Landscape Ecol (2009) 24:1037–1052
DOI 10.1007/s10980-008-9314-8

PERSPECTIVES

Landscape services as a bridge between landscape ecology and sustainable development

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Received: 1 September 2008 / Accepted: 11 December 2008 / Published online: 4 January 2009

Abstract Landscape ecology is in a position to become the scientific basis for sustainable landscape development. When spatial planning policy is decentralised, local actors need to collaborate to decide on the changes that have to be made in the landscape to better accommodate their perceptions of value. This paper addresses two prerequisites that landscape ecological science has to meet for it to be effective in producing appropriate knowledge for such bottom-up landscape-development processes—it must include a valuation component, and it must be suitable for use in collaborative decision-making on a local scale. We argue that landscape ecological research needs to focus more on these issues and propose the concept of landscape services as a unifying common ground where scientists from various disciplines are encouraged to cooperate in producing a common knowledge base that can be integrated into multifunctional, actor-led landscape development. We elaborate this concept into a knowledge framework, the structure–function–value chain, and expand the current pattern–process paradigm in landscape ecology with value in this way. Subsequently, we analyse how the framework could be applied and facilitate interdisciplinary research that is applicable in transdisciplinary landscape-development processes.

Keywords Landscape change · Collaborative spatial planning · Landscape functions · Pattern–process relations · Landscape value and valuation · Ecosystem services · Structure–function–value chain · Interdisciplinary research · Transdisciplinary research · Sustainability science

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Introduction

People living in developed countries, especially in urbanising areas and in regions where industrial agricultural practices are intensifying, are increasingly demanding high-quality landscapes (e.g., Jackson 2008; Matsuoka and Kaplan 2008; Stephenson 2008). In the Netherlands, for example, citizens and companies are challenging farmers by demanding that the landscape should provide more functions than food production alone. This implies that landscapes are expected to fulfil many functions at the same time. We consider landscape performance in the context of sustainable development; in other words, on the condition that the use of our world and its natural resources is based on a comprehensive consideration of all ecological, social and economic functions and without compromising the potential to deliver goods and services to future generations (WCED 1987; IUCN 1992; Linehan and Gross 1998). If we consider these principles to be valid for landscape development, then decisions on changes in landscapes have to be taken after consideration of economic, social and ecological functions and values. In sustainable landscape development, humans change the landscape to improve its functioning and create additional value. Therefore, scientific knowledge should allow linking of the physical structure and functioning of the landscape to the economic, sociocultural, and ecological values demanded by its users (Haines-Young 2000). For scientific knowledge that has an impact on landscape-development processes, therefore, the first prerequisite is that desired landscape values can be related to intended changes in structure and functioning of the physical landscape.

A second prerequisite follows from the trend towards a decentralised landscape planning policy. In most democracies, state-led planning is giving way to systems of governance planning (Friedmann 1993; Haughton and Counsell 2004), in which decision-making on landscape changes is becoming the domain of various groups of actors on regional and local scales (Brody et al. 2004; Azerrad and Nilon 2006). These actors make different demands on the landscape and hold different perceptions of the benefits that landscapes must deliver to society. This decision-making process is referred to as "collaborative planning" (Ryan et al. 2006) or "collaborative management" (Muňoz-Erickson et al. 2007). The trend towards bottom-up planning is based on the subsidiarity principle ("as much local as possible and only so much government regulation as necessary"; Berkes 2004). It is assumed that by involving local actors the sharing of management power and responsibility will result in more sustainable socioecologial systems (Schultz et al. 2007). Collaborative planning poses an unstructured problem to practitioners and scientists: the objectives of landscape change and how to accomplish them are not defined at the start of the process and the required knowledge is uncertain. For such unstructured problems, the literature recommends a transdisciplinary approach in which several scientific disciplines work together with regional actors (Ezrahi 1980; Hisschemöller and Hoppe 1995; Hisschemöller et al. 2001; Horlick-Jones and Sime 2004; Tress et al. 2005; Duff et al. 2008). The knowledge needed for decision-making on landscape development, therefore, needs to be relevant to the small scale at which local actors perceive their environment and decide about change. For example, pattern–process knowledge should be spatially explicit at the level of detail of individual landscape elements, such as hedgerows, ditches, and water pools. Moreover, because it needs to be suitable for negotiating multifunctional targets, knowledge about various landscape functions must have a common basis that allows integration and comparison, and it must be in a form that can be used in creative, design-driven processes for identifying synergies (win–win situations) and trade-offs between functions (Tippett et al. 2007; Opdam et al. 2008). This line of reasoning leads to the second prerequisite for effective knowledge—it is spatially explicit on the local scale, allows integration across disciplinary boundaries, and is suitable for collaborative decision-making.

