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Ecosystem Services at the Landscape Scale: the Need for Integrative Approaches

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Abstract

During the symposium "Ecosystem Services at the Landscape Scale" from the EU-IALE conference 2009, several challenges for future research on approaches to use the concept of ecosystem services at the landscape scale were identified, focussing on the need for integration. Three main research directions were discussed, (i) the definition of the potentials and limitations of the ecosystem service approach for landscape analysis, (ii) the identification of suitable methods and tools to apply the ecosystem service approach at the landscape scale and (iii) the demand of incorporating ecosystem and landscape services in decision making and management. This paper briefly addresses and discusses some of these topics and puts them into a broader perspective. From this viewpoint it becomes obvious that many high-quality sectoral studies are carried out, e.g. concentrating on specific services or specific linkages within the "ecosystem service cascade" which describes the relation between biophysical characteristics of the landscape, their functions, services, benefits and values for society. In order to provide useful information for decision makers, ecosystem services studies should be supplemented by investigations of the whole systems of interactions between ecological processes and societal valuations.

Keywords: ecosystem services, research challenges, methods, integration, landscapes

Introduction

In recent years, the concept of ecosystem services has found increasing attention in environmental science, policy making and practical applications (Daily and Matson, 2008, Fisher et al., 2008, ICSU, UNESCO, and UNU, 2008, MA 2005). Landscapes play a fundamental role in this approach because they contain many important functions which provide numerous goods and services to society (Helming and Wiggering 2003, Brandt and Vejre 2004, Haines-Young and Potschin 2004, de Groot 2006, Gimona and Van der Horst 2007, Willemen et al. 2008). These goods and services include provisioning (e.g. food, timber, and fuels), regulating (e.g. climate regulation and water purification) and cultural services (e.g. aesthetic values, sense of place). The provision of these services is based upon the performance of ecological structures, processes and functions.

An important feature of the ecosystem service approach arises from the inherent demand for interdisciplinarity: To characterize goods and services, basic ecological principles have to be taken into account as well as the social and economic aspects which determine environmental evaluations and decision-making processes. Therefore deep ecosystem comprehension and competent (economic) valuation are crucial. Figure 1 demonstrates the ambitious requirements to describe the 'ecosystem services cascade'. Here it is shown that biophysical structure and process define the specific functions at a location. These functions provide ecosystem services that contribute to human well-being. The value people attach to these ecosystem services depends on the specific benefits they obtain from them. The ongoing TEEB-study gives a detailed

