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EDITORIAL

Ecosystem services in changing landscapes: An introduction

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Abstract The concept of ecosystem services from landscapes is rapidly gaining momentum as a language to communicate values and benefits to scientists and lay alike. Landscape ecology has an enormous contribution to make to this field, and one could argue, uniquely so. Tools developed or adapted for landscape ecology are being increasingly used to assist with the quantification, modelling, mapping, and valuing of ecosystem services. Several of these tools and methods encased therein are described among the eleven papers presented in this special issue, and their application has the potential to facilitate the management and promotion of services within ecosystems. Papers are associated with each of the four key categories of services that ecosystems provide to humans: supporting, provisioning, regulating, and cultural. The papers represent work conducted in eleven different countries, especially from South America. Each carries a unique approach to address a particular question pertaining to a particular set of ecosystem services. These studies are designed to inform and improve the economic, environmental and social values of the ecosystem services. This knowledge should help to develop new management alternatives for sustaining and planning ecosystems and the services they provide at different scales in space and time. We believe that these papers will create interest and inform management of some potential methods to evaluate ecosystem services at the landscape level with an integrative approach, offering new tools for management and conservation.

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Ecosystem services are tightly linked with landscape ecology

The science of landscape ecology must consider the enormous ecological and economic changes occurring across the globe, primarily driven by the increasing demands of people and their intensified activities (Foley et al. 2005). In particular, human activities and demands are rapidly changing ecosystems, landscapes, and ecosystem service provisions, yet there remain significant gaps in our understanding of the spatial ecology of ecosystem services (ES). These gaps hinder our ability to manage landscapes effectively for multiple ES. Hence, gaining knowledge on monitoring and bolstering of ES is important for planning land use related actions towards sustainability targets of the planet's resources for a growing population. The concept of ES from landscapes is rapidly gaining momentum as a framework to communicate values and benefits to scientists, stakeholders, policy makers and the public. A Web of Knowledge search on "ES" and "landscape ecology" netted 99 papers (Accessed December 2013). Of these, 77 were published since 2009. A recent review of the use of landscape spatial metrics also shows an increase in using such metrics to characterize ES (Uuemaa et al. 2013), although work remains to develop common monitoring schemes within and across habitats (Feld et al. 2009). Landscape ecology has an enormous contribution to make to this field of monitoring and enhancing ES and, one could argue, uniquely so. Indeed, most ES are place-based, and thus best assessed, maintained, enhanced, and restored using a landscape ecological integrative approach. The tools of landscape ecology in fact also allow for both evaluation of past and projection of future services from these place-based ecosystems. In turn, ES are tightly bound to the sustainability of the planet; in fact, preserving ES must be at the core of sustainability (Termorshuizen and Opdam 2009; Levin 2012; Wiens 2013; Wu 2013).

It is well known that the planet's ecosystems are both impacted by multiple uses and influenced by global drivers: climate change, urban sprawl, agriculture abandonment, intensification of forestry and agriculture, invasion of exotics, changes in energy generation and use, expanding infrastructure networks, increased habitat destruction and degradation, and other drivers of change are often occurring in combination and at increasingly faster rates (MEA 2005; ten Brink 2011; Kumar 2012). In this issue, we focus on forested ecosystems, and the services provided by these ecosystems are impacted in a wide variety of ways, especially if forests are removed or heavily degraded. Consequently, forest restoration and adaptive forest management must play an increasingly important role in sustaining or enhancing ES (Ciccarese et al. 2012; Shackelford et al. 2013). At a local scale, multi-functionality of forests (wood harvesting, hunting, pasture, wildlife conservation, recreational) means that many different and sometimes conflicting goals exist regarding their management purposes. To achieve sustainable forest management, tools for assessing the forest system as a whole are thus needed.

Several recent papers highlight the importance of the place-based approach to evaluate ecosystem service states and trends. Helfenstein and Kienast (2014) develop a rapid method to assess selected ES over broad areas using trends in various land-use categories. Each land use-ecosystem service relationship is classified from a strong disservice to a strong service. The results are displayed in flower diagrams which display information on the ES in each land use, thus clearly summarizing trade-offs associated with changing land use. Potschin and Haines-Young (2013) present a framework for developing a place-based assessment of ES. They argue that such a place-based approach will allow a better understanding of issues of multi-functionality, the valuation of natural capital, and the role of landscape in framing debates about ES and sustainability. Turner et al. (2013) evaluate the role of spatial heterogeneity, a key place-based concept in landscape ecology, as it influences the provisioning of ES now and into the future in the Greater Yellowstone and Pacific Northwest regions of the United States. They determined that the amount and arrangement of surviving forest patches or legacy trees after disturbance are important for sustaining forest regeneration, primary production, carbon storage, natural hazard regulation, insect and pathogen regulation, timber production and wildlife habitat.

