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ECOSYSTEM SERVICES: THE ECOLOGY AND ECONOMICS OF CURRENT DEBATES

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ŚWIADCZENIA EKOSYSTEMÓW: EKONOMIA EKOLOGICZNA

STRESZCZENIE: Koncepcja „świadczeń ekosystemów" jest przedmiotem intensywnych dyskusji w środowisku naukowym. Jej praktyczne zastosowanie na poziomie Unii Europejskiej oraz w poszczególnych krajach spotyka się z pewnym sceptycyzmem. Skutkiem tego szereg zagadnień jest gorąco dyskutowanych. W artykule przedstawiono stan debaty nad czterema tematami, które zdaniem autora zasługują na szczególną uwagę. Są to: (1) Granica pomiędzy ekosystemami, a systemami ekonomicznymi: funkcje i świadczenia ekosystemów oraz korzyści dla człowieka; (2) Zależności pomiędzy bioróżnorodnością, a świadczeniami ekosystemów; (3) Problem identyfikacji i oceny świadczeń kulturowych; (4) Relacje między wartością ekonomiczną, a społeczną, czyli traktowanie ekosystemów jako podstawy wartości łańcucha produkcji.

SŁOWA KLUCZOWE: funkcje ekosystemu, świadczenia ekosystemów, świadczenia, bioróżnorodność, wartość ekonomiczna, wartość społeczna, wartość łańcucha produkcji

Introduction

Current Debates

Ecosystem services are "hot". The concept is intensely discussed in the scientific community, both in the natural and in the social science corners. It is used, developed and customised in the policy arena, with much energy at the European level, and on average a bit less, but increasingly, at Member State and regional levels. And, it is generally considered in a sceptical and apprehensive way in the so called "practice" domain, both in (former) government agencies which have to "get money" out of the market and in the business communities which realise that they should be ready to jump in potentially new markets, but also that they lack the knowledge to do so adequately. In this situation, a number of topics in the wide field that the concept of ecosystem services covers, have become hot debate issues[1]. In this contribution to the Symposium, I highlight four of those debates. The selection is my personal choice, and is based on what I meet in my research and advisory work for DG Environment (the MESEU project) and for DG Research and Innovation (the OpenNESS project), and on manuscripts submitted to the scientific journal "Ecosystem Services", of which I have the pleasure to be the editor-in-chief. The four debate issues are:

1) The boundary between ecosystems and economic systems: functions, services and benefits.
2) The relationship between biodiversity and ecosystem services.
3) Cultural Ecosystem Services.
4) Economic and Social Value: Ecosystems as the basis of the Value Production Chain.

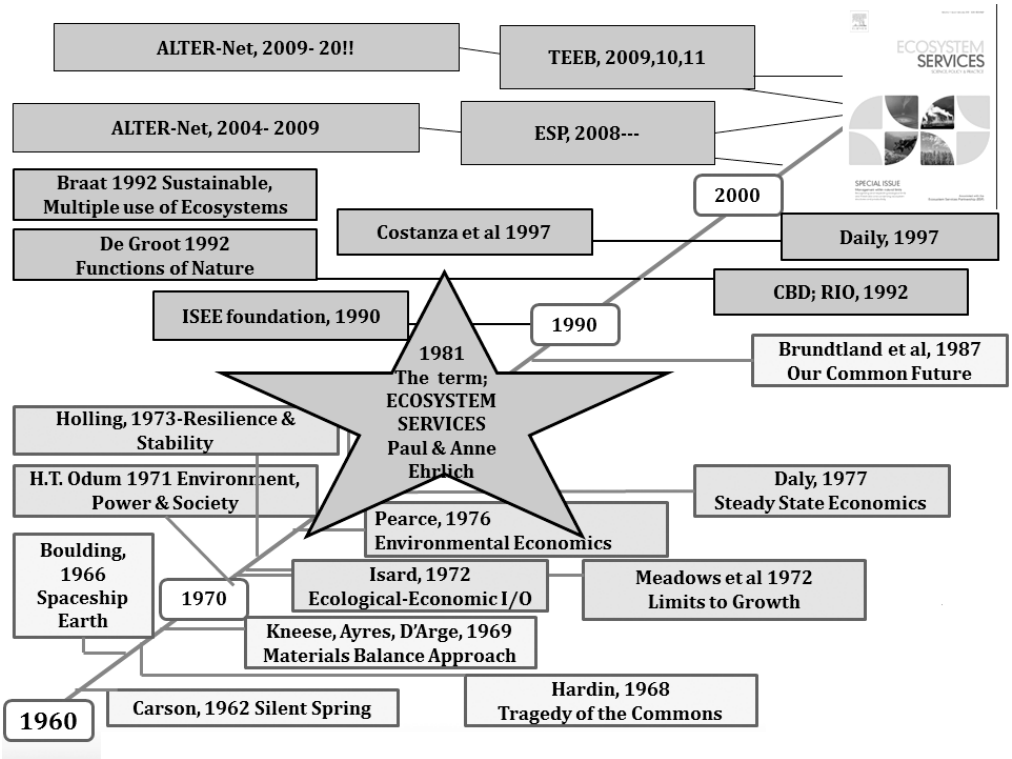
Historical Background of the debates

The diagram in figure 1 illustrates the two decades of ecological (medium grey boxes) and economic (pale grey boxes) concepts and their authors that were blended into the concept of ecosystem services (dark grey boxes) and the discipline of ecological-economics.