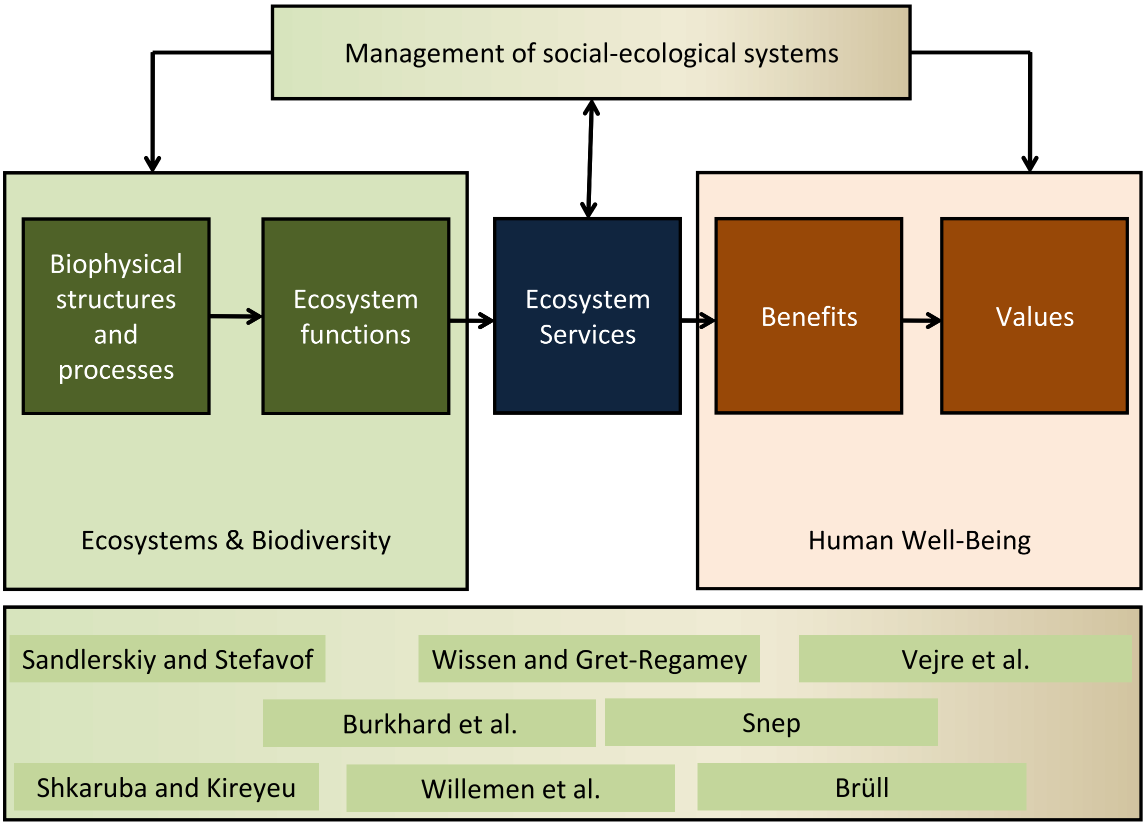

Figure 1: Assignment of papers referring to the ecosystem service cascade. Green colors indicate the objective natural sciences, while brown colors indicate the subjective, valuating social sciences. Ecosystem services are regraded as the interface of natural and scocial science. Authors are assigned to this natural-scoial science gradient. References: Sandlerskiy and Stefavof 2009, Wissen and Grêt-Regamey 2009, Vejre et al. 2009, Burkhard et al. 2009, Snep 2009, Shkaruba and Kireyeu 2009, Willemen et al. 2009, Brüll 2009.

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description and definition of these terms and concepts (de Groot et al. 2010). These demands for an integrative approach are well-suited to be coupled with the scope of modern landscape ecology (e.g. Wiens and Moss 2005, Wu and Hobbs 2007), qualifying landscapes as preferred objects for service research and application. Additionally also environmental management activities are strongly concentrated at the landscape scale. Therefore landscapes offer the optimal scale for respective research activities. This fact is underlined by the increasing number of service-based landscape analyses.

There are, however, still many challenges to be overcome, which have been intensely analysed by de Groot et al. (2010) or Verburg et al. (2009). In this paper some of these challenges will be briefly characterized, and one focal demand will be described in the end. The text is based on the contributions and discussions during a meeting of European landscape ecologists. To further the discussion about landscape functions and services, two major questions have been worked out in the symposium "Ecosystem Services at the Landscape Scale" as part of the European IALE conference 2009 at Salzburg: "What are the potentials and limitations of the ecosystem service approach for landscape analysis?" and "What are suitable methods and tools to apply the ecosystem service approach at the landscape scale?". Based on these questions, the contributions of this symposium have been arranged around three topics:

- Identifying and quantifying ecosystem and landscape functions and services
- Modelling spatial-temporal dynamics of ecosystem and landscape functions and services at different scale levels
- Incorporating ecosystem and landscape services in decision making and management

We will use these questions and topics to comment on some challenges of ecosystem service research at the landscape scale.

The working cases: Contributions of the Salzburg conference

Identifying and quantifying ecosystem and landscape functions and services

The first step of a service-based landscape analysis usually starts with a specification of the relations between landscape characteristics and their respective functions and services. Several approaches to conduct this "translation" are used in distinct studies, including empirical (Diaz et al. 2007, Willemen et al. 2008), process based, (Kremen 2005, Chan et al. 2006, Egoh et al. 2008) expert-knowledge based (e.g. Kienast et al. 2009; Haines-Young and Potschin 2004; Reyers et al. 2009) stakeholder related (Soini 2001, Brown 2006, Alessa et al. 2008) and monetary valuation methods (Troy and Wilson 2006, Nelson et al. 2009). Several of these methodological concepts have been discussed during this symposium. The basic contents of the assigned papers can be found in **Box 1**.