Historical perspectives of landscapes, when evaluated across space and time, increase our understanding of the

dynamic nature of landscapes and provide a framework of reference for assessing patterns, processes, and functions as they pertain to provisioning, supporting, cultural, and regulating services. In order to capture changes of landscapes' "essential characteristics", we can use past land transition information in tandem with environmental variables information. An important challenge to evaluate and assess ES in this regard is to integrate research across different scales, including spatiotemporal scales within an interdisciplinary and multidisciplinary approach. Within this framework, the understanding of "how land is used" and "managed" is critical to understanding the potential of single ecosystems and whole landscapes to provide services to humans in a sustainable way. We also need to ensure that any evaluation includes considerations of human culture and behaviour, especially operating at a local scale, to empower landscape ecology to be a science for design and action (Lovell and Johnston 2009; Opdam et al. 2013). The wall-to-wall spatial data on land cover and land use often available at national scales, along with research to better understand how pattern influences ES, is beginning to allow for spatially explicit solutions in managing a range of environmental targets and ES (Jones et al. 2013).

In this special issue, we attempt to present and discuss approaches on how to improve the information basis for assessment, evaluation, mapping, and restoration of the potentials of ecosystems to provide services to humans across various changing landscapes and across several continents. This issue is prepared by the International Union of Forest Research Organizations (IUFRO) Working Party (IUFRO 8.01.02 Working Party (Division 8)—Forest Landscape Ecology), the IALE–IUFRO Group, and ELI (European Land Institute). Thus, papers are a product of the research presented during the IUFRO LE Conference organized in 2012 in Concepcion, Chile and in a symposium organized for the Ecosummit by ELI and IUFRO LE in Columbus, Ohio USA. The former meeting had the theme "Sustaining Forests and Humans in a Changing Landscape: Forest, Society, and Global Change", and recognized the role of landscape ecology in the advancement of science and management, particularly within the context of emerging physical, sociocultural, economic, and political drivers of change which influence forest systems and the services they provide. The latter symposium had the theme "Structure matters—the potential of land-use pattern to contribute to ES provision", and was concerned with the pattern of ecosystems or land-types as it pertains to providing ES.

About this special issue

In this special issue, we present 11 papers with a variety of topics, all revolving around the concept of providing ES to humans. As the primary source of papers was via the conference in Chile, most of the papers featured authors and landscapes from South America (6.5 of the papers, including Chile, Brazil, Argentina, Colombia, Peru, Bolivia, Ecuador), 2.5 from Europe (Switzerland and Spain), and two from the United States.

In particular, the selected papers cover a broad range of methods and perspectives on ES to provide different visions of sustainable management practices that were assessed for different relevant services, thereby enabling identification of biophysical synergies and conflicts at different levels. The wide range of topics, all featuring tools and analyses common to landscape ecology, report on advances and case studies relevant to the four categories of ES: supporting (services necessary for the production of all other services, like primary production, dispersal of seeds or nutrients, and nutrient cycling), provisioning (goods obtained from ecosystems, like food, water, energy, minerals), regulating (services obtained from the regulation of ecosystem processes, like carbon sequestration and climate regulation, pollination, decomposition of wastes, purification of water or air, pest control), and cultural (nonmaterial contributions of ecosystems to human well-being through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences) (MEA 2005). Though many of the papers cover more than one of these categories, we present them here in one of the four categories as a means to highlight what we perceive as their most unique contributions in this special issue.

Supporting services

Ferraz et al. (2014) evaluate forest fragments in an agricultural matrix within the Brazilian Atlantic Forest

for services related to biodiversity, water, and nutrient cycling. They assess forest changes over the past 60 years, including large-scale replacement of old forests by young forests, and found that less than ¼ of the current forest cover is able to supply ES at the same level as old forests.

Grêt-Regamey et al. (2014) stress the role of non-linear relationships between landscape patterns and the sustainable provision of ES. They use a functional fragmentation measure, which accommodates marginal land use changes, to show how landscape pattern changes might lead to changes in the delivery of ES. They map changes in ES (carbon sequestration, pollination, recreation, food and timber production) in dry calcareous grasslands in Switzerland, and found that limiting fragmentation to be especially critical for maintaining the value of ES in species-rich habitats.

Provisioning services

Matthews et al. (2014) address how climate change may impact ES within the temperate and diverse forests of the eastern United States. They created an index, the Forest Related Index of Climate Vulnerability, to score overall vulnerability for any site (here using 149 US Department of Defense installations). The scores, derived from current and modeled future conditions, are then related to specific ES, including the provision of wood products and maple syrup.

Schindler et al. (2014) relate 38 management options for floodplain landscapes across the whole of Europe, including the use of green infrastructure, to 21 different ES relevant in floodplains. They found that restoration and rehabilitation consistently increased the multifunctionality of the landscape by generating win–win situations for enhancing provision, regulation, and cultural ES.

