinguished or compensated within an approved scheme.

There is as well no a priori consolidation between ecological debts and credits. Ecological credits occur when there is an improvement (measured in ECU) of the ecosystem capability in reference to an initial baseline. Restoration from degradation is debt reduction. Beyond restoration and maintenance, the development of ecosystem capability results in the creation of new ecological credits.

New ecological credits in ECU should be recorded after verification. Because they measure up to a large extent the good state of a public good, the holder of credits in ECU should not be allowed to trade or transfer them (no exclusion). Instead, he/she could lease new credits to those economic actors or countries eager to compensate their ecological debts, would it be on a voluntary basis or as the result of regulations, taxation or conventions. The market of ecological credits would be

[10] Pierre Mendès-France, « Choisir », 1974, quoted and analysed in Suzanne de Brunhoff, « *Les matières premières et le système monétaire international* », Tiers-Monde, Vol. 17, No 66, 1976. Mendès-France was the French representative at Bretton Woods, later on IMF Governor and Prime Minister 1955-56.

therefore different from the market of the ecosystem themselves, considered as economic assets. The lease of ecological credits would stimulate their production by improving the ecosystem capability while the exploitation of ecosystem economic resources leads in many places to ecosystem degradation. To the extent that new credits in ECU are cheaper in developing countries, this would be an incentive to improve the ecosystem situation of these countries in contrast to incomplete market-based prices which push these countries to sell off their resources and degrade their ecosystem capital.

Ecological debt is not limited to unpaid ecosystem capital consumption which is a flow of the current year. It also includes historical debt acknowledged and quantified by programs and restoration plans, national targets and international commitments. For example, EU Water Framework Directive contains targets of 'river basins good environmental quality'. The reports on distances to targets and costs to meet the objectives presented by the EU Member-States under the WFD reporting correspond to measuring physical debt and estimating a debt in money. Physical and monetary debts are thus extinguished by the double condition of programmes implementation and verification of bio-physical improvement up to stated objectives.

Considering debts embedded in international trade, it is clear that appropriate mechanisms must ensure that payments of debtor countries are used for ecosystem restoration of the creditors, who according to the rule of law can not claim their own fault for financial benefits. A specialized financial agency may be required to regulate the settlement of ecosystems effective restoration, bookkeeping physical and monetary debts and credits of both creditor and debtor countries and arbitrating compensation (Chichilnisky, 1995, 2011). The double recording of physical and monetary liabilities allows us to imagine such a mechanism where ecological debt repayment is done for the benefit of the ecosystem and that of the communities benefiting of its services. Such a mechanism is conceivable internationally. This compensation of current liabilities does not exclude political decisions in which historical purely financial debt (in the South) and historical ecological debt (in the North) could be swapped.

We can imagine as well that ecosystem capability, debts and credits in ECU are taken into account in portfolios of financial assets and liabilities in addition to other financial instruments. In that way, they could be considered for the allocation of loans to countries or companies on the basis that ecological degradation/development affects their net long-term worth. Ecosystem capability in ECU could as well be included in future baskets of 'special drawing rights' to guarantee a new international currency paying more attention to sustainable development.

Allocations of rights (credits in ECU, not in money) are even conceivable considering the importance for the global ecosystem of conserving specific ecosystems. Their role would be to encourage those countries prone at improving ecosystem capability and having the possibility to do it. Such credits would be the counterpart historical ecological debts acknowledged by restoration plan; they would prevent the country to be penalised in its financial capacity but they could not be leased – as regular credits could be. When ecosystem capability improvement is verified, the amount of allocated credits would be transformed in regular ones to be used in financial mechanisms and the historical ecological debt consolidated.

All these mechanisms have one thing in common: they can be seriously envisaged only if ecosystem capability, ecological debts and credits can be measured. There is no need of complicated measurements to start but of robust accounts, with transparent rules and conventions, based on verifiable data and statistics. Such ecosystem capital accounts need be conceptually well articulated with the SNA that they aim firstly at rebalancing. As the ecosystem is now global, the accounts should be implemented worldwide in order to capture the ecological leakages and record ecological debts forwarding when it happens. As all that is urgent, the first generation of accounts should be as simple as possible and focus firstly on physical accounts, then in a second step on valuations.

The current SEEA revision is preparing a special part on ecosystem accounts which is expected to be available in 2013. It is expected to be a decisive step in a process where several international organisations have started to move ahead: UNEP/Convention on Biological Diversity (CBD Aichi-Nagoya Strategy of 2010), World Bank (WAVES), or FAO (SEEA-Agriculture-Forestry-Fishery), to mention leading initiatives.

Europe is now producing physical ecosystem capital accounts at 'fast track' pace which combine a top-down approach for all EU deep-rooted in geo-statistical databases and the stepwise implementation of more detailed accounts at the national and local levels. One of the rationales of this choice is to test the feasibility of worldwide accounts with the monitoring data and socio-economic statistics available nowadays.

11. A pilot project on Ecosystem Capital Accounting in Europe

From late 2009, the European Environment Agency has undertaken a pilot project on Ecosystem Capital Accounting in Europe. This project is in line with the evolution of environmental-economic accounts as presented by the UN manual known as the System of Environmental and Economic Accounts (SEEA 2003) and with its revision.

The Part 1 of the new SEEA adopted in February 2012 by the UN Statistical Commission (UNSC), focuses on the extension of the conventional national accounts. Its purpose is twofold: to present environmentally relevant details of the core SNA (flows and assets) and to supplement the SNA tables with associated stocks and flows accounts in physical units. During the current SEEA revision, the UNSC has decided to include experimental ecosystem accounts in the SEEA framework, in order to better reflect economy's responsibility in respect to nature. While the SEEA Part 1 helps to describe economy's internal performance (resource consumption and waste discharge), the future SEEA Part 2 on experimental ecosystem accounts will help measure the physical impacts of withdrawals, discharge of waste, emission of pollutants and land development on ecosystem productivity and health and in turn, the feedback effects on accessibility to ecosystem services.

The ecosystem capital accounts will be established in physical units (stocks, flows, services and ecosystem degradation) and in monetary units (valuation of ecosystem services on the one hand and estimation of ecosystem capital consumption on the basis of remediation costs on the other hand). The approach combines centralised production of simplified accounts for the whole EU and stepwise implementation of more detailed accounts at the national and local levels on a voluntary basis.

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 1km x 1km 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 Ecosystem Capital Accounts in Europe (Weber, 2011) is an EEA input to the current preparation of SEEA Part 2.

The first accounts are to be delivered in May 2012. The preliminary results confirm the possibility to produce accounts at the macro scale based on geographical data (satellite and in situ monitoring) and socio-economic statistics resampled down to the 1km x 1km.

Conclusion

The ecological debt is in many ways similar to other debts that accumulate in our societies: transfers of charges to others, to future generations… They are however different on one point: there is no need to manipulate accounting books or to find fiscal heavens to get rid of them – they are simply not recorded anywhere. This is one of the ambitions of the ecosystem capital accounts EEA project to show that ecosystem capital accounts, certainly simplified to begin with, can be established on the basis of existing socio-economic statistics and the rapid progress of monitoring nature with Earth observation by satellite and in situ systems as well as of tools for processing, analysing and exchanging data. Such accounts are required to measure ecological debts. They can be produced now.

We can properly manage only what we measure.

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Jean-louis.weber@eea.europa.eu

Jlweber45@gmail.com

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