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PERSPECTIVE

Science for action at the local landscape scale

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Abstract For landscape ecology to produce knowledge relevant to society, it must include considerations of human culture and behavior, extending beyond the natural sciences to synthesize with many other disciplines. Furthermore, it needs to be able to support landscape change processes which increasingly take the shape of deliberative and collaborative decision making by local stakeholder groups. Landscape ecology as described by Wu (Landscape Ecol 28:1–11, 2013) therefore needs three additional topics of investigation: (1) the local landscape as a boundary object that builds communication among disciplines and between science and local communities, (2) iterative and collaborative methods for generating transdisciplinary approaches to sustainable change, and (3) the effect of scientific knowledge and tools on local landscape policy and landscape change. Collectively, these topics could empower landscape ecology to be a science for action at the local scale.

Keywords Community-based landscape planning · Cross-disciplinary synthesis · Capacity building · Science–practice interface · Sustainability · Transdisciplinary science

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Introduction

Wu has characterized landscape ecology as a highly interdisciplinary and transdisciplinary science of environmental heterogeneity "that aims to understand and improve the relationship between spatial pattern and ecological processes on a range of scales with the goal of achieving landscape sustainability" (Wu 2013). Quoting the Allerton Workshop report (Risser et al. 1984), which he described as the blueprint of North American landscape ecology, Wu noted that "…viewing landscape ecology as a branch of ecology, would … tend to exclude the formal analysis of human cultural processes that form landscapes." Instead he argued for the broader view proposed by the Allerton workshop, in which: ''Landscape ecology is … the synthetic intersection of many related disciplines…".

However, none of the 20 most cited papers in *Landscape Ecology* listed by Wu extends in scope beyond environmental science to include human cultural processes. Even now, most papers in recent issues focus on environmental science. Papers exploring the interface between environmental and social sciences are unusual (a notable exception is offered by the recent special issue on landscape sustainability, Musacchio 2013), and transdisciplinary approaches (in which scientists work together with practitioners) are rare (some examples are Duff et al. 2009; Steingröver et al. 2010). We therefore assert that landscape ecology is still a long way from embodying the synthetic intersection envisioned in the Allerton report, and that a failure to achieve this synthesis has impeded landscape ecology's capacity to contribute to landscape sustainability, conceived as a continuous reconciliation of societal objectives with landscapes' capacities to deliver ecosystem services and maintain biodiversity over the long term (cf. Clark and Dickson 2003).

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Sustaining local landscape change processes

To overcome this limitation, landscape ecology must consider how knowledge about pattern-process dynamics may constructively interact with societal processes. In order to understand such interactions, landscape ecology must extend to the social sciences and draw on the experiences of stakeholders and practitioners. Knowledge of environmental processes alone is not sufficient; knowledge of human behavior, values, and norms is essential to understanding the dynamics of coupled human and natural systems. Such understanding is increasingly regarded as indispensable to inform sustainable solutions to environmental problems (Carpenter and Folke 2006; Knight et al. 2006; Liu et al. 2007; McAlpine et al. 2010).

The need to bridge the gap between environmental science and policy has been addressed by many (see Arlettaz et al. 2010 for a recent example), but these typically focus upon national and international policies such as the Global Biodiversity Assessment and the Millennium Ecosystem Assessment (e.g. Carpenter et al. 2009; Perrings et al. 2011). However, responsibility for environmental policy implementation increasingly falls at local governance levels (Brown 2003; Brody et al. 2004; Gruber 2010; Swaffield 2012). By local level, we mean areas where physical landscapes interact directly with social networks of land owners, managers, and landscape users (Opdam 2013). Examples include local communities involved in forest management in the developing world (REDD+), regulation of non-point source water pollution in the US (Phase II-Clean Water Act), and natural resources planning in The Netherlands and New Zealand (Steingröver et al. 2010; Swaffield 2012). Persha et al. (2012) found that where local communities were involved in local forest governance, forest management was more likely to have sustainable outcomes (above-average tree species richness and subsistence livelihoods). However decentralization of governmental power in spatial planning (Beunen and Opdam 2011) challenges local communities to increase capabilities for planning and executing sustainable landscape solutions (Gray et al.

2005), and challenges landscape science to reconceive the context in which scientific knowledge is applied (Swaffield 2012), and to consider possible new requirements for actionable knowledge at a community level (Opdam 2013).

We assert that research at the scale of local human communities is therefore the key for landscape ecology to contribute significantly to sustainable landscape change. There is a growing consensus that sustainability must be achieved at the local level (United Nations 1992); it cannot be only a policy at higher levels of governance or a corporate commitment (Ostrom 2009). Local communities are where humans use landscapes to make a living and contribute to their quality of life, and where they adapt landscapes to create value from landscape services or prevent loss from external pressures such as climate change (Opdam 2013). Scientific support for such adaptation requires approaches based on integrated environmental, social and economic knowledge, made relevant within the local landscape context and for use in local landscape governance.

