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Review

The ecosystem services agenda:bridging the worlds of natural science and economics, conservation and development, and public and private policy

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ABSTRACT

The Ecosystem Services Journal starts in 2012 with a formidable basis in the reports and books from the Millennium Ecosystem Assessment and TEEB projects. Following a half-century history of growing awareness and associated scientific based policy development a bridging concept with natural and social science notions was developed and coined "ecosystem services". The agenda for the journal Ecosystem Services, presented in this introductory paper to the Journal Ecosystem Services is aimed at scientists and policy analysts who consider contributing to better knowledge and better use of that knowledge about ecosystem services. This should include knowledge of the ecological systems that provide the services, the economic systems that benefit from them, and the institutions that need to develop effective codes for a sustainable use. The agenda is derived from the experience of the authors in science and policy analysis and extended with some of the recommendations from the TEEB book for national and international policy making emphasising the science—policy—practice linkage, which is the philosophy of the Journal.

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1. A short history of the ecosystem services concept

1.1. Introduction

The Ecosystem Services Journal starts in 2012 with a formidable basis in the reports and books from the Millennium Ecosystem Assessment (see www.maweb.org) and TEEB projects (see www.teebweb.org/). Following a half-century history of growing awareness and associated scientific based policy development with respect to environmental pollution and resource scarcity issues (1960, 1970s) and subsequent notions of managing economic development under the concept of sustainable development (1980), a bridging concept with natural and social science notions was developed and coined "ecosystem services" (Ehrlich and Ehrlich, 1981). The creation of an integrating discipline called "ecological-economics" in the 1990s (Costanza, 1991) has led to a proliferation of concepts, methods, and case-study based evidence about the relationships between economic and ecological systems, or in laymen's terms between the economy and the natural environment.

An historic sketch of the development of the ecosystem services concept is clearly a personal selection of key persons and key events. We have borrowed heavily and duly refer to earlier histories, and note the fact that there are already a number of published history papers and chapters, but at some point in the near future a book by a professional historian is needed, if only to educate the students of tomorrow.

The origins of the modern history of ecosystem services are to be found in the late 1970s (see for an extensive historical analysis: Gómez-Baggethun et al., 2010). It involves the utilitarian framing of those ecosystem functions which are deemed beneficial to society, as economic services in order to increase public interest in biodiversity conservation. It continues throughout the 1980s in the sustainable development debate (WCED, 1987) into the 1990s with the mainstreaming of ecosystem services in the professional literature (Costanza and Daly, 1992; Daily, 1997), and with increased focus on methods to estimate their economic value (Costanza et al., 1997). The definitions of the concept have evolved through the various publications, with varying attention for the ecological basis or the economic use:

- Ecosystem Services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life—Daily (1997).
- Ecosystem Services are the benefits human populations derive, directly or indirectly, from ecosystem functions—Costanza et al. (1997).
- Ecosystem Services are the benefits people obtain from ecosystems—WRI 2005.
- Ecosystem Services are components of nature, directly enjoyed, consumed, or used to yield human well-being—Boyd and Banzhaf (2007).
- Ecosystem Services are the aspects of ecosystems utilised (actively or passively) to produce human well-being— Fisher et al. (2009).
- Ecosystem Services are the direct and indirect contributions of ecosystems to human well-being—TEEB Foundations (2010).

The definition is still being discussed with additional viewpoints and arguments from ecology and economics. Accepting that for practical reasons the term Ecosystem Services contains both the "work done" component as well as the "product" component (traditionally called "goods"), it is suggested that in the next stage of development of the concept, the distinction between goods and services should be re-established in the debate. Farley illustrates the discussion with the example that health, education, the financial sector, consulting, etc. are all "services" (the tertiary sector) in economic terms, the provision of which does not result in the physical transformation of the "fund" (i.e., the people) that provides them. The primary sector (concerned with the provisioning ecosystem services) deals with the extraction of raw materials (e.g., biomass) from nature (ecosystem goods) that generally must be physically transformed (i.e., consumed) in order to provide a benefit". Transforming the TEEB definition into a Goergescu-Roegen like definition would only require adding "flux of": *Ecosystem Services are the direct and indirect flux of contributions of ecosystems to human wellbeing.* (Josh Farley pers. comm.).

In the next few years the concept of ecosystem services shall undoubtedly be further elaborated, if only through the publications in this new journal. As departure point we shall stick to the TEEB definition, recognising the dimensions of the concept stressed in previous definitions and proposed by Farley. We follow in this paper a simple concept of tracing the roots of the components of the concept: ecosystems, economic systems and the services as the bridge between the human world and the natural world, with humans only virtually separated from that natural world. So in Section 2 we have used Mooney and Ehrlich's chapter in (1997) and added a number of items and authors we consider at least as worthwhile as the selection by Mooney and Ehrlich. In Section 2.1. we have used the paper by Gómez-Baggethun et al. (2010) which in turn is strongly influenced by Martínez-Alier (2005) and have made our personal selection from their extensive analysis of the economic roots of ecological economics and added a few notions of our own.

Of course, the term ecosystem services was already coined, according to most sources, in 1981 by Paul and Anne Ehrlich (although there were many earlier references to the notion of useful work and benefits from ecosystems, see Section 2), 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. The start of the present journal testifies to the condition that we still have quite a few challenges in this area that warrant scientific exploration, policy development and societal discussions.

1.2. Ecological roots

Marsh's book Man and Nature (1864) makes the point that America's resources are not infinite. He distinguished elements of a waste disposal service, without actually using the term. Leopold (1949; a Sand county almanac), Osborn (1948; Our Plundered Planet), Vogt (1948; Road to survival, including the term real capital of natural resources) had explored the role of nature in economic and social dynamics. The concept of ecosystem services thus builds on early publications highlighting the value of nature's functions to human society. See e.g. Carson (1962; Silent Spring), Ehrlich (1968; Population bomb) and Meadows et al., 1972; Limits to growth).