Landscape ecology is being positioned as the scientific basis for sustainable landscape development (Potschin and Haines-Young 2006; Wu 2006; Wu and Hobbs 2007). Considerable progress has been made in sustainability impact assessment (e.g., Helming et al. 2007) and in understanding driving forces of landscape change (Veldkamp and Lambin 2001; Sepp and Bastian 2007). In this paper, we show that little advance has been made so far in producing knowledge that meets the two prerequisites for collaborative planning of landscape change. We build upon the conclusion by Fry et al. (2007) that landscape ecology has produced little coherent theory so far to support its interdisciplinary and transdisciplinary maturation. The aim of this paper is to contribute to this theory building by offering a conceptual framework that connects the central pattern–process paradigm of landscape ecology to the social system in which human actors deliberate about sustainable landscape development. We explore how interdisciplinary and transdisciplinary approaches will be fostered by extending this paradigm, either within the landscape ecological domain or in the interaction between landscape ecology and other domains in science. Our focus is on science and therefore our search is within the scientific literature.

Although the framework could also have an impact on the development of landscape policy, exploring the grey literature on landscapes is outside the scope of this paper.

The following questions will be explored:

- To what extent does current landscape ecological research generate knowledge suitable for local collaborative landscape planning?
- Which existing scientific concept of valuation is most suitable for development into a new landscape ecological framework?
- How could the new concept enhance cooperation between scientific disciplines and between science and practice?

Because of the state of the art of this subject, the paper is exploratory and will generate hypotheses and questions rather than answers.

How does landscape ecology deal with sustainable collaborative landscape development?

There is a widespread demand for a science that has sufficient societal impact, calling for a fundamental transition in the relationship between science and society (Nowotny et al. 2001; Clark and Dickson 2003; Palmer et al. 2005; Potschin and Haines-Young 2006; McNie 2007). Much has been said in the landscape ecological community about the need to improve the interaction between landscape ecology and society (Potschin and Haines-Young 2006; Wu and Hobbs 2007) and, in particular, between landscape ecology and spatial development (Opdam et al. 2002; Termorshuizen et al. 2007), but little progress has been made in developing theory and methods in this interface (Tress et al. 2005; Potschin and Haines-Young 2006). In the following, we show that landscape ecological science has an insufficient performance on the two prerequisites for knowledge to be relevant to problem solving and significant to local actors in sustainable landscape development. We assume that the persistence of the gap between landscape ecology and sustainable landscape development is (at least partly) caused by this and discuss how the landscape ecological knowledge base can be improved for this purpose.

First, the issue of incorporating value. For a long time landscape ecology has focussed on the relationships between spatial patterns and ecological processes (e.g., Turner 1989; Wiens and Moss 2005) without explicitly considering the question of valuation. This may be because in large areas of landscape ecological research people were not seen as part of the landscape. They were either excluded from the research or considered to be a cause of landscape change (Bastian 2001; Antrop 2007; Wu and Hobbs 2007). Although a growing number of authors now stress the need to develop approaches that link landscape ecological science with society (e.g., Linehan and Gross 1998; Bastian 2001; Fry et al. 2007; Wu and Hobbs 2007; Potschin and Haines-Young 2006), the notion of valuation is absent from most papers that address the science/society interface (e.g., Leitão and Ahern 2002; Tress et al. 2005; Wu and Hobbs 2007). In contrast, the central notion in landscape development has always been that people are part of the landscape and that landscapes are changed for their benefit (Linehan and Gross 1998; Antrop 2001). Hence, landscape ecology and landscape planning have had a different orientation on the value of landscapes to humans.

Second, the issue of collaborative development. In organised decision-making on landscape change, different process phases have been recognised, which together constitute a cyclic process (Harms et al. 1993; Opdam et al. 2002). Phases that can be distinguished are, for example: assessment, target setting, strategy definition, design, implementation, monitoring, and back to assessment again. All phases are important for the landscape-development process. Literature shows that landscape ecological research that explicitly addresses sustainable development mainly focuses on assessment studies to measure the effect of policy measures on landscape patterns or performance (e.g., Metzger and Schröder 2006; Helming et al. 2007) and rarely on supporting design-driven collaborative decision-making with local actors (Luz 2000). In the symposia held at the last IALE world congress (in 2007), 50 out of 230 presentations (22%) were on assessment studies, but only 6% combined a local scale, valuation of landscape assets, and collaborative decision-making, and thereby met the two prerequisites proposed in the Introduction. Assessment studies have two characteristics related to solving structured problems. First, values and objectives are defined beforehand in policy and so negotiation about these is not part of the research procedure. Second, the assessment procedure is a linear process in which a chain of rules and indicators (often in GIS models) are used to measure progress towards the policy objectives against the indicators used. For example, many studies in Europe that are commissioned for the European Union use the linear framework "Driving Forces, Pressures, States, Impacts, Responses", developed by the European Environmental Agency (see Helming et al. 2007). Moreover, most assessment studies are designed to support national and international policies and are, consequently, based on large-scale databases. For example, the Millennium Ecosystem Assessment (2005) analysed global trends in ecosystem goods and services. Also, the majority of papers in the journal *Landscape Ecology* addressed broad spatial scales (Anderson 2008). Brunckhorst et al. (2006) have argued that such scales are inappropriate for civic engagement in land-use planning and management. Assessment tools are built on rigorous replicable methods developed by experts. These tools are suitable for answering questions, but less useful for deliberation, which is characteristic of bottom-up collaborative planning. Deliberation is based on discussion and reflection, which increases understanding of complex unstructured problems, typical for sustainable landscape development (Macleod et al. 2007). In this context, it is significant that ecological knowledge is generally found too rigid and prescriptive (Prendergast et al. 1999; Theobald et al. 2000; Morris et al. 2007) to be applicable to collaborative landscape planning. We suggest that most landscape ecological knowledge that has been developed for policy assessment is not on the proper spatial scale and not useful for deliberation. Further research is necessary to deepen our understanding of the different requirements that policy assessment and collaborative landscape planning and design pose to the structure of scientific knowledge.