Modelling spatial-temporal dynamics of ecosystem and landscape functions and services at different scale levels

Landscapes are continuously changing, and therefore the provision of ecosystem and landscape goods and services is subject to permanent change (MA 2005, Reyers et al. 2009). Additionally, the societal demand for goods and services change over time, affecting the valuation of goods and services. In order to support sustainable development these temporal changes have to be taken into account in our modelling approaches. Recently, spatially explicit (ecosystem) service provision modelling tools have become available that describe multiple service supplies and different function interactions (Boumans et al. 2002, Tallis and Polasky 2009, Villa 2009). These models are able to assess the impact of human activities on the provision and va-

Box 1: Salzburg contributions to the topic "Identifying and quantifying ecosystem and landscape functions and services"

Henrik Vejre, Bo Thorsen, and Frank Söndergaard Jensen presented a method on the 'Quantification and aggregation of landscape functions and services in multifunctional peri-urban landscapes'. In Denmark the provision of services is often well documented, and the service-providing areas are normally well defined. Based on this detailed available information, landscape services were identified, delineated, quantified and aggregated for a study area located in the peri-urban landscape of Copenhagen. Subsequently, the authors related the service provision to estimated costs and monetary benefits, making the relevance of service supply from peri-urban areas to society explicit (Verje et al. 2009).

To be able to quantify service supply for large regions with small data availability Robert Sandlerskiy and Sergey Stefavof presented a 'Baseline assessment of ecosystem services in respect of multispectral remote information, terrain digital models and field values'. For a study area in Russia, remote sensing techniques were applied that allowed for estimating a set of supporting and regulating services using indicators such as: energy, bound energy, enthalpy, net production index and other functions and services connected with meso-climate regulation of the landscape. Also productivity, humidity, temperature of the active surface and other landscape characteristics were estimated by remote sensing data. Geo-referenced field measurements of vegetation properties and soils were additionally used to improve the assessments of provisioning and regulating services (Sandlerskiy and Puzachenko 2009).

Ulrike Wissen and Adrienne Grêt-Regamey presented their work on 'Identifying the regional potential for renewable energy systems using ecosystem services and landscape visualizations'. For their study area in Switzerland they carried out a spatially explicit quantification of ecosystem goods and services, done by a participatory process to ensure proper identification of the ecosystem services at stake and their value. The results were used to identify potential locations and conflict areas for renewable energy systems. This provided decision-makers with a tool for balancing interests and designing optimal landscape development options in order to reduce the environmental impact of renewable energy systems while enhancing their public acceptability (Wissen and Gret-Regamey 2009).

lue of multiple services in space and time. However, these models do not yet explicitly simulate spatial and temporal feedbacks in service supply as a result of dynamics in service demand.

Two contributions showed their modelling concepts at the European Union scale and at a regional level (see Box 2).

Incorporating ecosystem and landscape services in decision making and management

In the last symposium topic, case studies and strategies were presented concerning the application of ecosystem and landscape services in environmental management and decision making. Different studies were presented, all aiming at an improved practical utilization of the ecosystem service approach at the landscape level. The contributions to this topic emphasised the importance of including ecosystems in governance and communication tools (see Box 3).

Discussion

The main questions during the symposium discussions were related to defining the potentials and limitations of the ecosystem service approach for landscape analysis and to identify suitable methods and tools to apply the ecosystem service approach at the landscape scale. Based on the research presented during the symposium, the following challenges and opportunities related to these questions were highlighted:

The overarching challenge in the identification and quantification efforts on landscape services arises from the lack of knowledge on ecosystem functioning (the processes behind the service supply) and from data availability. Depending on the focus of a study (i.e. which services have the main attention) and the respective scale level (the spatial extent and resolution), it is likely that different quantification and mapping methods are needed. Key in all methods is an effective use and integration of data sources.

Box 2: Salzburg contributions to the topic "Modelling spatial-temporal dynamics of ecosystem and landscape functions nd services at different scale levels"

Benjamin Burkhard, Felix Müller and Franziska Kroll presented a framework to define the impact of human actions on the provision of ecosystem goods and services. Their framework aimed at improving the understanding of their dynamical behaviour, adaptive capacity, resilience and the capacity to provide ecosystem goods and services, for evaluating future potentials, risks and limits of actions in ecosystem management. They presented a set of potential alternative regimes within the European Union and quantitatively compared the capacity to provide ecosystem goods and services, deriving the capacity of service provision from land cover data. The approach has recently been published in Landscape Online (Burkhard et al. 2009).