The term *ecosystem function* was originally used to refer to the set of ecosystem processes operating within an ecological system irrespective of whether or not such processes are useful for humans (Odum, 1956). In the late 1960s and early 1970s, some authors started referring to "functions of nature" to denote the work done, space provided, and goods delivered to human societies (Helliwell, 1969; Hueting, 1970; Odum, 1971; Braat et al., 1979). This did cause some confusion as the term functions was still in use in a strictly ecological sense. Golley (1993) reviews the history of the ecosystem concept in ecology. The term ecosystem is first used by Tansley (1935). Lindeman (1942) in his landmark paper states that "the ecosystem is hence regarded as the more fundamental ecological unit". Odum added thermodynamic and energy flow dimensions to the concept (e.g. Odum, 1957). Clearly, a lot of activity involving energy and matter transformations takes place in ecosystems (captured in the two ecological boxes in Fig. 2) before services are provided and benefits are generated.

If sustainable development is at stake, and we think that it is the core global societal challenge, decision-makers need to understand what this involves. As stated in De Groot et al. (2010a) it is therefore important to distinguish 'functions' from the fundamental ecological structures and processes, in the sense that the concept of functions not only describes the above mentioned combinations of structure and processes, but at the same time represent the *potential* that ecosystems have to deliver a service. For example primary production (=process) is needed to maintain a viable, reproducing fish population (=function) which can regenerate fish stocks after part of the population is harvested (=provisioning service) to provide food (a "good"); nutrient cycling (=process) is needed for water purification (=function) to provide clean water (=provisioning service). The benefits of the resulting services are manifold. For example, food provides nutrition but also pleasure and sometimes even social identity (as part of cultural traditions); clean water can be used for drinking but also for swimming (pleasure) and other activities aimed at satisfying needs and wants. Thus, the role of woodlands in slowing the passage of water through a catchment is a function which has the potential of delivering a service (water flow regulation which reduces flood risk) if some beneficiary exists to enjoy the benefit (safety). Services are therefore actually conceptualizations ('labels') of the "useful things" ecosystems "do" for people, directly and indirectly. It should be realized though that properties of ecological systems that people regard as 'useful' may change over time even if the ecological system itself remains in a relatively constant state.

The quantitative relationships between aspects of biodiversity, ecosystem components and processes, functions and services are still poorly understood. The specific nature of interdependencies between the structure and diversity of biotic communities and the functioning of ecosystems remains one of the most important unresolved questions in ecology (ICSU et al., 2008). Specific, measurable indicators are needed to comprehensively and quantitatively describe the interactions between the ecological processes and components of an ecosystem and their services. Two main types of indicators are needed: (1) state indicators describing which ecosystem process or component is providing the service and how much (e.g., total biomass or leaf area index (LAI)) and (2) performance indicators describing how much of the service can potentially be used in a sustainable way (e.g., maximum sustainable harvest of biomass or the effect of LAI on air-quality).

Some major questions regarding the 'ecology of ecosystem services' include: How will the loss of biodiversity affect ecosystem services? (already the subject of study since the 90s studies SCOPE, GBA (UNEP) Mooney et al., 1995). Is the concept of Service Providing Unit (SPU), introduced by Luck et al. (2009) useful to make the link between ecosystem character and service more explicit? Or the concept of functional traits? Is it possible to develop checklists of biophysical benchmark-values for the main ecosystem-types and their services (e.g., as Ruijgrok et al., 2006, attempted for ecosystems in The Netherlands)? To what extent can ecosystem services be replaced by technological substitutes (see ten Brink et al., 2009)?

As indicated above, in the late 1960s and early 1970s a wave of publications by mostly natural scientists was produced which addressed the notion of the usefulness of nature for society, other than an object of ethical concern. Some of these came from concern about pollution impacts, others from resource degradation and limits to the public enjoyment of nature. Helliwell (1967) used terms like functions of nature, amenity value and conservation value and compared these with economic values explicitly moving away from intrinsic values of nature and discussed the implications for the discount rate (Helliwell, 1974, 1975). Odum expanded his analyses of natural systems (Odum, 1957) to the world of man in Environment, Power and Society (Odum, 1971). Holdren and Ehrlich (1974) use the term public service functions of the global environment, Ehrlich et al. (1977) subsequently the term public service functions of the global ecosystem, and Westman (1977) nature's services. In The Netherlands, in the context of regional planning, Van der Maarel and Dauvellier (1978) produced a classification of functions of nature, and Braat et al. (1979) published an ecological-economic analysis, using the term functions of the natural environment, initiated by WWF, with statements such as "functions of nature have an economic value, since they represent ways to satisfy needs of man…" (p.21) and early notions of bundles of ecosystem services (cooperation and interactions of functions). This expanding field was finally captured concisely in the (Ehrlich and Ehrlich, 1981) paper when the term *ecosystem services* was coined.

1.3. Economic roots

Gómez-Baggethun et al. (2010) trace the treatment of nature's benefits throughout economic history from the classical economics period to the consolidation of neoclassical economics and economic sub-disciplines specialized in environmental issues. Some of the classical economists explicitly recognised the contribution of the "services" rendered by "natural agents" or "natural forces". However, they recognised only their *value in use*, but generally denied nature's services role in exchange value, because they were considered as free, non-appropriable gifts of nature. It is observed that only scarce resources have an exchange (marginal) value. When ecosystem services were abundant (i.e., enough for all desired uses), their marginal value (hence exchange value) was zero. This is obviously no longer the case. In contrast to the physiocrat's belief that land was the primary source of value, classical economists began to emphasise labour as the major force backing the production of wealth. Marx considered, at some point in his work, value to emerge from the combination of labour and nature: "Labour is not the source of all wealth. Nature is just as much the source of use values (and it is surely of such that material wealth consists!) as labour, which itself is only the manifestation of a force of nature" (see Martínez-Alier, 2005).