From 1981 on, an increasing number of publications appeared, together with international research projects, science-policy processes and political documents

[1] L. C. Braat, *The value of the Ecosystem Services concept in economic and biodiversity policy*. Chapter 10, in: S. Jacobs, N. Dendoncker, H. Keune (eds.) *Ecosystem Services, Global Issues, Local Practices*, Amsterdam 2013.

Figure 1
History of the Ecosystem Services Concept



Adapted from: L.C. Braat, *History of the Ecosystem Services concept*, Introductory presentation, at ESP Conference 2011, Wageningen 2011.

(see for an extensive historical analysis: paper of Gomez and co-authors[2]). The history involves the utilitarian framing of those ecosystem functions which are used by humans, as they are deemed beneficial to society, as economic services. The development continues throughout the 1980s in the sustainable development debate[3] and into the 1990s with the mainstreaming of ecosystem services in the professional literature[4], and with increased focus on methods to estimate their economic value.[5] In the 1970s and 1980s, a growing number of environ-

[2] E. Gómez-Baggethun, R. de Groot, P. L. Lomas, C. Montes, *The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes* "Ecological Economics" 2010 no. 69, p. 1209-1218.
[3] WCED (World Commission on Environment and Development), *Our Common Future*, Oxford 1987.
[4] R. Costanza, H. Daly, *Natural capital and sustainable development*, "Conservation Biology" 1992 no. 6, p. 37-46; G. Daily, *Nature's Services: Societal dependence on natural ecosystems*, Washington D.C. 1997.
[5] R.Costanza et al., *The value of the world's ecosystem services and natural capital*, "Nature" 1997 no. 387, p. 253-260.

mentally aware authors started to frame ecological concerns in economic terms in order to stress societal dependence on natural ecosystems and raise public interest in biodiversity conservation. Schumacher[6] was probably the first author that used the concept of natural capital and shortly after several authors started referring to "ecosystem (or ecological, or environmental, or nature's) services"[7]. One rationale behind the use of the ecosystem service concept was to demonstrate how the disappearance of diversity of structure and processes in ecosystems (short: biodiversity) directly affects ecosystem functions that underpin critical services for human well-being. The paper by Costanza and co-authors[8] on the total value of the global natural capital and ecosystem services was a milestone in the mainstreaming of ecosystem services. Their monetary figures, although surrounded by caveats, resulted in a high impact in both science and policy circles, manifested both in terms of criticism and in the further increase in the development and use of monetary valuation studies.

The definitions of the concept have evolved through the various publications, with varying attention for the ecological basis or the economic use. I take the viewpoint that "Ecosystem Services are the direct and indirect contributions of ecosystems in interaction with contributions from human society to human well-being", which is a variation on the definition given TEEB Foundations[9]. Of course, the term ecosystem services was coined, according to most sources, in 1981 by Paul and Anne Ehrlich[10] (although there were many earlier references to the notion of useful work and benefits from ecosystems), but the process of bridging the gaps between ecology and economics, and between the domains of nature conservation and economic development, and the landing in the political arenas took a few decades. And now it is the core of the EU Biodiversity Strategy and enters other EU policies, be it through the side door. With highlighting the four debates in this paper, I aim to vaporise some myths and create some better understanding of the challenging world of ecological economics.

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[6] E. F. Schumacher, *Small is Beautiful: Economics as if People Mattered*. Blond and Briggs, London 1973, p. 288.

[7] W. E. Westman, *How much are nature's services worth?,* "Science" 1977 no. 197, p. 960-964; L. C. Braat, S. W. F. van der Ploeg, F. Bouma, *Functions of the Natural Environment Institute for Environmental Studies*, Amsterdam 1979; L. C. Braat, *Sustainable multiple use of forest ecosystems: an economic-ecological analysis for forest management in the Netherlands.* Dissertation, Amsterdam 1992, p. 195; R. S. De Groot, *Functions of Nature: evaluation of nature in environmental planning, management and decision-making,* Groningen 1992, p. 345.

[8] R. Costanza et al., *The value of the world's ecosystem services and natural capital*..., op. cit.

[9] P. Kumar, P. Earthscan (eds.), *TEEB-The Economics of Ecosystems and Biodiversity. Ecological and Economic Foundations*, London 2010.

[10] P. Ehrlich, A. Ehrlich, *Extinction: the causes and consequences of the disappearance of species*, New York 1981.