Louise Willemen, Tom Veldkamp, Rik Leemans, Peter Verburg and Lars Hein also presented a modelling framework. This modelling framework described the spatial-temporal dynamics of multifunctional landscapes at a regional scale. The modelling framework linked the dynamics of landscape functions to changes in landscape properties and changes in demand for landscape services. The modelling framework included methods to quantify the relations between landscape characteristics, landscape functions and services supply, to quantify the compatibility of the use of landscape services, and to visualize trade-offs between landscape functions and services. An application of this modelling framework for a Dutch rural area was presented, demonstrating the relevance of modelling the dynamics of landscape function for environmental management and decision making (Willemen 2010).

Another important aspect related to the quantification of services is the choice of the measurement dimension. Ecosystem and landscape services can either be quantified in the unit of the actual service provision (e.g. m^3 clear water) or in the value of the service for society (e.g. monetary terms). This choice of quantification dimension strongly depends on the research goals. It should however be noted that figures on the actual service provision and service value can potentially be very distinct, and therefore measurement units should be selected with care.

Quantification of service provision is needed in order to be used as input in modelling frameworks, aiming at predicting changes in service supply affected e.g. by land use change. Here again, scale issues play a major role. Since service supply is a result of complex interactions between humans and their environment, changes at different scale levels influence dynamics in service supply. Consequently, a thorough scale definition of ecosystem service studies is necessary as well as an analysis of potential cross-scale interactions.

The role of stakeholders in the mapping and modelling approaches is conceived differently among the presented studies. Stakeholders can be seen as the focal target group of a study (they are the beneficiaries), and therefore the mapping and modelling of landscape services from this viewpoint should be done in a bottom-up manner, i.e. taking stakeholder perceptions and views as starting points. Consequently, these bottom-up techniques are applied in participatory approaches. On the other hand, in most symposium contributions the mapping and modelling was carried out in a top-down way, focusing on the larger scale processes and interactions, deducting the potential consequences for stakeholders from that perspective. To optimize the applicability of the ecosystem service approach, the linkages of these two distinct concepts have to be considered more thoroughly, preferably merging the bottom-up and the top-down strategies.

Models describing ecosystem and landscape functions dynamics should ideally be able to support governance, decision-making and management at the landscape level. Therefore modelling tools are not only a representation of system processes, they should also be used as communication tools by visualizing different futures and creating understanding for landscape system functioning. Thus, the implications of different policy actions should be depicted as model results in structural, functional and service related indications.

Another challenge in the growing field of ecosystem and landscape functions is a consistent use of terminology. The symposium contributions referred to terms like "ecosystem functions", "landscape functions", "agricultural externalities" and "land functions". The use of different terms reflects the disciplinary backgrounds of the research(ers) but could potentially lead to confusion, especially when research findings are communicated.

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Box 3: Salzburg contributions to the topic "Incorporating ecosystem and landscape services in decision making and management"

Anja Brüll presented her work on applying the ecosystem services concept to sustainable management of producing biomass as renewable energy source from a landscape architect's perspective. Sustainable production of biomass was assessed and developed within the context of sustainable landscape management on multiple scales, including (besides other components) a process of consensus building about ecosystem services and knowledge building on the dynamics and activities by which they are sustained. Drawing from her experiences in Germany, she argued that Sustainable Landscape Management based on ecosystem service assessment, is a suitable framework to implement new management strategies, and to support and coordinate decision making on patch, regional up to global level (Brüll et al. 2001).

Anton Shkaruba and Viktar Kireyeu presented a framework for the assessment of ecosystem services vulnerability to climate change, resistance of ecosystems, and robustness and adaptability of environmental governance institutions. In their study on forest ecosystems of Belarus the authors looked at three dimensions of ecosystem service vulnerability in a spatial context. Based on statistics, climatic indices relevant for plant growth and ecosystem metabolism were identified. Ecosystem service vulnerability scores were presented in a spatially explicit way, aiming at supporting management decisions on forest ecosystems.