In the 19th century, industrial growth, technological development and capital accumulation triggered a series of changes in economic thinking that led nature to lose importance in economic analysis. By the second half of the 20th century, land or more generally environmental resources, completely disappeared from the economic (mathematical) production function and the "shift from land and other natural inputs to capital and labour alone, and from physical to monetary and more aggregated measures of capital, was completed" (Hubacek and van der Bergh, 2006). In the second half of the 20th century, some economists started to analyse environmental problems. The undervaluation of the contributions by ecosystems to welfare in public and business decision-making was partly explained by the fact that they are not adequately quantified in terms comparable with economic services and manufactured capital (Costanza et al., 1997). From this perspective, non-marketed ecosystem services are viewed as positive externalities that, if valued in monetary terms, can be more explicitly incorporated in economic decision-making. The definition of externalities has become increasingly less rigorous. Initially, externalities were defined as unintended consequences on one agent of an economic activity carried out by another agent, for which no compensation occurred (see e.g., Pearce and Turner, 1990 or Daly and Farley, 2010.). From this definition, the loss of ecosystem services is a negative externality, but the provision of ecosystem services by natural ecosystems is not necessarily a positive externality, unless the owner of the ecosystem forgoes its use.

Discussions within the society of Environmental and Resource Economics throughout the 1970s and 1980s caused some of the members to move away and create the society and journal of Ecological Economics (see Costanza, 1991). Ecological Economics conceptualises the economic system as an open subsystem of the ecosphere exchanging energy, materials and waste flows with the social and ecological systems with which it co-evolves. The focus on market-driven efficiency, typical for Neoclassical Economics, is expanded to include the issues of equity and scale in relation to biophysical limits, and to the development of methods to account for the physical and social costs involved in economic performance using monetary along with biophysical accounts and other non-monetary valuation languages (Martínez-Alier, 2002). A major issue in the debate between neo-classical and ecological economists is the sustainability concept. The so-called "weak sustainability" approach, which assumes substitutability between natural and manufactured capital, has been mostly embraced by neoclassical environmental economists. Ecological economists have generally advocated the so-called "strong sustainability" approach which maintains that natural capital and manufactured capital are in a relation of complementarity rather than of one of substitutability (Costanza and Daly, 1992). A second area of controversy relates to ecosystem services valuation. Although monetary valuation of ecosystems had been in use since the 1960s, this type of study strongly increased in the 1990s as a growing number of natural scientists recognised the appeal that framing ecological concerns in economic terms could have for decision makers. This is all discussed in more detail by Farley, (2012).

1.4. *Synthesis: ecosystem services*

In the 1970s and 1980s, a growing number of environmentally 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 (1973) 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" (Westman, 1977; Braat et al., 1979, Pimentel, 1980; Ehrlich and Ehrlich, 1981; Thibodeau and Ostro, 1981; Kellert, 1983; De Groot, 1987; Braat, 1992, De Groot, 1992). The rationale behind the use of the ecosystem service concept was mainly to demonstrate how the disappearance of biodiversity directly affects ecosystem functions that underpin critical services for human well-being. The paper by Costanza et al. (1997) on the total value of the global natural capital and ecosystem services was a milestone in the mainstreaming of ecosystem services. The monetary figures presented resulted in a high impact in both science and policy making, manifested both in terms of criticism and in the further increase in the development and use of monetary valuation studies.

Recently, global environmental problems have been framed in economic terms and been approached with cost-benefit analysis. Examples are the Stern Review on the Economics of Climate Change (Stern, 2006) and the Cost of Policy Inaction study initiated by the European Commission (Braat and ten Brink, 2008). The TEEB study, building on this initiative, has brought ecosystem services in the policy arena with a clear economic connotation (www.teebweb.org/). 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. Farley observes (pers.comm.) that these instruments are better described as 'market like' rather than 'market based', as there are very few examples that really meet the criteria for market mechanisms.

Following the 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 Programme (UNEP): the Millennium Ecosystem Assessment (MA; see Fig. 1). It was soon followed by an exploration of The Economics of Ecosystems and Biodiversity (TEEB; again under UNEP umbrella; see Fig. 2).

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 MA diagram stresses the various components of the ecosystem concept and of human well-being and the width of the arrows suggests a relative importance of the links between the components. The TEEB diagram places ecosystem services explicitly between the natural and human systems and identifies benefits for people following from services (and goods) delivered by ecosystems, and separates benefits and values. It also shows more clearly that ecosystem services stem from the ecological structure and processes and their functions in ecosystems. The TEEB diagram is an extension of the so called cascade model published by Haines-Young and Potschin (2009).

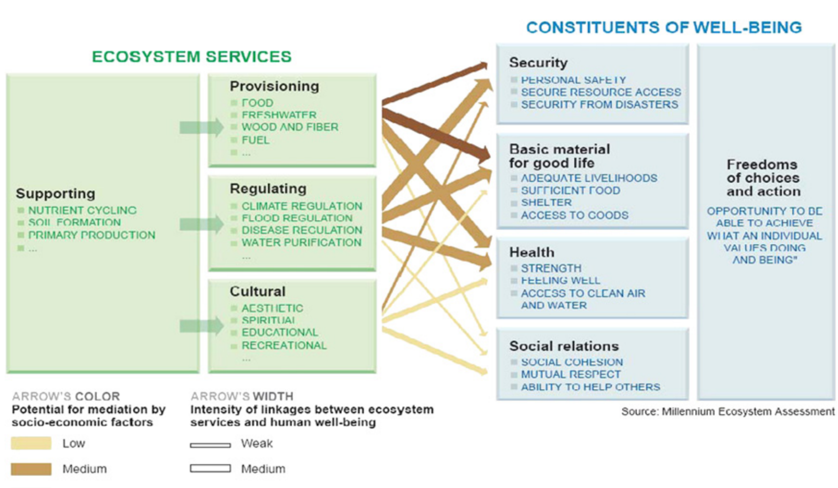

Fig. 1. Millennium ecosystem assessment (MA) overview diagram.