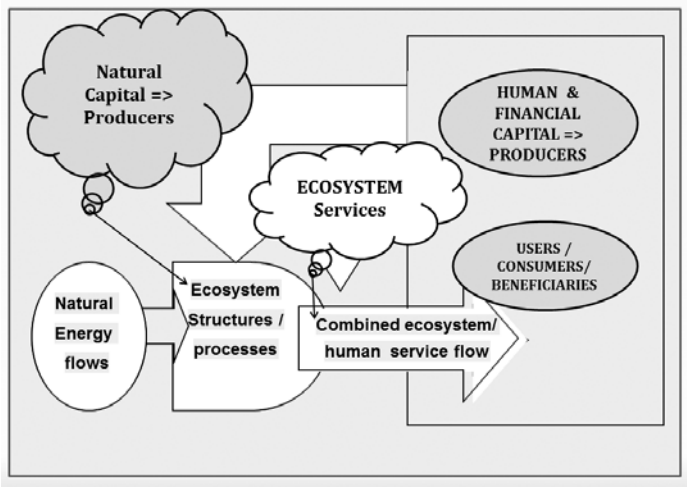
Debate issue 1: The boundary between ecosystems and economic systems: functions, services and benefits

The term Ecosystem Services still causes frowns in many places. It is not immediately clear to all that it is in fact a contraction of Ecosystem-Based Goods and Services. It does also not refer, within the name, to the essential role of humans in influencing the flows of services, either directly by harvesting the biomass and perceiving the information from ecosystems, or by investment and management of the ecosystems that provide the work that regulate the environment for Homo sapiens, humanity. Ecosystem is a concept from the natural science discipline Ecology describing, measuring and analysing the world of biotic and abiotic components, flows and cycles, in biophysical terms and units such as kilograms, meters and seconds (see e.g. Fundamentals of Ecology[11]). Services (from Latin: servus; to serve, to work for….) is a concept from Economics, a social science discipline, describing the organisations and activities of people (Homo sapiens; a particular biological species) developed for their survival (e.g. acquisition of food) and well-being (e.g. through specialisation of skills, trade and financial mechanisms).

The diagram in figure 2 illustrates the relationships between "ecosystem services" which follow from the interaction between energy and matter from Ecosystem Structure and Processes (also called Natural Capital) with the energy and matter from the Society (Aubergine box and circle; Human, Social and Financial Capital). The services are recognised by people via the benefits, which are the (partial) satisfaction of human needs and wants. In the pre-historical Hunter-Gatherer stage, humans can be viewed as still fully living inside as integral part of the ecosystem, and like deer and wolves, enjoying the ecosystem functions, while being part of them. Sometime around 6000 years ago in North-West Europe, Homo sapiens created their own localised agro-ecosystems, with crops and livestock. Humans were still very much dependent for the satisfaction of their needs on the direct supply of goods and services from the local ecosystems, even far into the late medieval times. With the industrialisation, human society developed energy sources independent from current sunlight energy, the so called fossil fuels, in fact: fossilised biomass, so embodied sunlight energy. The mental distance between humans and nature started to become larger and widespread, and more so as a majority of people in the world now lives in cities, where the share of biotic processes has been reduced to marginal proportions. My model of the current ecosystem-(human/social/cultural) economic system is presented in figure 3, which is an adaptation of the TEEB diagram12. Ecosystem functions, following from structure and processes are aggregate dynamics which produce new structure and adapted processed as ecosystems evolve. By "definition", when ecosystem functions are used by humans, they are called ecosystem services. This is the logical corollary of the utilitarian approach to the biology of

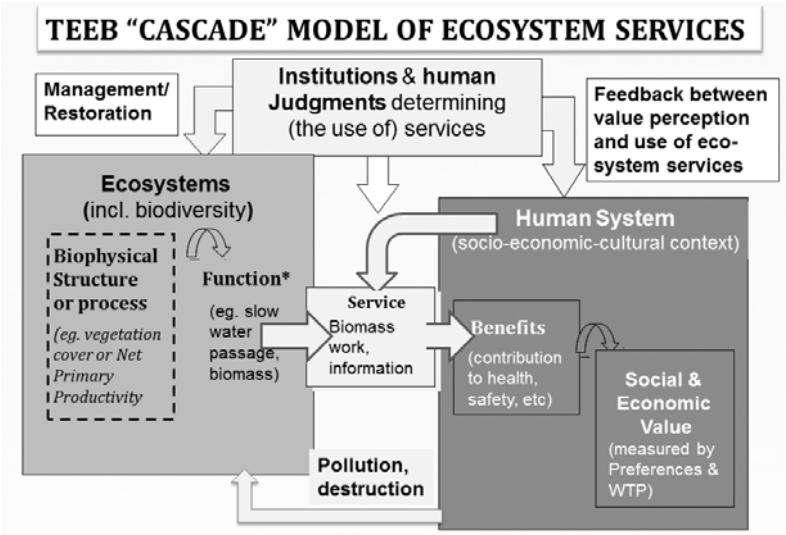
[11] H. T. Odum, *Systems ecology: and introduction,* Wiley, New York 1983.
[12] TEEB, *The Economics of Ecosystems…*, op. cit.