DeFries et al. (2012) highlight the need to build sustainability science capacity for solution-oriented approaches, and this also applies to the mainstream of landscape ecological methodology. Landscape ecology has employed many different measurement, assessment and evaluation methods, but it has only begun to apply iterative and reflexive approaches which start from societal demands and translate these into desired adaptations of the landscape structure. Such approaches typically make use of local knowledge to develop science-based interventions in co-production with local actors (Nassauer and Corry 2004; Duff et al. 2009; Steingröver et al. 2010). That there is still a major shortfall is illustrated by a recent review of 153 papers on ecosystem services research, revealing that public involvement is rare (Seppelt et al. 2011). Most papers published in *Landscape Ecology* take a purely analytical approach (including impact assessment and landscape change evaluation). To go further and suggest solutions that will change future landscapes, landscape ecology has to reach beyond its current boundaries. We argue that landscape ecological paradigms and methods must therefore expand to be responsive to local human communities by using iterative, design-oriented approaches. It will therefore be necessary to draw on and interact with knowledge, paradigms, and methods from social sciences and spatial planning.

These research needs have been noted before but have not been systematically investigated. If scientific tools used in landscape ecology are to be salient to societal problem solving, their relevance should be improved and complemented by observations and measurements of their social impacts. Cases are needed to learn how scientific knowledge can be integrated into practice, and how scientific methods and tools can be adjusted to better support adaptation of local landscapes to future demands (Opdam 2010).

Three additional research topics

These research challenges to "incorporate human cultural processes" (in the words of Risser et al. (1984) are not in the top-10 research topics proposed by Wu (2013). We therefore propose the following three additional research topics as essential for landscape ecology.

Investigating the local landscape as a boundary object

A boundary object (Star 2010) is plastic enough to adapt to local needs and to different conceptual perspectives, but is also robust enough to maintain conceptual coherence across scientific disciplines and across the science-practice boundary. We propose that the local landscape could serve as a boundary concept for landscape ecology, offering a common ground to scientists and practitioners with different backgrounds, values and interests (Nassauer 2012).

Developing iterative and collaborative methods for generating solutions

In situations in which stakeholders have divergent values and little agreement about problem definition, we propose that iterative methods developed in the design and planning disciplines and social sciences (Nassauer and Opdam 2008; Swaffield 2012), but rarely practiced in landscape ecology, may suggest new questions and approaches to actionable science.

Understanding the impact of landscape ecological knowledge and tools on local landscape change processes

Building capacity for local action requires a systematic scientific approach to measuring impact of science in society and learning how to optimize methods for a variety of situations. It is not enough to adopt new methods- we must also evaluate their effect and respond to this feedback.

The local landscape as transdisciplinary boundary object

The concept of local landscape can provide a focus around which to organize collaboration between scientific disciplines and between science and practice. Knowledge formation and integration at the local landscape scale affords advantages that have not yet been adequately recognized and incorporated into landscape ecology. A local landscape can be known to its inhabitants and to scientists, practitioners and policymakers as a holistic entity, in which processes and values related to prosperity, livelihood and quality of life can be associated with biophysical characteristics (Sayer and Campbell 2004). Local landscapes are tangible to participants—in the field, in images, and in maps, and their visual character promotes the experience of local identity and sense of place. This inherent integration and "knowability" of the landscape scale (Swaffield 2005) stimulates building common visions, shared decision-making and collaborative invention of solutions (Nassauer 2012). Most significantly, the local landscape can also serve as a boundary object to merge environmental and social sciences. Existing terms with a related meaning are less likely to serve such a role. While "place" is mostly limited to social sciences (Swaffield et al. 2013) and "ecosystem" is mostly limited to the environmental science domain, the meaning of landscape is recognized in both social and environmental sciences. Employing landscapes as boundary objects can allow scientific concepts and terminology to be reframed in ways that are meaningful to multiple experts and stakeholders. For example, Termorshuizen and Opdam (2009) noted that the ecosystem concept may not be meaningful to local communities and social scientists. They proposed the term "landscape services" as a boundary concept to expand the ecosystem services concept beyond its current ecological-economic limits into the social sciences and local landscape planning. Linking the local physical landscape with its human community would allow landscape ecology to contribute to theories of social–ecological systems (Ostrom 2009; Pickett et al. 2011; Cook et al. 2012; Opdam 2013). Concepts like resilience, adaptive capacity and adaptive governance could then enrich the pattern-process paradigm of landscape ecology and enable landscape ecologists to develop the spatial dimensions of social–ecological systems.