Finally, Robbert Snep presented a study on ecosystem services of urban landscapes based on the example of biodiversity conservation at business parks, industrial estates and ports in the Netherlands. He explored options and opportunities for current and future business sites to accommodate ecosystems as a source of ecosystem services. Using different empirical datasets and modelling as well as statistical techniques he studied how to incorporate biodiversity conservation measures in the business site's planning, design and management. The presented study quantified the contribution that current business sites make to biodiversity conservation, and illustrated the extent to which this contribution can be enlarged for future business sites by optimizing the business site's potential for biodiversity conservation (Snep et al. 2009).

Most of these items have been put together by de Groot et al. (2010). Their focal research questions are summarized in Box 4.

Additional demands arise from the fundamental requirements of the ecosystem approach (Shepherd 2008, Smith and Maltby 2003, Burkhard and Müller 2008) and the main concepts of ecosystem research (e.g. Fränzle et al. 2008, Joergensen and Müller 2000, Joergensen et al. 2007). Both approaches are based on holistic ideas, trying to integrate different subsystems into an integrative perspective which can consider the multiple indirect effects which often are governing the dynamics of environmental systems (see Joergensen et al. 2007). Applying these holistic principles to the ecosystem service concept, several connecting systems-based research items, that still need further attention, can be elucidated:

- *Integrating multiple services or service types:* As ecosystem services mostly are quantified or indicated to provide information for actual management trade-offs, it is important to represent all potentially significant services within the respective assessment study. Focussing only on a special service group (e.g. only provisioning services) will deliver a biased picture of the service-providing capacities of the sites. Of course for this summarizing purpose we need the reducing transformation methodologies of single services, but it should be clear that these techniques have to be linked in the end to create a sufficient information base for the decision maker. Additionally, suggestions for best practices should be jointly created, e.g. including a minimum set for respective assessment studies.
- *Integrating biophysical features and ecosystem services:* Throughout the development of the Millennium Assessment studies, supporting services have been an important part of the ecosystem service indicator sets. Mainly due to accounting problems, they are more and more often neglected although in fact the ecological conditions provide the basic physical, chemical and biological conditions of any service provision. Furthermore, the preservation of biodiversity and the related ecosystem structures and functions has been one focal motivation to create the ecosystem service concept. Therefore, in assessment studies and throughout environmental evaluations, the change of ecosystem state variables always should be taken into account. Ecosystem services should not be used as the only features to describe ecosystem performances. Due to the joint conceptual sources, concepts such as ecosystem integrity (e.g. Müller 2004, 2005, Müller et al. 2006, 2010) or ecosystem health (e.g. Rapport et al. 1999, Burkhard et al. 2008) provide well-suited methodological fundamentals to account for both, the potential change of ecosystem states (e.g. by integrity) and ecosystem impacts (e.g. ecosystem services).

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Box 4: Main research questions in need to be resolved in order to better integrate ecosystem services in landscape planning, management and decision-making (from: de Groot et al. 2010)

a. Understanding and quantifying how ecosystems provide services

(1) What is the state-of-the art regarding the typology of ecosystem services?

(2) How can the relationship between landscape and ecosystem characteristics and their associated functions and services be quantified?

(3) What are the main indicators and benchmark-values for measuring the capacity of an ecosystem to provide services (and what are maximum sustainable use levels)?

(4) How can ecosystem/landscape functions and services be spatially defined (mapped) and visualized?

(5) How can relationships between ecosystem and landscape character and services, and their relevant dynamic interactions, be modelled?

(6) What is the effect of (changes in) dynamic conditions (temporal and spatial) of landscape functions on services, in terms of sustainability and resilience? Are there possible critical thresholds?

b. Valuing ecosystem services

(7) What are the most appropriate economic and social valuation methods for ecosystem and landscape services, including the role and perceptions of stakeholders?

(8) How to make economic and social valuation of landscape and ecosystem services consistent and comparable?

(9) What is the influence of scaling-issues on the economic value of ecosystem and landscape services to society?

(10) How can standardized indicators (benchmark-values) help to determine the value of ecosystem services and how can aggregation steps be dealt with?

(11) How can values (ecological, social and economic) be mapped to facilitate the use of ecosystem services in (spatial) landscape planning and design?

c. Use of ecosystem services in trade-off analysis and decision making

(12) How can all the costs and benefits (ecological, sociocultural and economic) of changes in ecosystem services and values of all stakeholders (in time and space), be taken into account properly in discounting and cost-effectiveness issues?