Donoso et al. (2014) assess the provision of ES in the urban–rural interface, in a case study from south-central Chile, where remnant native forests in a protected area are surrounded by a matrix of planted exotic trees or agriculture. The paper reports on 4 years of implementation of an ecosystem management plan using an adaptive co-management approach on a watershed, which aims to balance multiple societal demands (including fresh water for city of Valdivia) and ecosystem functions.

Regulating services

Santos de Lima et al. (2014) assess feedbacks between deforestation, climate, and hydrology in the Southwestern Amazon and evaluate their implications in providing ES. They assess impacts of potential deforestation on the water balance of three river basins using coupled climatic and hydrologic models under several deforestation scenarios. Their models show that deforestation increases the dry-season length and the seasonal amplitude of water flow, which may aggravate the economic losses from large droughts and floods, such as those experienced in the region several times in the last decade. The work highlights the importance of forests for regulating climate, water cycling and, consequently, river regimes, and contributes towards better understanding the effects of changing landscape pattern on local and regional climate processes (Wu 2013).

Huang et al. (2014) use fine-resolution data from Michigan, USA to concentrate on land-cover change within individual exurban residential parcels in order to assess homeowner preferences and land-management strategies and the ecosystem service of carbon storage. In this agricultural-dominated landscape, they found the changes in land cover resulting from urbanization quite dramatically increased carbon storage because of increasing tree cover and manicured lawns in the region. The analysis and results provide the foundation for understanding how this important regulating service may change in human-dominated landscapes.

Vanacker et al. (2014) derive a model on the specific regulation service of erosion control as a function of human disturbances to the vegetative cover across the landscape, and then tested and validated the model in two contrasting mountainous sites: the Tropical Ecuadorian Andes and the Spanish Beltic Cordillera. They also model the pre-disturbance erosion on both sites, to allow comparison of natural erosion to human-accelerated erosion. They found the sensitivity to human-accelerated erosion to be ecosystem dependent, where the potential for erosion regulation is larger in well-vegetated ecosystems (e.g., Andes) relative to lesser-vegetated systems (e.g., Spain).

Grimaldi et al. (2014) evaluate a gradient of land-use intensity in Amazonian landscapes in Brazil and Colombia. They measure composition and structure

and relate them to the services of carbon sequestration, water cycling, and soil fertility at the farm scale and the plot scale. Carbon stocks in above-ground plant biomass and water infiltration rate decreased with land-use intensity, whereas soil chemical quality and plant-available water storage capacity increased.

Cultural services

Nahuelhual et al. (2014) evaluate recreation and ecotourism service in southern Chile, as modified by land use changes over three decades. They create land use change trajectories from Landsat imagery and use two types of indicators (based on recreation potential attributes and carrying capacity factors) to determine a dramatic loss in the ecosystem service, likely due to a large degree from forest degradation and fragmentation. The most important land use change trajectory was an early and permanent transition from old-growth forest (with its relatively higher biodiversity services including the emblematic flora and fauna and forest structure) to secondary forest; this study documents the tight link between this ecosystem service and the landscape-level analysis appropriate to make the assessment.

Mastrangelo et al. (2014) use a meta-analysis approach to seek linkages between ES and the multifunctionality of landscapes. They devise a framework to evaluate multifunctionality or the joint ES supply that a particular landscape may provide, and construct a typology of methodological approaches based on scores for criteria describing the evaluation method and the level of stakeholder participation in assessments of joint ES supply. The result is a hierarchy of approaches, culminating in process-based and socially relevant multifunctionality, with an example from the Argentine Chaco.

Concluding thoughts

This collection of papers provides a set of studies that represents state-of-the art research on integrating aspects of landscape ecology and the provision of ES. Most papers have highly relevant case studies of the application of landscape ecological principles and techniques in resolving questions concerning certain ES. The papers cover multiple scales, countries, ecosystems, and types of ES, but all are grounded in landscape ecological principles aimed at promoting the evaluation, monitoring, and sustaining of key ES for the humans living in those places. As such, this special issue can be considered a follow-on issue from the excellent foundational special issue on the "Key concepts and research priorities for landscape sustainability" published in volume 28 of Landscape Ecology and guest edited by Musacchio (2013).

Landscape ecology and the tools used by landscape ecologists have developed and evolved rapidly over the past three decades (Turner 2005; McIntyre et al. 2013; Risser and Iverson 2013), permitting a much better application of decision tools in land management and planning, including the provision of various ES. Many of these advances are presented in this set of papers. We believe the papers should be of widespread interest to landscape scientists, policy makers, and managers throughout the world because no matter the place or particular ecosystem service or organisms being studied, many of the methods and analytical procedures can be applied elsewhere. Landscape ecologists are continuing to make important strides, with many new approaches presented in the papers here; these new approaches will undoubtedly continue to evolve as theory, data sources, and techniques continue to improve in the coming years. Exciting times to be in this field!

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