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Short communication

The indicator side of ecosystem services

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ABSTRACT

In this short welcome note for the new journal "Ecosystem Services", the main interrelations between the ecosystem service concept and the approach of ecological indicators are briefly discussed with respect to three key issues: at first, some definitions are analyzed to answer the question if ecosystem services can be understood as ecological indicators. Due to a positive answer, the position of ecosystem services in the DPSIR indicator framework is determined as the central impact component. It is stated that different viewpoints are possible to interrelate the services; an environmental starting point focusing on the linkage to ecological processes and functions on the one side, and the relations with human well-being criteria and management obligations on the other. Finally, the actual needs for further research and application are outlined from an indicator-based aspect and the broad field of potential contributions for the new journal is summarized.

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1. Introduction

The concept of ecosystem goods and services has gained an enormous and steadily rising attractiveness for environmental scientists, managers and decision makers. Transferring Ulanowicz's distinctions (1986) of systems dynamics, an extraordinary *growth* of produced and applied information on ecosystem services could be observed during the last years which will now be complemented by an innovative *development*, which is strongly related to the articulation of the information flows, i.e. by the new journal "Ecosystem Services". In the following short note, some items will be discussed which are linked to the potential function of ecosystem services as indicators in human-environmental systems. We will raise some questions and sketch potential answers from the viewpoint of ecosystem service indication.

2. Can ecosystem services be comprehended as ecological indicators?

Ecological indicators are communication tools that facilitate a simplification of the high complexity in human-environmental systems. Following Wiggering and Müller (2004), indicators generally are variables that provide aggregated information on certain phenomena. They are selected to support specific management purposes, with an integrating, synoptic value, functioning as depictions of qualities, quantities, states or interactions that are not directly accessible (Dale and Beyeler, 2001; Turnhout et al., 2007; Niemeijer and de Groot, 2008; ten Brink et al., 2011). Heink and Kowarik (2010, mp. 590) distinguish descriptive, evaluative or prescriptive viewpoints in assessing states and trends in human-environmental systems and propose the following definition: "An indicator in ecology and environmental planning is a component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals".

As ecosystem services can be understood as the direct and indirect contributions of ecosystem structures and functions — in combination with other inputs — to human well-being (de Groot et al., 2010a; Burkhard et al., 2012), they certainly are following the above mentioned criteria and therefore can be nominated as indicators, if the target is a management-relevant communication about recent, past or potential future states of human-environmental systems. Moreover, Fisher et al. (2009) define ecosystem services as ecological phenomena, supporting their designation as ecological indicators. Of course, all indicator as well as ecosystem service definitions and classifications depend strongly on the characteristics of the investigated ecosystems and the decision context for which they are being applied (Reyers et al., 2010; Fisher et al., 2009, Boyd and Banzhaf, 2007). Layke (2011) consequently characterizes ecosystem service indicators as policy-relevant representations to identify gaps and communicate trends for information on sustainable use of these services and benefits to maintain them for future generations.

Ecosystem services provide very interesting indicator sets as they include descriptive aspects as well as evaluative items, following the above mentioned distinctions (Reyers et al., 2010). Therefore, indication strategies have to be selected which are

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capable of integrating indicators with very different degrees of normative loadings.

3. Which is the typical position of ecosystem services in indicator frameworks?

In human-environmental systems we can find a very high complexity of elements, connections and cause and effect relations. There are several attempts to bring some order into these complicated human-environmental system structures, and the most common organizing approach seems to be the *DPSIR* framework (*D*rivers, *P*ressures, *S*tate, *I*mpact, *R*esponse; see Borja et al., 2006; Burkhard and Müller, 2008; de Groot et al., 2010a; van Oudenhoven et al., 2012). The single components of the *DPSIR* approach have been constructed as a causal pathway integrating the subsequent steps of environmental management and monitoring. The basic idea is that social, demographic and economic developments, consumption or production patterns in societies and the corresponding changes in motivations and lifestyles – the *drivers* – produce certain *pressures*. These pressures can be described as environmental inputs including dismissals of substances, physical and biological agents as well as the concrete utilization of land and resources by human activities. Land management has been identified as main driving force for land use change and respective indicators have to represent this interrelationship (van Oudenhoven et al., 2012; Syrbe and Walz, 2012). Global climate change and its exceptional position as additional pressure in human-environmental systems have been mentioned in Burkhard and Müller (2008) and in de Groot et al. (2010a). Inputs corresponding with these pressures change the *state* of the environmental systems, which refers to the environmental, physical, biological and chemical conditions in a defined area. Due to these changes, *impacts* on natural and human systems are arising which can be understood as changes in the provision of ecosystem goods and services and in the socio-economic system. Finally, after the perception of these dynamics, actions are carried out by society and governments to minimize the negative impacts imposed on the human-environmental system *(response)*.