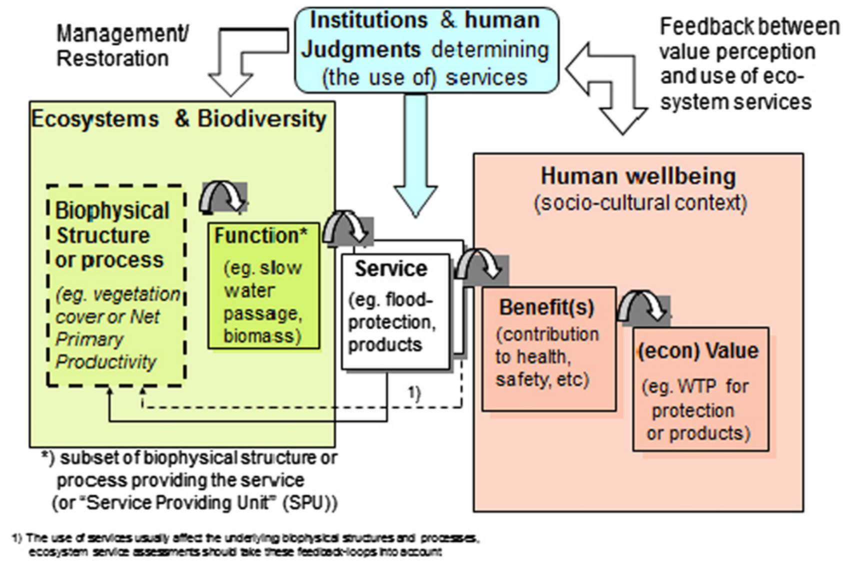

Fig. 2. The Economics of Ecosystems and Biodiversity (TEEB) overview diagram. De Groot et al. (2010a), adapted from Haines-Young and Potschin (2009).

The cascade model may be elegant in its simplicity, but there are a few features which deserve critical attention. In the diagrams of the cascade model, the "unidirectional downward flow" can be and is often interpreted to imply that ecosystem services flow effortlessly from ecosystems to human well-being, just like water in a cascade waterfall, without input by the receiving box in the diagram. A negative (=reducing; in cybernetic terms) feedback via pressures, including pressure—mitigating policies adds one of the relevant features of a real world system to the original model. There are similarities with the DPSIR (Driver, Pressure, State, Impact, Response) model (see www.eea.europa.eu). The so called TEEB diagram, shown in Fig. 2 adds positive (=enhancing) feedbacks via institutions, judgements, management and restoration which connect the "social sciences" angle with the "natural sciences" angle to ecosystem services.

Following Odum's energy flow approach to complex systems (see e.g., Odum, 1983), we argue that in the real world, provisioning and cultural ecosystem services are only delivered (and subsequently beneficial and of value) to humans with some investment of energy, e.g. labour, by humans (see Fig. 3). The energy content of the ecosystem services flows is in all such cases a combination of natural (ecosystem processes based) energies with human energies.

Even a basic provisioning service, such as food delivery, requires labour in the form of gathering, hunting or harvesting work. All cultural services (by definition) involve activity of human sensory organs and brains to absorb and process, respectively, the information provided by the components, structure an dynamics of ecosystems. The group of regulating services is diverse in this respect. They all are forms of work by ecosystems which contribute to an environment humans (and many other species) can live in (e.g., climate regulation by carbon sequestration; air pollution capture), buffering extreme events (floods, droughts, erosion) or facilitating other services (pollination), without human labour required in that ecosystem work directly. In practice, at least in developed economies, human interventions have often reduced the capacity of ecosystems to perform such regulating services, so that targeted restoration and management are necessary to re-establish the capacity for regulating services. In economic terms there are always opportunity costs involved, e.g. by having a forested land not available for urban activities. Finally, in the cascade diagram, the transition from benefits to values is a deceptively simple step, which in fact is most often a very complex process in the real world of appreciation by humans, depending on location, relative scarcity, time in life, cultural background etc.

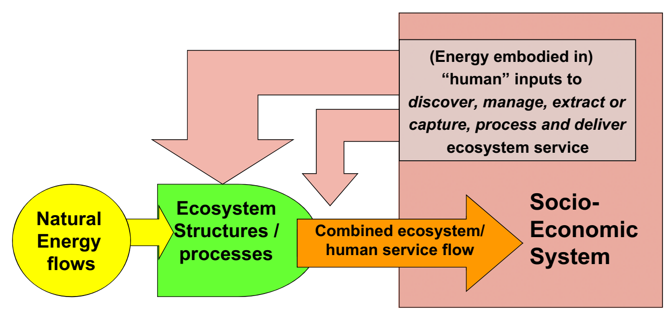

Fig. 3. Ecosystem services as product of ecosystem and human energy. Braat, adapted from Odum (1983).

2. Agenda

2.1. Introduction

As we have seen in the previous section, nature and biodiversity have increasingly become a factor in economic development planning and decision making since the 1970s, be it mostly via concepts as functions and, later, services. With the introduction of Environmental Impact Assessment (EIA; EEC, 1985) and its relative, the Strategic Environmental Assessment (SEA, EC, 2001), the foundations were laid. Many countries are now extending these decision support instruments and combine them with traditional cost-benefit analysis into so called social cost-benefit analysis or sustainability assessment. The "TEEB procedure", as outlined in TEEB Synthesis Report 2010, could then be seen as the next step in the process of maturation of ecologically based, social and economic decision making (see e.g., Fig. 4).