Iterative and collaborative methods

Local implementation of environmental policy is an integral part of environmental governance. Landscape management and change is deliberated and negotiated by stakeholders with varying views and aspirations, and often, this negotiation has many uncertainties and little agreement about shared values (Hoppe 2011). Science-based assessments, alone, often are inadequate to foster creative action (Reed et al. 2006; Swaffield 2012). To become more effective in supporting such local processes, we advocate that solutions and further science questions suggested by landscape ecological knowledge be discussed, contested and reshaped collectively with practitioners through a social learning process (Pahl-Wostl 2009; Albert et al. 2012). This may require that scientific tools and inquiries be co-constructed and adapted with local stakeholders to be applicable to local problems and flexible enough to adjust to local values and interests (Cash et al. 2003).

Good examples of iterative co-production of landscape knowledge are emerging. For example, the credibility of maps of local environmental functions and values improves if local inhabitants can incorporate their knowledge in the mapping (Castella 2009; Pouwels et al. 2011). Participatory processes including interactive tools that engage local people have been used to map ecosystem services hotspots in Zanzibar (Fagerholm et al. 2012), to design landscape infrastructure networks for ecosystem services in the Netherlands (Steingröver et al. 2010), and to design community forestry systems in Laos (Bourgoin et al. 2012). Visualization techniques used within such participatory processes have been found to increase understanding of scientific concepts and of trade-offs between future scenarios among local stakeholders (Sheppard and Meitner 2005; Schroth et al. 2011).

Effect of science and tools on local landscape change

Capacity building in landscape ecology requires learning from applying knowledge and tools in the context of local practice (Opdam 2010). Landscape scientists may learn that the tools they consider as simple and useful are not perceived that way by practitioners (McIntosh et al. 2011); potential causes for that discrepancy need to be investigated. Developing usable tools requires systematic research to better understand the science–practice interface, for example, by experimenting with new scientific tools in practice and observe how practitioners respond and how the tool affects the social process.

Recent examples (Castella 2009; Bourgoin et al. 2012) have shown how collaborative approaches can be used to build geo-visualisation tools in landscape design. Such learning requires monitoring how these tools work in practice, and adjusting them to enhance their flexibility, validity and effectiveness. For example, Lusiana et al. (2011) measured users' perspectives on the validity of a landscape simulation model and determined the tool needed to be revised to better reflect the interests and time frames of local users. Cohen et al. (2012) evaluated the effectiveness of using visualizations of predicted snowpack to convey long-term implications of global climate change scenarios on local water supply. The insights obtained from such research can contribute to more effective landscape ecological tools to support the management of local landscape change.

Conclusions

Landscape ecology science has not yet developed adequate capacity to support implementation of environmental policies at the local level. To do this requires much better understanding of the role of scientific knowledge and tools within social processes in local communities. This conclusion is consistent with the earliest aspirations of landscape ecology in America, as reflected in the 1984 Allerton Workshop report, to include "the formal analysis of human cultural processes that form landscapes". Integrating environmental and social sciences to shape action in particular locations is the specific competence of certain disciplines within landscape ecology, including landscape architecture and planning. It can also be seen as an aspiration for the entire interdisciplinary field of landscape ecology. We propose that for landscape ecology to become an interdisciplinary field it is necessary to increase its focus on human–nature relationships. We argue that to do so it is not enough to broadcast our findings to social sciences, but that we must improve our understanding of the arenas in which our knowledge is being interpreted, used for influencing power relations, and applied in negotiations about feasible solutions. We expect that this will result in enhanced influence of landscape ecology in societal processes. In such processes deliberation about how added values of landscape change are distributed among local actors play a key role (He et al. 2008). Therefore, pattern–process relationships should be attentive to values, and solutions should be offered as a range of options related to a variety of values, rather than as a single track to the future (Termorshuizen and Opdam 2009; Swaffield 2012). We argue that improving such a capacity requires systematic research on the impact of landscape ecological knowledge in local landscape change processes. Such research may employ social science methods in concert with natural science methods (for example in agent-based modeling, see Chen et al. 2012; Schouten et al. 2013). We argue that landscape ecology should more actively exemplify interdisciplinary endeavors (often in cooperation with other sciences) and contribute to understanding of socio-environmental systems. Fundamentally, we propose that the local landscape can be a common ground for scientists to find a shared pathway to interdisciplinary research and transdisciplinary understanding, and also bring new insights into the practice of landscape change adaptation. Interestingly, applying social research techniques to improve the effectiveness of conservation planning was recently proposed by Raymond and Knight (2013).

We identified three specific topics for research to move landscape ecology further toward exemplifying an effective transdisciplinary approach to achieving sustainable landscapes. Clearly, such an approach must build on what landscape ecology has accomplished over the past thirty years. A major contribution of landscape ecology is the recognition that local landscape processes function within many different social and natural systems at multiple spatial scales (Liu and Taylor 2002; Liu et al. 2013), which highlights the need for concepts and procedures to link global and regional dynamics with local solutions (Swaffield and Primdahl 2006). Our intent is to reinvigorate and refocus the aim of landscape ecology towards cooperative knowledge production in order to better integrate landscape science into local practice, and to adjust scientific methods to better support actions at the local level.

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