These observations suggest, first, that for landscape ecology to achieve a central position in sustainable landscape development it has to extend its pattern–process approach by incorporating perceptions of value in its scientific scope (Fig. 1). This would allow landscape ecological knowledge to connect the physical structure and functioning of

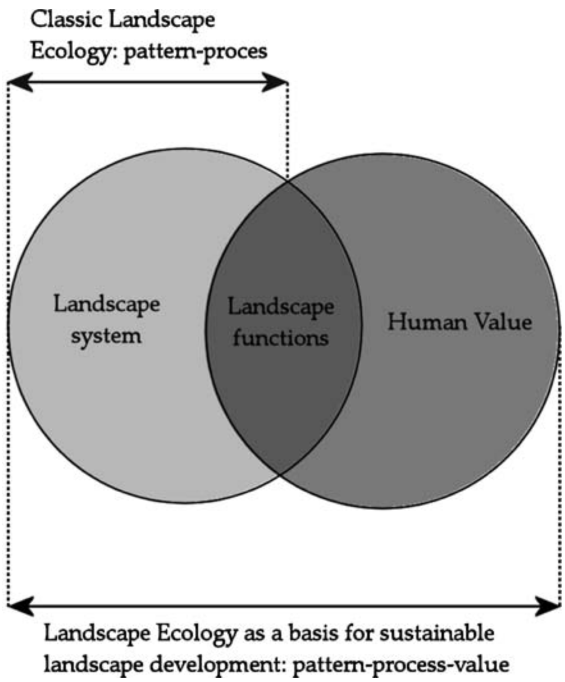

Fig. 1 Landscape functions are part of the pattern–process paradigm in landscape ecology, but can also be considered from the point of view of values that humans attribute to landscapes. By incorporating value into the pattern–process paradigm, landscape ecology can be developed into the basis for sustainable landscape development

the landscape with the values demanded by its users (prerequisite 1). Second, there is a need for scientific methods that allow actors in collaborative landscape development to develop a science-based vision, to negotiate about objectives and options, and design and develop a landscape structure that functionally supports the provision of demanded values (prerequisite 2). By definition, meeting this challenge requires interdisciplinary collaboration. Valuation techniques require the integration of approaches taken from economics, psychology, and sociology with pattern–process knowledge from the natural sciences. Hence, there is an obvious need to intensify communication between these sciences. We argue that this communication challenge calls for a strong unifying principle. This principle should also provide a common ground between scientists and actors in local landscape development (Nassauer and Opdam 2008). In the next section, we will search for such a principle.

The landscape services concept as a bridge between landscape and value

Landscape as a value-delivering system

For landscape science to contribute to sustainable development, the view on what "landscape" is should be consistent with this objective. This is not obviously so: views on the landscape concept vary widely among landscape sciences and in society. Therefore, we have to mark our position in the landscape debate first. In landscape science, landscape values have long been narrowly defined. We distinguish two views: one view based on nature conservation values in relation to an ecophysical definition of the landscape (Jobin et al. 2003; Wiens and Moss 2005) and a second considering the landscape as a cultural (Stephenson 2008) or aesthetic phenomenon (Nohl 2001); both related to "the cultural landscape" concept in which the landscape is regarded as visual scenery. In landscape-planning literature, in comparison, landscapes have been considered as a human–ecological concept for decades (Linehan and Gross 1998; Gobster and Westphal 2004; Nassauer et al. 2004), emphasising their economic, cultural and ecological values. Recently, geographers and landscape ecologists have been increasingly advocating a multifunctional landscape concept, which includes both the aesthetic aspect and the services it provides to humans (Bastian 2001; Fry 2001; Tress et al. 2001; Musacchio and Wu 2004; Potschin and Haines-Young 2006; see also Stephenson 2008 for a review). Variation in landscape views can also be found in landscape policy. The UNESCO flagship programme on world heritage cultural landscapes lays a strong emphasis on conservation of cultural values of landscapes (Rössler 2006). The landscape convention of the Council of Europe (2000) also emphasises the visual and cultural aspects, but at the same time takes sustainable development of landscapes as a principle for landscape change. So, both scientific and societal views differ in the emphasis on conservation versus development, on natural versus cultural values, and on aesthetic versus multifunctional user values.