In the diagram a Step 0 is introduced for those studies where teams which have little or no experience in ecosystem services analysis are urged to consider the wide range of cases and discussions available in the report series of the Millennium

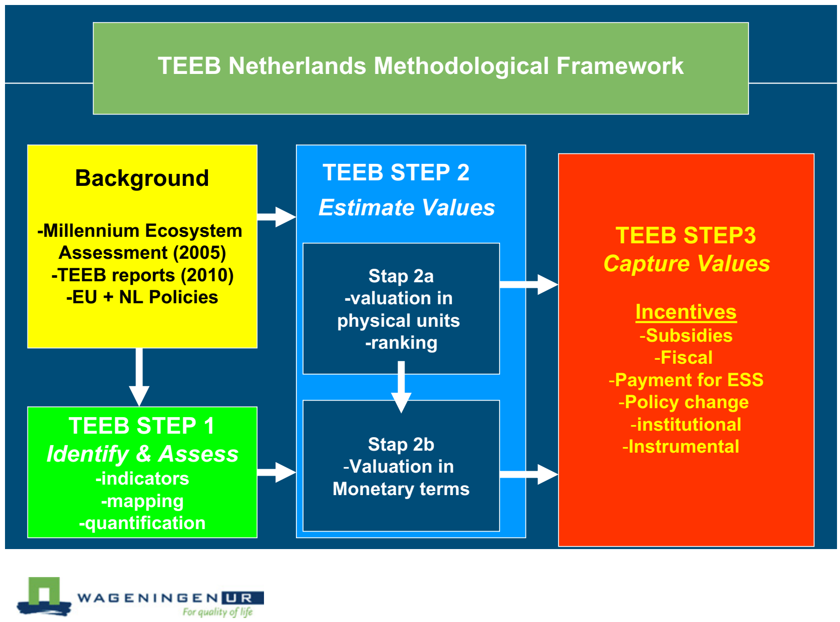

Fig. 4. TEEB Procedure (see TEEB Synthesis report, 2010). Step 1: Identify and Assess the full range of ecosystem services affected and the implications for different groups in society, Step 2: Estimate and Demonstrate the value of services and Step 3: Capture the value of ecosystem services and seek solution to overcome their undervaluation, using economically informed policy instruments.

Box 1–Research priorities regarding TEEB Procedure STEP 1 (Identify and Assess)

1) Development of tools to contribute to adequate mapping of land- and sea-scape areas in terms of ecosystem service provision?
2) Specific tools to contribute to better assessment of spatial and temporal dynamics of service provision, especially in relation to beneficiaries.
3) Models to assess total social value at different geographical scales of bundles of ecosystems services.
4) Models to assess consequences of land use changes for ecosystems services, benefits and economic value.

Ecosystem Assessment (www.maweb.org) and The Economics of Ecosystems and Biodiversity (www.teebweb.org/).

To achieve recognition of the value of biodiversity for survival of the human species, and for material wealth and spiritual well-being of humans in their complex economies is a considerable feat in itself. To transform recognition into concrete policies and management actions that lead to improved ecosystem quality and maximum sustained levels of service provisioning is an even more formidable challenge. The TEEB authors argue that greater economic and ecological rationality in addressing natural capital and ecosystem services is not only necessary but possible, and indeed, that it is well supported by case evidence “which deserve more attention, investment, and opportunity to replicate and to scale into wider use around the world” (TEEB Foundations, 2010). The paper by De Groot et al. (2012) illustrates this with a great number of valuation exercises. In the next sections we briefly discuss these steps to structure the major agenda items for the Ecosystem Services journal emphasising the science—policy—practice linkage, which is the philosophy of the Journal as expressed in the sub-title of this paper. The Research Priorities given in the three boxes below have mainly been selected from the TEEB reports and a paper by De Groot et al. (2010a,b), synthesising the findings of the ICSU report (ICSU et al. 2008) and adapted on the basis of the experience of the authors (Boxes 1–3).

Box 2–Research priorities TEEB Procedure Step 2 (Estimate and Demonstrate)

1) *Valuation and benefit transfer method*: Models are needed for easy but correct adjustment of monetary values of ecosystem services when making use of generic and average values for specific situations.
2) *The relevant ecological knowledge in economic decision-making*: Models are needed for applying ecological knowledge about system dynamics (including carrying capacity constraints, non-linearities, boundary effects) in valuation and decision contexts.
3) *The relationships between natural capital (ecosystems, biological diversity; stocks) and the ecosystem services (flows)*: ‘‘One of the central challenges in economics is to determine how much ecosystem structure should be converted into economic products, and how much left intact to generate ecosystem services. Before society can decide how to answer this question, however, it must prioritise the desirable ends, and must also have a firm understanding of the nature of the scarce resources’’ (Farley, 2012).

2.2. Identify and assess: indicators, mapping and quantification (STEP 1)

2.2.1. Biodiversity and ecosystem services indicators

There is clear evidence for a central role of various aspects 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. We can state with a high degree of certainty that maintaining functioning ecosystems capable of delivering multiple services requires a consistent approach to sustaining a

Box 3–Research priorities TEEB Procedure Step 3 (Capture and manage values).

1) *Natural capital and ecosystem services value in regional planning*: The mapping, assessment, valuation and accounting of natural capital and ecosystem services are on their way to become established elements of national and regional planning schemes. However, much still needs to be done about each of the steps as well as the overall embedding of the steps in planning procedures, legal systems and education systems to train professionals in these fields.
2) *Payments and compensation for ecosystem services*: Inclusion of non-market values in regional planning and investment decisions may take place by extension of market-based (or market-like) schemes of Payments (or compensation) for Ecosystem Services (PES), as explored in the past decade.
3) *Trade flow policies based on ecosystem service value : a new WTO*We need to consider restructuring the international markets for goods and services, and subsequently the pricing mechanisms for trade flows, incorporating the real values (including the externalities) of the trade commodities based on ecosystem services accounting.

considerable level of these (and other) aspects of biodiversity, in the long term also when a single service is the focus.