Besides the explained DPSIR elements, Fig. 1 shows the linkages between environmental state descriptions (ecosystems and biodiversity) and human systems (human well-being) as a part of the adaptive management cycle, based on the 'ecosystem service cascade' from Haines-Young and Potschin (2010). In this comprehension, the *state* is described by several biophysical structures and processes (ecosystem properties) which are processually linked in the cascade component of ecosystem functions. They are understood as the basic producers of ecosystem services. At the impact side, we can arrange ecosystem service modifications with their consequences for human-well-being and the respective valuation.

This framework can be observed and analyzed from different viewpoints: an ecological approach will ask for the consequences of pressures on states and how the impacts can be characterized. That is a focal question which is discussed for example in the journal "Ecological Indicators". But of course one can also ask for the consequences of ecosystem service changes on the response components, or the drivers as well as the forthcoming pressures and impacts. This viewpoint focussing on the relations between service provision, human well-being, social and economic valuation, management and policy is the main viewpoint of the new journal "Ecosystem Services". Besides many problems which arise within the different components in Fig. 1, a very interesting subject for future investigations will be the linkages between the components. From this aspect, a fruitful cooperation between the active persons and related media in the field can be expected.

4. How can we improve the suitability and quality of ecosystem service indicators?

Besides that conceptual positioning, the quality of indicators is an interesting point which will show linkages between the different thematic fields of ecosystem service research and which can be used to list some challenges and demands for future development of ecosystem service science. There are several features which can be used to assess the quality of an indicator (e.g. Kandziora et al., in press). Taking a look at the ecosystem service community, some of these demands still have to be improved, thus intensive future activities ought to be related to the following tasks:

- *Conceiving the linkage between indicator and indicandum more concretely*: Ecosystem service quantifications need a very high degree of information which very often is not available in the demanded extent; the object of interest (the indicandum) then has to be represented by an available set of variables. Due to several quantification problems and data scarcity, often only a small group of potentially representative variables is used, e.g. milk production for indicating provisioning services as a whole. These indicators often can only reflect a certain section of the object, but in fact the object itself is very comprehensive. Indicator developers and users should be aware that for example concerning ecosystem services, it should always be attempted to work with comprehensive indicator sets which do not highlight only one (may be minor) aspect to indicate that broad concept. This demand becomes even more important when trade-offs between different ecosystem services or competing forms of land management have to be dealt with. Therefore, there is a clear demand for the development of comprehensive indicator sets which are optimally capable of reflecting the complex object that they are representing on the one hand, but which should be easily measurable on the other hand.
- *Improving knowledge about relevant cause-effect relations between indicandum and indicator*: A basic legitimate demand on indicators is the need for significant interrelations between the investigated pressures, states and impacts. These relationships have to be clear and explicit. If that is not the case, the indicated information will be insufficient and potential measures and management strategies in response of a disturbance might be failing.
- *Improving our recognition on the interrelations between the components of indicator sets*: If we follow the demand for ecosystem service indicator sets as required e.g. by Niemeijer and de Groot (2008) or van Oudenhoven et al. (2012), we have to enhance knowledge about the systems-based interrelations between the components of those sets. For instance when applying the DPSIR concept, we have to analyze not only the relationships between the individual components (e.g. the multiple interactions between functions and services), but also the relationships within one component. Such network-based analyses might for example be very helpful to determine the role of biodiversity for ecosystem service provision. Another interesting application arises from the interactions between ecosystem services themselves, which can provide significant information on mutual supports or competitions and exclusions (Kandziora et al., in press).
- *Improving the transparency of the indicator derivation strategies*: Whenever indicators are applied, the user must be aware of the conception which has been used to define the indicators. Otherwise indicators will be ambiguous and the user will not be able to handle the results in a responsible manner. Therefore, the documentation of derivation concepts as well as of the calculation of indicators on ecosystem functions, ecosystem services and benefits in clear reproducible units must be