Figure 2
Ecosystem services as the result of ecosystem and human interactive production



Adapted from: L. Braat, R.S. de Groot, *The ecosystem services agenda: bridging the worlds of natural science and economics, conservation and development, and public and private policy*, "Ecosystem Services" 2012 no 1, p. 4-15.

Figure 3
Ecosystem Services as the linking pin



Adapted, based on: R.S. De Groot, et al., *Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. Chapter 1*, in: P. Kumar (ed.), *TEEB Foundations The Economics of Ecosystems and Biodiversity (TEEB): Ecological and Economic Foundations*, Earthscan, London 2010, p. 9-40, www.teebweb.org [20-10-2014]].

Homo sapiens. We look at (the rest of) nature as a system to feed, comfort and inspire us, in other words, as provider of provisioning, regulating and cultural services.

Following almost 20 years of academic explorations, in the early part of the present millennium a large study of the state and relevance of ecological systems for society was conducted under the umbrella of the United Nations Environmental Program (UNEP): the Millennium Ecosystem Assessment[13]. It was soon followed by an exploration of The Economics of Ecosystems and Biodiversity[14]. This study, building on this initiative, has taken ecosystem services in the policy arena with a clear economic connotation[15]. With increasing research on the monetary value of ecosystem services, the interest of policy makers has turned to the design of market-based instruments to create economic incentives for conservation, e.g. payments for ecosystem services. Both models of ecosystem services position the *natural science domain* on the left side and the *human, social and economic domain* on the right side in the diagram. Ecosystem services flow from left to right. The TEEB diagram places ecosystem services as a linking pin between the natural and human systems and identifies benefits for people following from services (and goods) delivered by ecosystems, and separates benefits and values[16]. It also includes the "feedback" structure of control and investment through institutions and ecosystem management. My diagram in figure 4 is a further elaborated version, which adds a negative feedback of pollution and destruction. The TEEB diagram in turn was an extension of the so called cascade model published by Haines-Young & Potschin[17].

Money comes into the model, if so desired, as a flow which goes from beneficiaries to producers. In the real world, people pay money for goods and services to other people, and never to the ecosystem, even when the ecosystem is clearly a co-producer. There are representatives of the ecosystem collecting money, at least there should be, but they are human owners or managers, not the animals or the plants. These owners and managers should use the money to " buy" resources for the ecosystem to replenish its stocks and buy time to rebuild damaged structure and re-boot processes. In the diagram in figure 4, the ecosystem services flow from natural systems via, agro-ecosystems to urban (industrial) systems, and are exported to other regions. Money flows in the opposite direction, paying for the services and goods, both with the regional system and across the boundaries for imports. Exports generate cash flows to pay for those imports. And again, no money flows to the natural ecosystems, nor to the ecological part of the agro-ecosystems. However if no investment and compensatory management is executed (and adequately paid for), the system cannot be sustained.

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[13] *Ecosystems and Human Well-being: Synthesis*, Island Press, Washington D.C. 2005; www.maweb.org [20-10-2014].

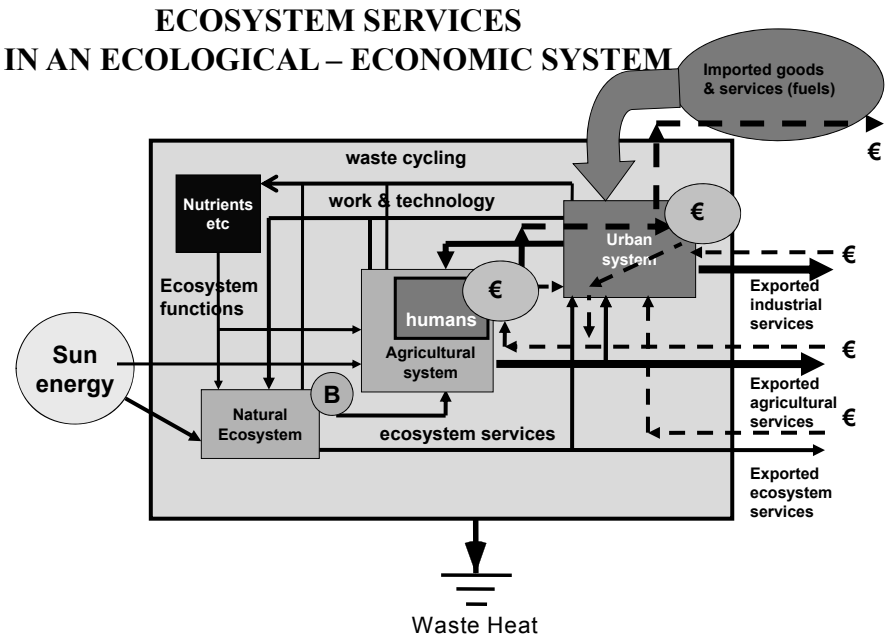
[14] TEEB, *The Economics of Ecosystems…*, op. cit. (again under UNEP umbrella).