We build on the multifunctional view of landscape and incorporate both natural and cultural aspects, because this view enables consideration of the landscape as the physical basis for sustainable landscape development. In this view, landscapes are spatial human–ecological systems that deliver a wide range of functions that are or can be valued by humans because of economic, sociocultural, and ecological reasons (Chee 2004; DeFries et al. 2004; De Groot 2006), for example food production, climate regulation and education (De Groot 2006). This view implies that the functioning of landscapes is the result of the interaction between physical structures, which are the basis for natural processes, and human actions. Because functions can be valued by humans, they connect the performance of the landscape system to human values and use (Fig. 1). If we suppose that in collaborative landscape development on the local scale, actors change the landscape to obtain added value, which concept would be the most appropriate to link landscape ecological pattern–process knowledge with other scientific domains and with collaborative landscape planning?

We propose that "services concepts", for example ecosystem services, landscape services, and environmental services, emphasise the connection between physical systems (ecosystems or landscapes) and human values. "Services" (which is shorthand for "goods and services") are essential for the existence and convenience of humanity (Daily 1997; De Groot et al. 2002; Millennium Ecosystem Assessment 2005). Examples of services are energy, flood prevention, and recreational activities (De Groot 2006). The systematics of services, e.g., the definition and the differences from functions and processes, have been under construction and debate since the term was first used in the literature (see, for example, Bastian et al. 2006; Wallace 2007). For the time being, we use the following construct, based on our human–ecological view of the landscape. "Functions" can be translated into "services" when they are valued by people (Fig. 2); one function can offer

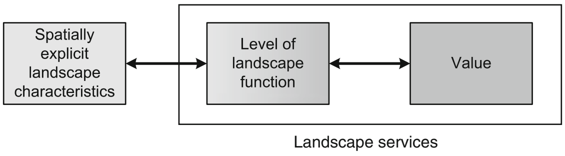

Fig. 2 The structure–function–value chain as a framework for landscape ecological knowledge, which gives meaning to the term "landscape services" for collaborative landscape development

several services. Thus, functions continue to exist in the absence of people, whereas services exist because people use and value the landscape. For example, plant roots and soil biota (ecosystem components) fulfil the function of soil retention. People value this because it prevents damage from erosion, so a service provided by the function "soil retention" is "prevention of damage from erosion". In theory, the costs of creating and maintaining vegetation strips can be recouped from the money saved on repairing damage. Changes in goods and services affect human wellbeing (Daily 1997; De Groot et al. 2002; Millennium Ecosystem Assessment 2005).

As already mentioned, in sustainable landscape development, actors change the landscape to obtain added value. This can be translated now by characterising sustainable landscape development as adapting landscapes to provide better services. Therefore, "landscape services" seems an appropriate concept to link landscape ecological knowledge to the field of collaborative landscape planning. However, a quick scan in Scopus (Table 1) demonstrates that this term has hardly been used in recent literature (2007–2008). "Ecosystem services", on the other hand, is far more popular: in the years 2007 and 2008, 614 articles mentioned "ecosystem services" in their titles, keywords, or abstracts. Of these articles on ecosystem services 75 mention "planning". However, a closer look of the abstracts of this part reveals that only a few articles are relevant for the field of collaborative landscape development with ecosystem services. In about half of the articles the term "ecosystem services" is just mentioned, as a kind of buzzword, and not further developed. Of the remaining articles, another half describes research on a scale too large to be applicable to local planning. Only a few studies on local to regional scales also dealt with landscape-change processes with local actors (Elbakidze et al. 2007; Schultz et al. 2007; Cowling et al. 2008). None of these considered the question how the term "ecosystem services" is interpreted and used by local actors. Many of the articles were about payments for ecosystem services, assessment of policy, valuation of ecosystem services, mapping of ecosystem services, etc. This information could be essential to collaborative landscape development, but its user value was not tested in on-the-ground decision-making on landscape change involving local actors.

Table 1 The number of articles, articles in press, and reviews in the Scopus abstract and citation database (from 2007 and 2008; search conducted on 18 November 2008) with search terms in the title, keywords or abstract

Search terms	Number of articles
Services concepts in general	
Ecosystem services	614
Environmental services	157
Green services	1
Landscape services	3
Services concepts in combination with planning	
Ecosystem services and planning	75
Environmental services and planning	20
Green services and planning	1
Landscape services and planning	0

The scarcity of literature on ecosystem services applied in collaborative landscape development, indicates that this concept needs further specification to make it relevant and acceptable for application in landscape development. We will explore below why "landscape services" may serve that purpose.