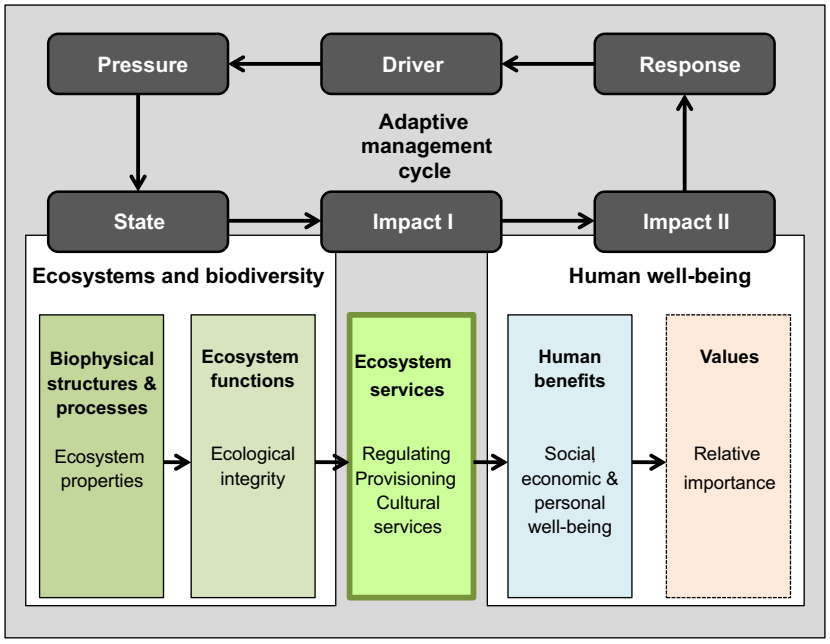

Fig. 1. Ecosystem services as parts of the adaptive *DPSIR* management cycle for human-environmental systems, following the ecosystem service 'cascade of Haines-Young and Potschin (2010). While the traditional field of environmental indication is mainly situated at the left side of the sketch, the anthropocentric components of the management cycle are situated at the right.

acknowledged as an important (not only exhausting) part of indicator reports (Seppelt et al., 2012).

- *Finding a case-specific optimal degree of indicator aggregation*: As indicators are developed to support the solution of practical problems and their accuracy depends on the purpose of the analysis, indicators are very often accompanied by a science-policy dilemma. While the developer mostly will prefer to increase the number of indicators and indices for security and significance reasons, the politicians are more satisfied with a minimal number of quantifications. So we can for example ask, if it is satisfactory to aggregate all ecosystem service provisions of a certain area within one (e.g. monetary) value, or if information on the different service classes or on single attributes is needed. We have to be aware that with the respective aggregations, the provided information of an indicator analysis will be reduced and that certain specialities or risks are lost in the compressed indication outcome. Thus, it makes sense to work with indicator hierarchies which provide information for different levels of management. In an optimal case, the users should be informed about the respective information loss which appears with an increasing degree of aggregation.
- *Estimating the normative loadings in the indicator set*: All indicator sets provide a normative component which arises from the respective objectives and the basic viewpoints of developers and users. While it is rather easy to decrease that normative loading in purely ecological indicator sets due to inter-subjective scientific fundamentals, a valuation cannot be carried out without normative influences. Working with indicators, these potential biases should be reflected, discussed and documented. That demand becomes extremely relevant if we apply economic or social valuation strategies where corresponding biases cannot be avoided. Therefore, a critical review of the normative elements in indicator sets and results should be included in all valuing studies.
- *Improving transparency and comprehensibility*: Returning to the DPSIR framework which has been recommended for ecosystem service indicator studies, we are facing an enormous complexity with several different components and very distinct linkages. This complicatedness might be one reason for the slow process of ecosystem service applications in practice (Koschke et al., 2012). But in the end, it should be the decision making process to be addressed that determines the ecosystem service assessment's level of precision and respective data (and indicators) to be used (Scolozzi et al., 2012). Consequently, one task of future development in the field will be
- *An improvement of the information exchange strategies and their didactics*: International networking initiatives such as the Ecosystem Services Partnership ESP[1] or the Intergovernmental Platform on Biodiversity and Ecosystem Services IPBES[2] are suitable communication interfaces for the scientific community and policy makers.
- *Improving measurability and service quantification*: There is not much use of an indicator which cannot be characterized by qualitative or quantitative features (ten Brink et al., 2011; Staub et al., 2011). Fortunately, ecological models and related holistic indicators have become very powerful today (Jørgensen and Nielsen, 2012) and many of them are ready to be used in ecosystem service assessments and environmental management. Thus, several groups are working at several places on methods and concepts for ecosystem service quantification, and the respective reports will be contributing to the progress of the overall approach. As a consequence, comprehensive ecosystem service data bases and concept-based ecosystem service monitoring systems are developed and implemented.
- *Assessing indicator uncertainties*: The development of indicator sets should always be accompanied with an honest declaration of the related uncertainties. This information will show the user the reliability of the tool and it will give her or him an idea about the potential error that might arise from a consequent application of the indicator set. Scolozzi et al. (2012) suggest to define different degrees of "acceptable" uncertainties in ecosystem service assessments, because different decision contexts may need different degrees of results' precision.