Most of the current measures and indicators of biodiversity and ecosystems were developed for purposes other than economic assessment. They are therefore not always able to show clear relationships between components of biodiversity and the services or benefits they provide to people. A reliance on existing measures will in all likelihood 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 into the future. 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 be based on accepted methods that reflect the aspects of biodiversity involved in the service that is 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. From the World Resources Institute (WRI) a proposal came based on indicators mentioned in the MA (Layke, 2009) and the European Environment Agency has coordinated the development of such a set of indicators under the name SEBI2010 (Streamlining European Biodiversity Indicators for 2010; EEA, 2010). Muller and Burkhard (2012) address the challenge of developing indicators for ecosystem services in their contribution to this first issue of Ecosystem Services. They observe that to make progress in establishing an adequate, credible and effective indicator set, future activities may well have to consider, among others, improving our recognition of the interrelations between the components of indicator sets, finding a case-specific optimal degree of indicator aggregation and improving measurability and service quantification and assessing indicator uncertainties.

2.2.2. Mapping

It is essential to map the ecological and human 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 et al. (2012) give an introduction to and overview of the challenges of mapping ecosystem services. The PRESS studies (Maes et al., 2011; Maes et al., 2012) were developed in the context of the EU Biodiversity Strategy 2011–2020 (EC, 2011). This Strategy is the EU elaboration of the Aichi Targets of the CBD agreed in, 2010 at the 10th Conference of Parties in Nagoya, Japan. It sets an ambitious research agenda recognising the high potential of mapping ecosystem services for policy support and decision making. To allow EU policy development in an effective way, clear and specific definitions of the different ecosystem services are deemed necessary including the appropriate indicators and units for quantification so that they can be used for setting policy and management objectives as well as for natural capital accounting.

2.2.3. Quantification and modelling

We shall not consider here straightforward measurements, estimation and modelling of physical quantities in individual ecosystem services flows. This is considered the domain of the specific sciences dealing with these flows, e.g. timber production, air pollution, water purification, pollination or outdoor recreation. We look briefly here at the challenges of quantifying 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, anthropocentric, 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 ten Brink (2008) provide a provocative visualisation of the trade-offs between provisioning and other ecosystem services with an increase in intensity of land use (see Fig. 5).

In the diagram, there is a gradual drop of regulating service levels (e.g., water, air, climate) with increasing degradation of the ecosystem. For recreation and tourism, values of ecosystems for humans are high if a certain degree of accessibility and infrastructure is provided, whereas the levels also drop with the degradation of the ecosystem leading to humans seeking for a substitution of the service. Hence, the optimum of the recreation benefits can mostly be found in ecosystems with light use. For provisioning services, e.g. in agriculture, the maximum gross output will be in intensive agriculture land use, while the net output in those intensive systems will of course be lower. Comparing systems, less intensive agricultural is quite often more energy efficient (see Pérez-Soba et al., 2012). However, exceptions exist as for instance wine areas are intensively managed, but have additional recreational service benefits because they are highly appreciated in their aesthetic value by many people.

Regarding trade-offs between different ecosystem services, past research mainly highlighted the externalities incurred from e.g. agro-ecosystems as a result of optimising production or provisioning services at the expense of other (regulatory or cultural) eco-system services (see de Groot et al., 2002). Recent research, however, emphasises more strongly the importance of informed management to mitigate the trade-offs between

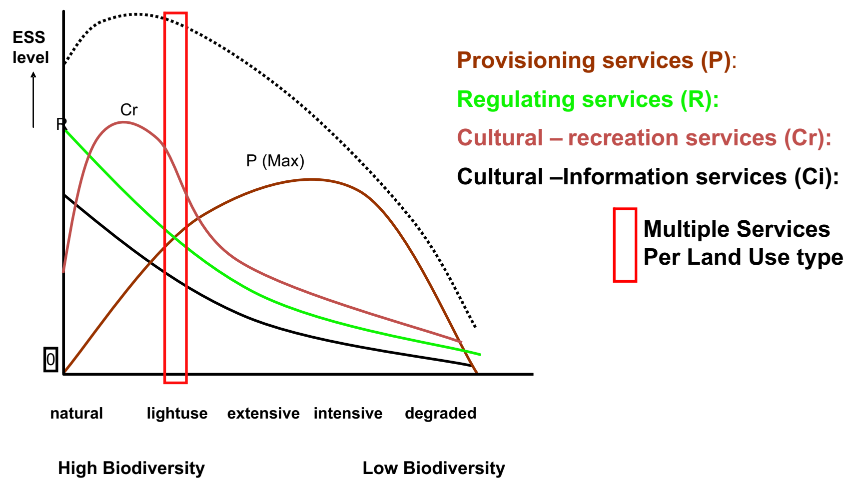

Fig. 5. Land use, biodiversity and multiple ecosystem services (after Braat and ten Brink, 2008).

provisioning and other ecosystem services and to enhance the often overlooked regulating and cultural services of agro-ecosystems. A research challenge regarding multiple service land use planning and management is to find the balance between different ecosystem services, and find optimal mixes. Several approaches are being considered to find such a balance, with ecological tolerance, multiple enhancement of management actions, and maximisation of total economic value of output as examples Another guiding measure for finding the right balance between ecosystem services could be minimisation of the level of degradation, because the value of all ecosystem services are declining with further degradation of the ecosystem—even though the gradient might be different. A core question is therefore, to what extent degradation can or should be tolerated in order to maximise the value across all ecosystem services.