[15] www.teebweb.org [20-10-2014].

[16] De Groot et al., *Integrating the ecological and economic…*, op. cit.

[17] R. Haines-Young, M. Potschin, *The links between biodiversity, ecosystem services and human well-being*, in: D. Raffaeli, C. Frid (eds.), *Ecosystem Ecology: a new synthesis. BES ecological reviews series*, Cambridge 2009.

Figure 4
Money flows in an ecological economic system



Source: own elaboration.

Debate Issue 2: The relationship between biodiversity and ecosystem services

There is clear evidence for a central role of various features of biodiversity, e.g. abundance of different gene pools and of populations of key species, of functional traits, and spatial heterogeneity of habitat structure, in the delivery of some – but not all – services, viewed individually. Maintaining functioning ecosystems capable of delivering bundles of ecosystem services requires a consistent approach to sustaining a considerable level of these (and other) aspects of biodiversity. Most of the current measures and indicators of biodiversity and ecosystems were not developed for economic assessment. They are therefore not always able to show clearly the relationships between features of biodiversity and the benefits they provide to people. A reliance on existing indicators will capture the value of only a few species and ecosystems relevant to e.g. food and fibre production, and will miss the role of the biological diversity in species, food webs, nutrient processing chains and ecosystem productivity in supporting the full range of benefits, as well as their resilience in dealing with human induced stress, regulating services. A set of indicators is therefore needed that is not only

relevant and able to convey the message of the consequences of biodiversity loss, but must also reflect the aspects of biodiversity relevant to the ecosystem service of interest, capture the often non-linear and multi-scale relationships between ecosystems and the benefits that they provide, and be convertible into economic terms. A relevant and well-structured overview of relationships between biodiversity features and ecosystem services as they appear in the professional literature is available in paper by Harrison and co-authors[18].

Debate issue 3: Cultural Ecosystem Services

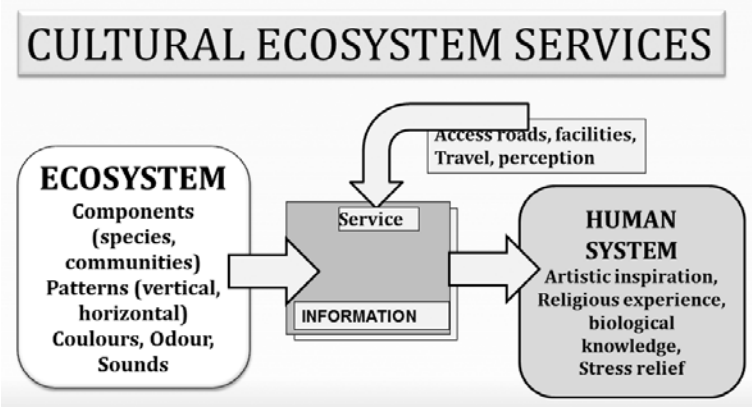
Cultural services are referred to in the professional literature as the group which has not been research as much as the other types of services. This may be true for ecologists and economists alike, but the phenomenon has been receiving much attention in research disciplines dealing with social psychology, recreational behaviour, and especially landscapes.

In my view ecosystems deliver information from their (change in) structure to observers, i.c. humans (see figure 5). Following information theory and various indices that measure aspects of information, the more diverse the source system observed (e.g. in structure, horizontal and vertical patterns, colour, smell, sounds), the more information is available to be perceived (following Shannon-Weaver Index). Humans that "are exposed to the same ecosystem" experience different aspects of the information flows. So artists, priests, professional biologists, outdoor recreationists that all visit a particular ecosystem can see in principle the same, and obtain the same information, with their eyes or other sensory organs, but their minds (mental filter) defines the information that is processed, and therefore the benefits they receive (figure 6a). So culture in the Cultural Ecosystem Services is the Mental Filter (maybe a Cultural frame of filters at group level) that humans consciously or unconsciously apply to the information from ecosystems. Different factors determine in combination the development of the filter, which is the reason that artist, priest, biologist and recreationist all perceive different things in the same forest (figure 6b). The classifications of ecosystem services schemes (MA, TEEB and CICES[19]) refer to these information flows and experiences, but do not clarify the process of information perception and the mental filters. The model of cultural services is in fact very similar to those of provisioning services, except that biomass and water are replaced by information. Similarly, humans have to invest energy to obtain the information, e.g. one may need to invest in access and facilities.

To assess economic or social values of cultural services, one needs to record the values that individuals to the benefits they receive with the experience of the information flows; economic value at individual level is based on "preference" for

[18] P. Harrison et al., *Linkages between biodiversity attributes and ecosystem services: A systematic review,* "Ecosystem Services" 2014 no. 9.
[19] www.cices.eu [20-10-2014].