[1] 〈http://www.es-partnership.org〉.
[2] 〈http://www.ipbes.net/〉.

Besides this application-related necessity (which is rarely found in the literature), the formulation of uncertainties also is an important segment in the science process because it will be very helpful in creating new tasks and innovative methodologies.

This list of indicator-related challenges and questions is of course only one aspect of the overall research needs in ecosystem service science and application. And also many of the challenges which can be found in the literature can be related to ecological indicators.

For example Elmqvist et al. (2010) ask for future research with respect to an analysis of the linkages among biodiversity, ecological functioning, ecosystem processes, and the provision of valued goods and services. They ask for better understanding of the resilience of the complex and coupled human-environmental systems with reference to all components of the DPSIR scheme and for more knowledge on the regulating interactions at the species, ecosystem and landscape scale. Furthermore, the dynamics of ecosystem services have to be investigated with special emphasis on the interactions between different service categories. Progressive methodologies in ecosystem service mapping and investigations of the contributions of spatial landscape aspects for ecosystem service supply are demanded as well as the creation of new management tools (Syrbe and Walz, 2012). Respective assessment indicators must be developed accordingly. Hereby the problem of interacting scales will be a focal challenge in the future (Feld et al., 2007).

Stepping into the specific field of the new journal "Ecosystem Services", the TEEB study (Kumar, 2010; ten Brink et al., 2011) asks for better management practices, more effective instruments and governance institutions, and a better understanding of the dynamics of governance and management of ecosystems and ecosystem services (ten Brink et al., 2011). Additionally, the management of ecosystem service trade-offs and complementarities involved in the provision of bundles of ecosystem services provide significant fields for future investigations together with a multitude of economic, social and political questions referring to the management and valuation of non-market goods.

Further challenges have been exemplified by de Groot et al. (2010b). Besides the points listed above, the authors ask for increasing research on ecosystem service typologies, on the derivation of maximum sustainable use and benchmark values, they demand a more intensive modeling strategy to reliably calculate ecosystem services and for a derivation strategy for the determination of management thresholds. Therefore, comprehensive sets of indicators are needed, which need to be selected systematically and in a reproducible manner. The indicators have to reflect complex ecosystem properties, ecosystem functions and ecosystem services (van Oudenhoven et al., 2012).

Concerning valuation and ecosystem governance, de Groot et al. (2010b) ask for appropriate economic and social valuation methods. Moreover, they pose the question how to make economic and social valuation of ecosystem services consistent and comparable and how to map them. Considering the complexity of the human-environmental system, de Groot et al. (2010b) ask how all the costs and benefits of service dynamics as well as the values of all stakeholders can be taken into account properly in discounting and cost-effectiveness issues. Further challenges are seen in methods, tools and strategies for an effective participatory ecosystem service policy and in the prevailing data availability and reliability.

Summarizing, there are many questions to be answered and many challenges to be faced in the field of ecosystem services. Therefore, the editorial board of "Ecological Indicators" is looking forward to a fruitful cooperation with the new "family member" "Ecosystem Services". and we are transferring our very best wishes for the growth and development of this interesting new information platform.

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