2.3. Estimate and demonstrate: valuation and monetisation (STEP 2)

2.3.1. Decision making and valuation

In applications of the TEEB procedure, the comparison of assessments of quantitative physical changes in ecosystems and ecosystem services of alternative autonomous developments or policy scenarios were part of Environmental Impact Assessments to inform decision makers of the consequences of proposed actions. EIA does not provide direct insight in welfare gains and losses. Historically, this was thought to be obtained from Cost Benefit Analyses. Both the costs of development as well as the benefits recognised in the market were included in the cost-benefit equations. The costs of loss and the benefits of conservation of non-market ecosystem services, as most regulating services are, were generally ignored (see Braat and ten Brink, 2008, for global costs of policy inaction regarding biodiversity and associated ecosystem services). So a broader approach, including the non-market aspects of welfare and well-being must be added to the decision making process. If marginal changes are the issue, scenario comparison is considered particularly important for monetary valuation, since this enables analysis of changes in service delivery and subsequent change in marginal values (see TEEB Foundations, 2010, Chapter 1). When, however, the proposed land use change involves nearly complete loss of ecosystems, biodiversity features, and disappearance of ecosystem services, marginal value changes are in fact irrelevant. To quote Farley (2008): "In the vicinity of thresholds, marginal analysis is inappropriate". Farley (2012) explains that "when a system crosses a threshold, a very small change in economic activity can have enormous impacts. Crossing such thresholds can lead to the irreversible loss of critical natural capital, with unacceptable costs to society".

Valuation, and especially monetary valuation, is sometimes understood to imply that ecosystem services must be privatised and commodified (traded in the market). Firstly, this is not a necessary corollary, but secondly something that can be countered by demonstrating that public goods and services (and the natural capital they come from) may better be managed in the public domain.

2.3.2. Valuation and biodiversity

"Valuation, including economic valuation, functions as a system of cultural projection which imposes a way of thinking and a form of relationship with the environment and reflects particular perceived realities, worldviews, mind sets and belief systems." (TEEB Foundations, 2010). When discussing the value of nature or biodiversity, the traditional, and until recently dominant, argument was based in moral, ethical perspectives, invoking abstract concepts as intrinsic value or more concretely, but generally not operational, the right to live of other species than humans. The so called utilitarian concept, where the value of biodiversity is assigned via the use value of the ecosystems and their services, of which biodiversity presumably is an essential part, has become at least as important in arguments for conservation and sustainable use, more recently, in fact since the Millennium Ecosystem Assessment was assimilated in the CBD agenda and in Europe in the European Biodiversity Strategy. Christie reports on a case study relating to the Great Britain's Sites of Special Scientific Interest (SSSI) to demonstrate the potential ecosystem service benefits that can be derived from biodiversity conservation policies (Christie, 2012).

2.3.3. Valuation and society

An interesting view on valuation processes is proposed in TEEB Foundations, 2010, where it is depicted as a form of "regulatory adaptation by serving as a mechanism to provide feedback in an economic system". In this view, the valuation of changes in biodiversity, natural capital and ecosystem services then becomes a logical and necessary element of the sustainable development policy cycle. Economic valuation which produces a broadly (market and non-market) based tabulation of the benefits and costs may well contribute to adjust policies and regulations to the natural science based knowledge of productive and carrying capacity of ecosystems, dose-response relationships of biodiversity components and the survival, welfare and well-being requirements of human beings. Primmer and Furman (2012) observe that ''Natural resource and land use management have (historically) been based on economic criteria'', while Muradian and Rival (2012) explain that ''more useful insights for the management of ecosystem services can be derived from the literature on institutional arrangements for governing common-pool resources than from the literature on Coasean approaches to resolve environmental externalities''. They contend that it is ''analytically more appropriate to conceptualise payments for ecosystem services as incentives for collective action rather than as quasi-perfect market transactions to solve market failures''.

2.3.4. Monetisation issues

''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, if only that 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. Farley (2012) discusses these issues in detail. Terminology is important to make discussions count in policy design and decision making. A distinction between monetisation and expressing ecosystem service values in monetary terms is proposed and discussed in De Groot et al. (2012) of Ecosystem Services.

New methods, techniques and combinations of different methodological approaches (e.g., monetary, deliberative and multi-criteria methods) are looked for, to deal with the challenges of decreasing natural capital, increasing demand for provisioning, cultural and regulatory services at the same time in the same region and increasing involvement of stakeholders with wide ranging interests and preferences. Collaboration between ecologists and economists, including learning each other's language, paradigms, methods and models, are considered mandatory to develop valuation techniques that are better suited to dealing with the above listed complexities of life on earth. The paper by De Groot et al. (2012) summarises the latest state-of-the-art regarding monetary valuation of the total bundle of ecosystem services provided by the main ecosystem types. Brander et al. (2012) report on a meta-analysis and value transfer application with respect to ecosystem service values for mangroves in Southeast Asia.

2.3.5. Time aspects

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 required natural restoration time may run into decades for wetlands and grasslands and hundreds of years for forests. And while in medieval times, cathedrals took a century to complete, in modern times complex economic systems, such as cities may be rebuild in decades (see for example cities in post-World War 2 Germany). 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 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. See also Gowdy in TEEB Foundations, 2010 (p.20).

2.4. Capture and manage the values (STEP 3)

2.4.1. Introduction

Step 3 in the TEEB procedure is interpreted as ''to capture the values for a sustainable society''. In TEEB for Policy Makers (2011) the message is that the TEEB approach entails ''providing information about benefits, creating a common language for policy-makers, business and society, revealing the opportunities to work with nature, emphasising the urgency of action and generating information about value for designing policy incentives''. To a large extent the third step is represented in the TEEB diagram (Fig. 2) by the feedback loop from the economics box to the ecological box, and to the services flows, as institutional, policy and societal response. The 3-step approach presented in the TEEB synthesis report (see www.teebweb.org/) is supposedly linked to basic processes in society, which are already institutionalised or need to be so (quotes in *italics*):

1. *Recognising value in ecosystems, landscapes, species and other aspects of biodiversity is a feature of all human societies and communities, and is sometimes sufficient to ensure conservation and sustainable use.*

The TEEB authors contend that ''protective legislation or voluntary agreements can be appropriate responses where biodiversity values are generally recognised and accepted''. They conclude that under such circumstances, monetary valuation may be unnecessary, or even considered counterproductive.