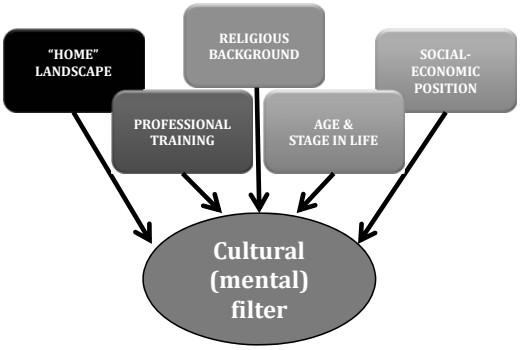
Figure 5
A cultural ecosystem services model



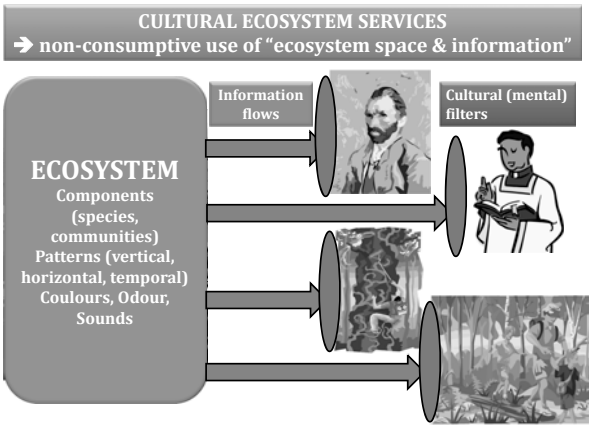
Source: own elaboration.

Figure 6
Perception of information and cultural mental filters

A



B



Source: own elaboration.

which an individual is prepared to "pay" something (or give up something else). Social value is how the ecosystem (via the service) leads to benefits in the social domain (e.g. group excursion enhancing social structure etc. To calculate or estimate such values of an ecosystem's cultural services, one could calculate the sum of values of individuals, but also the values assigned as stakeholder groups (e.g. recreation entrepreneurs) and as society (e.g. subsidies to protect and maintain national landscapes). Monetary equivalents reflecting how important people consider an hour of experience of exposure to ecosystem information can be calculated from Willingness To Pay methods, with all their limitations, and proxy methods as travel cost involved. Recreation entrepreneurs have of course real costs (investment and operation) and their balance sheets provide information on how much people actually spend to recreate and enjoy the information from ecosystem's cultural services.

Debate Issue 4: Economic and Social Value: Ecosystems as the basis of the Value Production Chain

The EU Biodiversity Strategy 2011-2020 has six targets and twenty Actions. Target 2 is about ecosystem services, and Action 5 about the knowledge of ecosystems and their services, which is deemed necessary to make sustainable use of the ecosystems possible. Action 5 includes 3 steps, which are in essence based on the TEEB 3 step procedure, named (1) recognising value (by mapping and assessment of ecosystems and their services), (2) demonstrating value (economic and social valuation) and (3) capturing value (developing policies for sustainable use via accessible data in accounting systems).

Mapping and assessment

It is essential to map the ecological, and also the human user systems, in the landscapes where ecosystem services are to be assessed. Without precise delineations of system boundaries, the quantification processes will be unreliable, and in human systems ultimately legal consequences of policies require exact property boundaries. Maes and co-authors[20] give an introduction to and overview of the challenges of mapping ecosystem services. The PRESS studies[21]. were developed in the context of the EU Biodiversity Strategy 2011-2020[22]. To support EU policy

[20] J. Maes et al., *Mapping ecosystem services for policy support and decision making in the European Union,* "Ecosystem Services" 2012 no. 1, vol. 1, p. 31-39.
[21] J. Maes et al., *A spatial assessment of ecosystem services in Europe: methods, case studies and policy analysis – phase 1, PEER interim report*, Ispra 2011; J. Maes, et al., *A spatial assessment of ecosystem services in Europe: methods, case studies and policy analysis. Synthesis, Phase 2. PEER report*, Ispra 2012.
[22] *Our life insurance, our natural capital: an EU biodiversity strategy to 2020,* COM 244 final, Brussels 2011.

development, clear and specific definitions of the different ecosystems and of the services have been produced in the MAES process (Mapping and Assessment of Ecosystems and their Services) run by the EU with the Member states to implement Action 5[23]. The describe the search for appropriate indicators, mapping methods and techniques, data sources.

Most challenging is the quantification of the so called bundles of ecosystem services. In assessing trade-offs between alternative uses of ecosystems, the total bundle of ecosystem services provided by different conversion and management states should be included. Economic assessment should be spatially and temporally explicit at scales meaningful for policy formation or interventions, inherently acknowledging that both ecological functioning and economic values are contextual, anthropo-centric, individual-based and time specific. Ecosystems produce multiple services and these interact in complex ways, different services being interlinked, both negatively and positively. Delivery of many services will therefore vary in a correlated manner, but when an ecosystem is managed principally for the delivery of a single service (e.g. food production) other services are nearly always affected negatively. Braat and co-authors[24] have examined the practices of mapping and assessment in a number of European countries and regions and provide insight in best practices.