Landscape services versus ecosystem services

Why do we think that "landscape services" is a better concept than "ecosystem services" to unify scientists of different disciplines to build an interdisciplinary knowledge base that is suitable for collaborative landscape planning? Why should the "landscape services" concept be recognised as more relevant and acceptable both by local actors and scientists from various disciplines, such as environmental and social sciences, landscape planning, and architecture? We present three lines of arguments for preferring the term "landscape services" to "ecosystem services".

Landscape services better associate with pattern–process relationships

The core message of landscape ecology is that landscape pattern matters to landscape functioning. To put it in the context of the services concept: the unique contribution of landscape ecology to sustainable landscape development is understanding spatial pattern-functioning relationships and linking these to valuation of landscape services (Haines-Young 2000). These relationships might be most critical in multifunctional, fragmented landscapes that are heavily used by humans, where the provision of services not so much depends on the features of the individual, small ecosystem patches, but rather on the spatial interaction between these patches and between patches and human elements, such as footpaths and roads, causing synergies and trade-offs between services. An example is pest suppression in crops by parasitic and predatory insects, which need a specific structure of landscape elements to develop a viable population (Bianchi et al. 2006). The spatial position of the supply of services compared with the position of the service users is also important, for example the distance of users' dwellings from a forest where they can recreate or the upstream placement of ditches or trees with respect to a village that needs flood protection. Because of these intricate relationships between the spatial pattern of landscape elements and (horizontal) landscape processes, we prefer the term "landscape" because it highlights the importance of spatial pattern, whereas the ecosystem concept highlights the functional (vertical) relationship between ecosystem components (a.o. O'Neill 2001).

Landscape services better unify scientific disciplines

Among scientists, "landscape" is a term popular with planners and landscape architects and is also used in social sciences (Linehan and Gross 1998; Steiner 2000; Dramstad et al. 2006). However, "ecosystem" is not part of the language used in these scientific domains. For example, Macleod et al. (2007), in their paper on sustainable catchment management, use the word landscape to denote the management unit, but not "ecosystem". Instead, "ecosystem" is increasingly becoming a core concept in environmental science and associated with nature, biodiversity, and environmental protection. Many recent papers on ecosystem services relate services to biodiversity in natural ecosystems (e.g., Martinez and López-Barrera 2008; Cowling et al. 2008) and use it as a core concept in environmental policy assessment (see for example the Millennium Ecosystem Assessment 2005). "Landscape" is a broader concept than "ecosystem", because more disciplines can recognise themselves in it.

Landscape services are more relevant and legitimate to local practitioners

For local actors, the concept must elicit associations with the multidisciplinary character of the landscape and also with a place where they live and work and for which they are responsible. Connected with these associations is the detailed pattern of landscape elements that the locals perceive, valuate and manage. We propose that the term "landscape" includes all these aspects, whereas "ecosystem" does not, because of the following. We observe, at least in our part of the world, that the term "ecosystems" is connected to (semi)natural areas with legal protection, with recreation on Sunday, and with biodiversity and natural processes. We did find some studies in which the concept of ecosystem services was applied on the local landscape scale, but these studies were completely science-driven without involvement of local actors (Patil et al. 2001; Li et al. 2005; Grêt-Regamey et al. 2008; Lovell and Johnston 2008). When we encountered the term ecosystem services in scientific papers on collaborative management, the unit of management appeared to be large-scale areas, such as semi-natural farms in Arizona and vast wetland area in Sweden (Olsson et al. 2004; Schultz et al. 2007). Hence, "ecosystem" may be associated with large-scale, natural processes, and conservation instead of with human habitat, cultural patterns, and development.

Based on these three lines of argument, we hypothesise that to guide landscape ecology towards a sustainable development science, the term "landscape services" is more appropriate as a unifying concept between scientists and between scientists and local actors than "ecosystem services". Contrary to "ecosystem", "landscape" may be appealing to non-ecological scientific disciplines and may be associated with people's local environment, with the place for which they feel responsible, and with distinct spatial elements that they can change to improve the ecological, social, and economic value. Therefore, we propose the term "landscape services" as a specification (rather than an alternative) of "ecosystem services" for use in landscape ecology, when striving for development of an interdisciplinary science base for collaborative landscape development. Other related terms might be considered, for example "natural capital" (Haines-Young 2000; Chiesura and De Groot 2003; Blaschke 2006), "environmental services" and "green services" (Ojeda et al. 2008; Rogge et al. 2007), which are sometimes used as synonyms for ecosystem services. The last two are also used to depict financial arrangements (e.g., "Payments for Environmental Schemes"; Jack et al. 2008). We suggest that these terms are, like "ecosystem", primarily associated with the ecological functions of landscapes. Therefore we believe they are less effective in unifying scientists from different disciplines, while being less relevant and legitimate to local actors in collaborative planning. They also lack the emphasis on spatial pattern–process interaction. We call for future research to determine whether our arguments for preferring "landscape services" are supported by empirical evidence. For now, we will build on these arguments and develop a theoretical framework for landscape services that may guide landscape ecology to merge better with social and planning science to develop a science base for collaborative sustainable landscape development.