2. *Demonstrating value in economic terms is often useful for policy-makers and businesses, in reaching decisions that consider the full (market and non-market) costs and benefits of a proposed use of an ecosystem.*

The marginal value approach dictates that (monetary) valuation should only be applied for assessing the changes in welfare which result from changes in the real world, and not be used for the total value of ecosystems. We contend that it is important to identify, quantify and valuate all changes in ecosystem services. Pittock et al. (2012) observe that e.g. in Australia, the term ''ecosystem services'' appears widely but often in a superficial way, often with reference to only a few services. ''The full suite of services, benefits and beneficiaries if humans and the natural environment are to coexist in the long term have not been systematically included in decision making and management ''. To choose a priori and arbitrarily to exclude some classes of services makes no sense. A systematic check list of ecosystem services should lead the selection process. And the capital stocks of those services which are then shown to be prominent, should also be part of the analysis. In addition, decision makers also need information about who is affected and where and when the changes will take place. Such a demonstration of economic value may also lead to more efficient use of natural resources.

2. *Capturing value, the final tier of the economic approach, involves the introduction of mechanisms that incorporate the values of ecosystems into decision making, through incentives and price signals.*

The capturing of course refers to making the ''value'' in the service actually 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. The development (or adjustment) of the legal system with respect to rights over natural resources and liability for damage to ecosystem service potential is essential.

2.4.2. Effectiveness and economic costs and benefits of ecosystem management policies.

In exploring the economics of ecosystems and biodiversity issues, much attention was first given to the costs of policy inaction (COPI) (Braat and ten Brink, 2008), but subsequently also the benefits of action (BOPA) were examined. Both approaches may reveal ways to improve current policies, and a number of suggestions came from these studies, ranging from strict regulation of access to and use of natural capital, to market-based instruments taxes to eliminate externalities. The effectiveness of the policies is the dominant criterion, as efficiency is only one of the three sustainability criteria (see Farley, 2012). Maestre Andrés et al. (2012) propose a framework for studying the interdependences between biodiversity, ecosystem services and conservation policy. They argue that a necessary (not sufficient) condition for making a transition to a truly sustainable economy is that the analysis of biodiversity conservation takes into account unwanted and avoidable indirect effects of all kinds of biodiversity policy. The thesis of the present paper is in fact that the design of sustainable development policies can be much better informed (than is currently practised) by properly using economic valuation and accounting exercises, which include the non-marketed services, and wisely use expressions of value in monetary terms to make public decision making transparent.

2.4.3. Crisis, shrinking economies and ecosystem services

The current economic crisis may be used profitably by examining it for its potential to teach humanity what ecosystems and biodiversity are contributing to welfare and well-being now that the virtual money economy is in distress, and the real physical economy is the one that keeps societies liveable, although some luxury is lost. On the other hand, in times of scarcity in developing nations with relatively rich natural resources, ecosystem exploitation (e.g., harvesting trees for timber and fuel) is often increased by an incentive to increase wages and employment, while at the same time, government budgets for the management of these resources are even more constrained. Another feature of the current crisis is that it has slowed down the rate at which humans are degrading ecosystems, but it has also reduced the financial resources that countries are willing to dedicate to restoring them.

3. Conclusions

The agenda for the journal Ecosystem Services is aimed at scientists and policy analysts who consider contributing to better knowledge and better use of that knowledge about ecosystem services. This should include knowledge of the ecological systems that provide the services, the economic systems that benefit from them, and the institutions needed to develop effective codes for a sustainable use. The agenda is derived from the experience of the authors in science and policy analysis and extended with some of the recommendations from the TEEB book for national and international policy making (TEEB for Policy, 2011). In addition to the research priorities per TEEB step as presented in the boxes above, we have listed a number of items which together constitute the agenda of the journal Ecosystem Services.

- We should involve the specialists in legal and institutional dimensions of societal development to address such issues around sustainable management of natural capital and ecosystem services.
- We should focus our energies to aid planners and decision makers at all levels to make the value of nature an integrated and 'natural' element to consider in economic activity, equating it with human well-being.
- We should investigate the physical characteristics of ecosystem services, such as temporal and spatial distribution, excludability, rivalry, substitutability and so on, and based on these characteristics, investigate the types of institutions—economic, political, and social—that are best suited for their protection and restoration.
- We should examine the specific features of planning and decision making situations where economic valuation is needed, and in which form that would be useful, including the non-marginal change, radical uncertainty or tipping points.
- We should explore the ecological, economic and social consequences of decisions involving the welfare of future generations, and assess the implications of flexible discount rates, including zero and negative rates.
- We should investigate the options to develop transparent systems of national accounts which include the value of changes in natural capital stocks and ecosystem services, and which give support to decision making at all levels of society.
- We should examine the consequences of a new World Trade Organisation, and for that matter also a new World bank and International Monetary Fund, based on the ecological economics of the future, instead of the neo-classical economics of the past.
- We should develop tools to facilitate the principles of 'No Net Loss' or 'Net Positive Impact' to make them normal business practice.
- We should examine the potential to contribute to sustainable development of principles such as 'polluter pays', 'beneficiary pays' and 'full-cost-recovery'
- We should focus some of our energies on the relevance of and conditions for involvement of stakeholders in ecosystem services management.

All these issues will be the subject of this new Journal, and many are introduced in more detail in this first journal issue. An important asset of the Journal is that it is closely affiliated with the Ecosystem Services Partnership (ESP) (www.es-partnership) which is a global network to stimulate the science, policy and practice of ecosystem services research and application. ESP has a large number of working groups which provide an ideal platform for further discussion of the main issues, whereby this Journal can serve as an important outlet to publish the latest insights.

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