Valuation

Valuation is a mental process which includes assessment of situations and making decisions on whether to act or refrain from action. All people do it, all the time, mostly unconsciously, in view of so-called desirable ends (see figure 7a and b).

However when major changes in ecosystems and ecosystem services are at stake with change in welfare and well-being, for example as a consequence of land use change, economic or environmental policy, structured and transparent valuations need to take place, also in view of desirable ends, but not at the individual but at societal level. Traditionally such projects were concluded with a financial cost-benefit analysis, in which the costs of development as well as the benefits recognised in the market were included. Also traditionally, costs of loss and benefits of conservation of non-market ecosystem services, as most regulating services are, were generally ignored.

A broader approach, including the non-market aspects of welfare and well-being is now being developed in many places, with the aim to integrate the objectives of ecological sustainability, social justice and economic efficiency into the public decision making process[25] (see figure 10b). The understanding of the

[23] See: J. Maes et al., *Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020,* Luxembourg 2013.

[24] L. C. Braat et al., *Mapping of Ecosystems and their Services in the EU and its Member States (MESEU)* ENV.B.2/SER/2012/0016; October 31, 2013: Final Report (1st year contract) Part 1: Introduction, Summary&Conclusions 2013.

[25] J. Farley, *Ecosystem services: The economics debate,* "Ecosystem Services" 2012 no. 1, v. 1, p. 40-49.

Figure 7
Valuation and desirable ends

A

Step 2. ➔ demonstrating value
assess the economic value of these services,

Valuation...
is consciously & unconsciously done
.....by all humans
to assess situations
to decide on actions
.....in view of desirable ends

B

Desirable ends **(~ in view of survival & wellbeing)**

1. Ecological-Sustainability-
=>longer lives and obligations to future generations.

2. Social-Justice –
=>to avoid anarchy

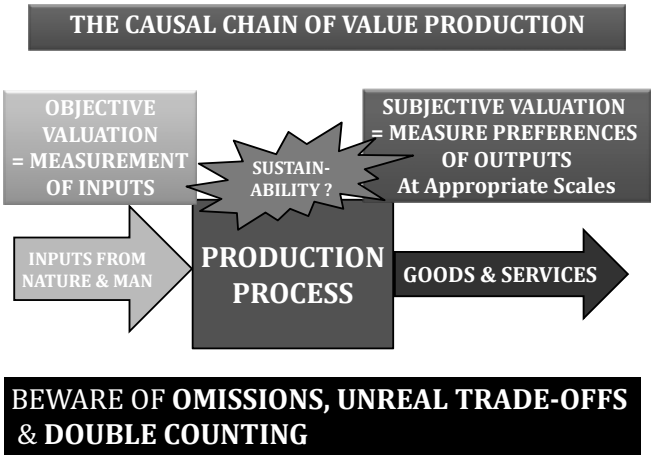
3. Economic-Efficient allocation –
=>finite resources and unmet needs

Based on: J. Farley, *Ecosystem services: The economics debate*, "Ecosystem Services" 2012 no. 1, v. 1, p. 40-49.

complexity of the development of economic and social value (as depicted in the TEEB diagram) is increasing, but still not generally embedded in decision making. In those situations where goods and services are co-produced by ecosystems and human activity, the "value production chain" should be considered as a causal chain, which implies that the valuation takes place at the end of the chain, based on the preferences of consumers, stakeholder groups or regional to international societies (see figure 8).

This valuation is by definition subjective in that it reflects to what extent the "ends" are realised in the perception of the valuators. The counterpart in this process is the valuation of the inputs, both the biophysical inputs derived from ecosystems (Natural Capital), and the financial capital, labour and technology inputs from humans. One may choose to quantify those inputs, and include these objectively obtained numbers in the "input" or "cost" side of the valuation table, but they should not be included in the total value estimate, as double counting will then occur. One should also not put subjective value assignments on ecosystems features like species richness as a so called ecological value in the cost-benefit equation. Although done in some cases to give adequate attention to the im-

Figure 8
The causal chain of value production



Source: own elaboration.

portance of the ecosystem in producing economic and social values, this is already taken care of as in such value production chains, there is no economic or social value without the ecosystem inputs. In addition, if ecological values are listed as seemingly independent values assigned by people, next to economic and social values, a risky and unreal situation may come into existence where decision makers trade-off economic against ecological values. To avoid omissions of essential factors in producing benefits, a systematic approach which uses the classification tables of ecosystem services as produced by the TEEB project or more recently by the CICES project is an advisable approach.