The knowledge task for science: the structure–function–value chain of knowledge

How can we translate the concept of landscape services into a knowledge structure that helps to converge knowledge generation in scientific disciplines and at the same time strengthens the relationship between science and practice? To answer this question we analyse how the pattern–process relationship, expanded to include value, could be transformed into a knowledge chain that meets the needs of the landscape-development process. We assume that in obtaining a sustainable outcome, scientific knowledge can make a difference by guiding local actors to define common future values and helping to identify a landscape structure that will support those values. However, scientific knowledge is of a generic nature and, for implementation, needs to be reframed within the local context by linking it to area-specific information. In collaborative local development, actors involved in decision-making should be able to understand the generic knowledge and to apply it correctly in the specific context of the planning region (Opdam et al. 2008). In this section, the emphasis is on the generic knowledge; the following section deals with the question of applying it in local landscape planning processes.

To change landscapes in a way that adds value, targets must first be set (Termorshuizen et al. 2007). This requires indicators of landscape functions and knowledge about how these indicators relate to ecological, social, and economic values and benefits. Much research addresses these relationships (for a review see Chee 2004). Realising targets requires insight into the relationship between function indicators and spatial structure (Termorshuizen et al. 2007). These are the relationships landscape ecology has focussed on traditionally. However, relatively little attention has been paid to how actors in local landscape planning and design use this pattern–process information, whether they tend to focus on functions or on the spatial structure, and how they deal with value. Actors must be able to negotiate about their different perceptions of value and translate these into preferred changes in landscape structure, taking into account the spatial trade-offs between functions. Shifting targets often also demand a shift in the intended changes of landscape structure, because of the functional relationship between structure and value (via functions). The concept of landscape services can therefore be operationalised in a knowledge chain with two links—the first between spatial structure and landscape functions and the second between functions and values. We call this conceptual knowledge chain the "structure–function–value chain" (Fig. 2). Figure 3 gives two examples of structure–function–value chains. The three entities in the chain are represented by measurable, quantitative indicators (for value, functioning, and changeable physical features) because a quantitative indicator is more verifiable, reproducible, and negotiable than a qualitative one. Examples of quantitative function indicators include the expression of carbon storage in t C/ha (Bailey et al. 2006), the provision of reeds in

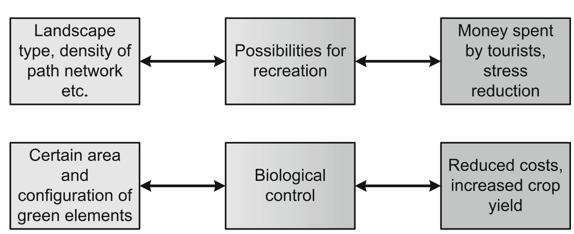

Fig. 3 Examples of structure–function–value chains

kg/ha/year (Hein et al. 2006), and species richness in number of species (Bennett and Radford 2004; Lindenmayer et al. 2005). Value can be expressed in monetary and non-monetary terms. We envisage the two links in the structure–function–value chain as quantitative relationships.

The form of the relationships between structure and function and function and value is crucial information for decision-making—will a certain investment lead to added value? Many relationships are nonlinear (Eiswerth and Haney 2001; Fahrig 2002; Farber et al. 2002; DeFries et al. 2004; Huggett 2005). Therefore, an investment does not always lead to more value. For example, if the relationship shows a limit, the actual physical state of the planning area determines whether it is possible to improve a function or that it is already at its maximum (Fig. 4a). For example, increasing the spatial cohesion of an area initially improves the performance of a specific population, but when certain cohesion has been achieved, additional investments will not lead to further improvement of performance (Hanski 1994). If the relationship follows a bell-shaped curve with a single optimum (Fig. 4b), investing in structure may initially increase the function level, but further investment will lead to a loss of functioning (and thereby of value). For example planting more and more trees to increase landscape quality for recreation will eventually result in a forest which is too dark. The shape or position of the relationship between the supply of a landscape service and the landscape characteristics differ according to the area-specific context. For example, when habitat quality is bad, more area is needed for a specific species (Opdam et al. 2003).