(13) How can analytical and participatory methods be combined to enable effective participatory policy and decision making dialogues?

(14) How can spatial and dynamic ecosystem services modeling be linked to participatory trade-off assessment methods to optimize multi-functional use of the "green and blue space"?

(15) How can landscape design-alternatives be visualized and made accessible for decision-making, e.g. through expert systems and other decision and policy support tools?

d. Use of ecosystem services in Planning and Management

(16) How to incorporate resilience of landscape functions, and thresholds of service-use, into methods for landscape planning, design and management of 'green and blue space'?

(17) What are the main bottlenecks in data availability and reliability with regard to ecosystem services management and how can they be overcome?

(18) What is the relationship between ecosystem management state and the provision of ecosystem services (both on individual services and the total mix of ecosystem services)?

e. Financing sustainable use of ecosystem services

(19) What is the adequacy of current financing methods for investing in ecosystem and landscape services? How can they be improved (and linked to valuation-outcomes)?

(20) How to communicate ecosystem and landscape services, and their social and economic importance, to all stakeholders.

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- *Integrating the linkages between the components of the ecosystem service cascade:* Figure 1 includes the "ecosystem service cascade" which demonstrates the flow of information necessary to derive values from ecological structures and processes. Several recent articles are focussing on one of the linkages, e.g. between ecosystem functions and ecosystem services. While we need the methodological development about each aspect of these coupling points, for a comprehensive assessment study such a reduction will not be sufficient. The authors should explain and argue for their conceptual construct, representing the whole chain of effects and values from integrity or health variables up to monetary calculations.
- *Integrating ecosystem services into assessment and indicator systems*: Ecosystem services are extremely suitable means for valuations in socio-ecological systems. In spite of the enthusiasm for this approach it should not be forgotten that they are often used as indicators for one specific part of indicator systems only. While carrying out a respective assessment, the authors should be aware that the services have to be related to the changes of drivers, pressures, states and responses. Ecosystem services are optimal representatives of the impacts, conveying modifications of ecosystem states and human well-being; but in isolation they can hardly provide sufficient information referring to the demands of holistic indicator systems.
- *Integrating processes at different spatial-temporal scales, including long-term developments:* Another important level-of-integration is related to the different scales of the subsystems within the "ecosystem service cascade". Taking into account the related cause-effect-networks, many different scales have to be considered, each of them exhibiting typical spatial and temporal characteristics. For example, all components of the DPSIR management cycle are operating on different scales. This implies that also the spatial resolutions of the focal variables are different, provoking the demand for a theory-based integration of processes with distinguished grains, extents and frequencies.
- *Integrating stakeholders and decision makers:* To ensure an optimal suitability of applied ecosystem service studies, the idea of participation should be realized. Scientists can optimize their efforts if the questions, problems and valuations of the concerned actors are integrated from the beginning of a study.

Conclusions

Based on the discussions during the ecosystem service symposium of the European IALE conference in Salzburg, several challenges for future research and application of the ecosystem service approach have been pointed out in this paper. Additionally, a recent overview of the many remaining challenges in ecosystem and landscape services research and application can be found in de Groot et al. (2010), in a Special Issue in Ecological Complexity on "Ecosystem Services – bridging ecology, economy and the social sciences" (edited by Burkhard and colleagues). Besides addressing many sectoral issues, the ecosystem service approach highlights the need for integration. Therefore, one of the conclusions of the symposium was the necessity to improve cooperation, to foster the respective interdisciplinary communication, to increase collaboration in joint projects and to improve the organizational background of the ecosystem service research community.

To enhance the integration of collaborative efforts on ecosystem services at the global, national and local level the Ecosystem Services Partnership was launched recently. The ES-Partnership is a network organization that connects practitioners, researchers, and stakeholders around the world who are working toward better understanding, modelling, valuation and management of ecosystem services. Many of the above presented issues will be further discussed during regular ESP meetings, such as the conference on "Solutions for Sustaining Natural Capital and Ecosystem Services: Designing Socio-Ecological Institutions" from June 7-11 2010 in Salzau, Germany, which has been organized by the Partnership (for further information see http://www.es-partnership.org/). Besides providing long-term support to communication and information on many of the issues discussed in this paper, the partnership hopes to contribute to a better understanding and sustainable management of our natural ecosystems and socio-ecological landscapes.

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