Many methods have been developed to obtain quantitative estimates of economic and social values, as they are assigned by individuals, groups or societies. For example most provisioning services provide benefits which are readily monetarily valued with market prices, while cultural services are often non-monetarily valued, or with shadow pricing methods. Such combinations are risky if the interdependencies between ecosystem services and their inputs are not accounted for, as indicated above. The HYBRID valuation approaches need therefore to be examined closely for such inconsistencies, and the search is now for "integrated valuation", which "is defined as a systems approach recognising causal relationships between components of ecological-economic systems in assigning values to benefits (resulting from ecosystem services) at individual, social group and society level[26]".

"To value is to monetize" in the eyes of many, some of which state this with enthusiasm, others with horror. The limitations of monetary valuation are many,

[26] E. Gómez-Baggethun et al., *State-of-the-art report on integrated valuation of ecosystem services,* OpenNESS project Deliverable 4.1, Helsinki 2014.

if only that it is always time and location dependent, the currencies employed may be quite instable, the market based methods suffer from the same flaws as the markets themselves, and when ecosystems are near critical thresholds and ecosystem change is irreversible, money values do not help as regulatory mechanism[27]. Terminology is important in scientific and policy debates. A distinction between monetization and expressing ecosystem service values in monetary terms is proposed and discussed in paper by De Groot and co-authors[28]. Monetary valuation is sometimes understood to imply that ecosystem services must be privatized and commodified (traded in the market). This is of course not a necessary corollary. As indicated above, money does not get paid to ecosystems, so the monetary value assigned to services should represent (1) reflect the direct costs for (and therefore payments to) human co-producers of ecosystem services and (2) the costs for (and therefore payments to) maintaining the quantity and quality of the ecosystems (natural capital), which are the other co-producers of ecosystems. Non-Monetary valuation methods are most useful at the level of (stakeholder) groups which have decisions to make which affect all of the participants, but most likely in different ways and degrees. The biophysical assessment methods are alternative ways to assess the input contribution from the ecosystems.

Braat & De Groot[29] summarise the crucial issue of time in valuation: "inter-temporal distribution of costs and benefits is firstly a moral issue for all decision makers in general, and secondly a technical issue for those dealing with ecosystem services, as ecological and economic systems involved in trade-offs may have different clock-speeds. At the ecosystem level, the required natural restoration time may run into decades for wetlands and grasslands and hundreds of years for forests". Another relevant time aspect are of course the time-lags between economic activities and their impacts on ecosystem services, e.g. climate change, extinction debts, etc. The consequence is that the application of fixed discount rates to ecological as well as economic systems, as is common practice in conventional economics and based on national interest rates, leads to results which affect future generations disproportionally. While at the personal level, most people seem very much aware of and concerned with the education of their off-spring and their retirement financing, the awareness at the group level is rather small, and political choices reflect that (lack of) awareness and prioritisation"[30]. It suggests a dual approach to dealing with time in the human mind, which has been labelled "thinking fast and thinking slow"[31].

27 See: L. C. Braat, R. S. de Groot, *The Ecosystem Services…*, op. cit.

28 R. S. De Groot et al., *Global estimates of the value of ecosystems and their services in monetary terms,* "Ecosystem Services" 2012 no. 1, vol. 1, p. 50-61.

29 L. C. Braat, R.S. de Groot, op. cit.

30 See also: J. Gowdy, *Neoclassical economics and its discontents*, in: *TEEB-The Economics of Ecosystems...* op. cit., p. 20.

31 D. Kahneman, *Thinking, fast and slow*, Straus and Giroux 2011.

Capture (and manage) the values

Step 3 in the TEEB procedure is "to capture the values for a sustainable society". In TEEB for Policy Makers[32] the capture message is "providing information about benefits, creating a common language for policymakers, business and society, revealing the opportunities to work with nature, emphasizing the urgency of action and generating information about value for designing policy incentives". The third step is represented in the TEEB diagram (see figure 4) by the feedback loop from the economics box to the ecological box and to the ecosystem services flows, as institutional, policy and societal response. Capturing value thus involves the introduction of mechanisms that incorporate the values of ecosystems into decision making, through incentives, social arrangements and price signals. The capturing also refers to making the "value" in the service actually tangible and visible, in some cases cash-able and accountable, and generally includes payments for ecosystem services, reforming harmful subsidies, tax breaks for conservation, or creating a green market economy. Essential is the development (or adjustment) of the legal system with respect to rights over natural resources and liability for damage to ecosystem service potential. In Action 5 of the EU Biodiversity strategy, the third step is focused on the (accessible) storage of the values of ecosystems and their services in Natural Capital Accounts. The aim is undoubtedly to have these values readily available for use or reference in future decision processes involving expected changes in ecosystems and their services. A lofty aim, but a challenge for all involved, from the scientists and policy makers to the stakeholders and the decision makers. And one which will definitely not make life simpler for those involved and those with ultimate responsibility, but one that definitely holds more promise for a sustainable world.

[32] TEEB, *The economics of ecosystems and biodiversity for national and international policy makers*, P. ten Brink (ed.), London 2011.