The innovative aspect of the knowledge chain is that it highlights the need for interdisciplinary research. In this context, interdisciplinarity has two aspects. First we will elaborate on interdisciplinarity within the structure–function–value chain, caused by the fact that knowledge on both links is required at the same time. Subsequently, we will discuss interdisciplinarity between chains, thus between functions, needed to support multifunctional landscape development.

Integration of knowledge within the chain is needed. The structure–function part of a chain may be the domain of ecologists or geographers, while the function–value part requires cooperation with economics and sociology. To our knowledge, this integration needs a strong impulse. For each function, quite a lot of information on bits and pieces of the chain can be found scattered throughout the literature, obtained in different places and landscape types and on varying spatial scales, but the complete chain is rarely investigated. For example, the recent interest in the role of biodiversity in suppressing crop pests has produced a few reviews and papers (Tscharntke et al. 2005; Bianchi et al. 2006, 2008) in which landscape features are quantitatively related, among others, to the percentage of plants in fields that are infected with parasites. Bianchi et al. (2006) showed that increasing structural complexity on the scale of agricultural landscapes can contribute to increased predation and parasitism of pests and reduced crop damage. However, these papers do not give information about the economic profit for the farmer resulting from lower costs of pesticide application. The absence of complete chains of knowledge in research is reflected in the disciplinary journals, which have

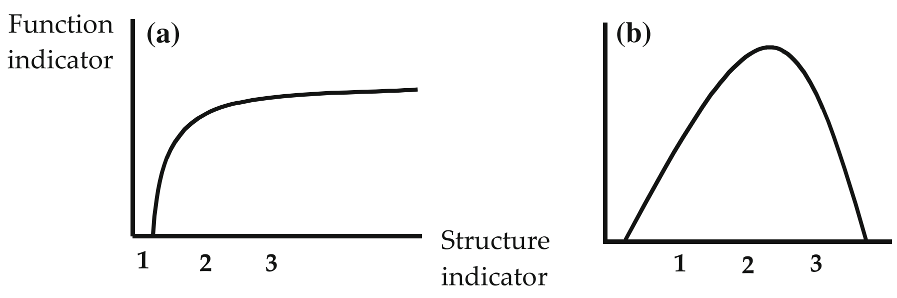

Fig. 4 A structure–function curve with a limit (**a**) and one with a bell-shape (**b**). If a certain structure in the planning area were to be changed from 1 to 2, a considerable increase in the function indicator could be expected. If, however, the structure were to be changed from 2 to 3, it would not have much effect (**a**) or it would have a negative effect on the output of the function (**b**)

focussed on one link only for a long time, for example *Ecological Economics* (function–value) and *Landscape Ecology* (function–structure). The emergence of integrative journals, for example *Sustainability Science*, is rather recent but promising. At the moment the structure–function–value chain is not yet incorporated into the research published in this journal.

Also, integration of knowledge between chains/functions is needed. Different functions are being studied in different scientific disciplines that communicate insufficiently to produce knowledge that can be used in collaborative landscape development. The knowledge needs to be integrated in order to support multifunctional landscape development, in which functions have to be weighed and spatially combined. For example, to integrate information on the capacity of landscape to retain storm water, on the capacity of purification of air by vegetation, and on the perception of landscape structure by humans, it is required that similar spatial scales, levels of detail, and definitions of landscape structure are applied.

From this it can be concluded that the scientific community faces a considerable task in producing integrated knowledge. The structure–function–value chain is an overarching concept that invites scientists from different disciplines to coordinate their research and guides their efforts towards outcomes more suitable for integration. This integrated knowledge must, in its turn, be applicable to transdisciplinary landscape-development processes.

Crossing the boundaries between science and practice

To explore how the structure–function–value chain could facilitate a collaborative landscape-development process, we have designed a conceptual framework for application (Fig. 5). In this section, we discuss its use in the planning process and the expected performance in the light of criteria for effective knowledge transfer (Cash et al. 2003).

Figure 5 shows how the structure–function–value chain can be applied in collaborative decision-making on landscape change. On the left of the figure, the landscape change component of the framework, we emphasise that the goal-setting and design process must result in a structure appropriate to the desired functions and a level of functioning that corresponds to the desired value. If not, the designed structure is not sustainable and must be adapted. Local actors, for example farmers, tourist offices, and nature-conservation organisations, choose which functions they prioritise and which values the landscape functions must provide, taking into account area-specific aspects such as relevant policy and available space. Hence, the objective of collaborative landscape change is to alter the landscape structure to improve its capacity to provide selected services up to a level that is negotiated by the local actors. By achieving this, added value is generated for landscape users.

The right of the figure, the socioeconomic system, depicts the interactions between the actors capable of

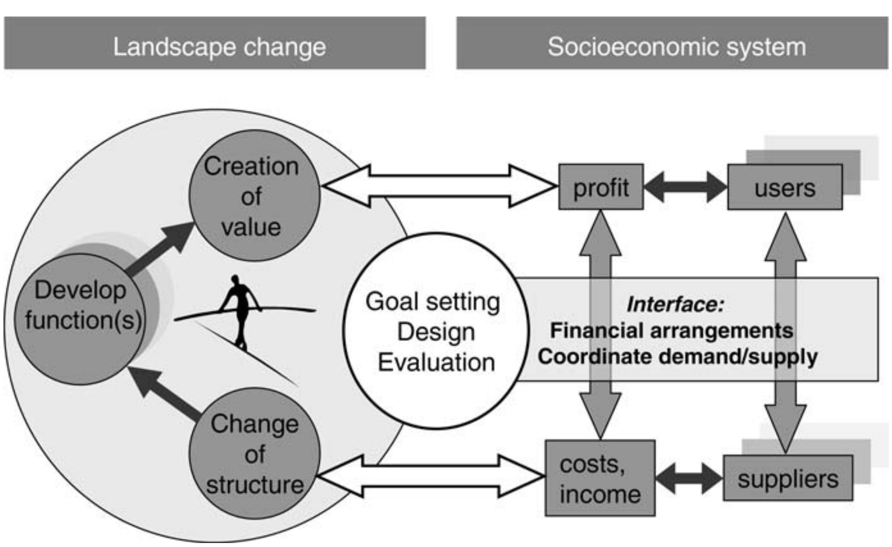

Fig. 5 A conceptual framework for collaborative landscape development, showing the position of the structure–function–value chain in relation to the interacting forces demand and supply in the provision of landscape services. The outcome of the change process needs to ensure that structure, function, and value are in equilibrium and that profits accruing to landscape users equal costs + income to the suppliers

supplying landscape services and the actors using these services, linked by financial arrangements. Hence, the landscape change is considered in a market situation of demand and supply. The demand may come from inside the planning region or from outside it, for example from the nearby urban population, or it may follow from legislation implemented by the national government. Ideally, the suppliers earn income and incur the costs of changing the landscape and managing it; the users gain profit in the form of quality of life (health, recreation) or save money because the landscape takes over regulatory functions (e.g., water supply, waste treatment). By placing the landscape in a context of supply and demand between suppliers and users, a condition is created for sustainable landscape development.

The central part of the figure depicts the objective setting, design, and evaluation process. It includes decision-making, but also the coordination and organisation of the demand–supply interaction, and implementation of regulatory mechanisms to make this work. Steps in this process may include selecting functions to be developed and choosing how the physical structure of the landscape will be changed to improve it for the selected functions. An important part of the landscape-change process is the transfer of money from the demand to the supply side. This may require a fund managed by a local board of representatives of interest groups, financed from both private and public sources. If functions or values are demanded that transcend the scale of the planning area (such as protected species or clean air), local and national governments may be involved to protect large-scale public values and supply budgets to achieve this. The objective setting, design and evaluation phases form a cyclic process, which will probably never come to a final conclusion, but be continuous as landscape changes will lead to changes in the socioeconomic system that will lead to new landscape changes. This process is typically designed as a learning process in which local practitioners, planners, landscape architects, and other professionals cooperate with scientists in a transdisciplinary coproduction of knowledge (Duff et al. 2008).

We are anxious to learn how the framework could facilitate cooperation between scientists and practitioners. For example, in the function–value linkage, scientists may provide a list of possible landscape functions to be improved, from which local actors choose preferred functions to invest in. Scientists may provide generic indicators and relationships between function and value, for example in monetary terms (Farber et al. 2002), but local actors decide how they perceive the values provided by the actual landscape and they determine the aspiration level for the future landscape, for example for the level of water purification or the level of biodiversity. Thus, where scientific knowledge is related to values, it needs to be reframed in a subjective context determined by local actors. This is less so with knowledge about the relationship between structure and functioning—generic relationships between ecosystem area and the level of the water purification function, for example, need to be interpreted for the specific ecosystem types and water quality in the planning area, but can still be measured in objective terms. Scientists may indicate ways to determine limits of sustainability to change the functioning of the landscape system (sustainable use levels; De Groot 2006), but local actors decide how to deal with limits to acceptable change. Moreover, scientists can offer local actors room to manoeuvre by indicating different spatial structures that deliver about the same function level instead of a single optimum solution (Potschin and Haines-Young 2006).

How may we expect the landscape services framework, worked out as the structure–function–value chain, to perform in knowledge transfer between science and society? Cash et al. (2003) argue that scientific information is likely to be effective in actions for sustainable development when the information is credible, salient, and legitimate. *Credibility* addresses the question of scientific adequacy. We expect the landscape services concept, as a boundary concept, will help to clarify what should be known to change a landscape and identify the scientific knowledge that needs to be provided. Development of well-tested methods and tools for showing the interrelationship between landscape pattern, the functioning of landscape, and its benefits to people, together with improvements to the availability of knowledge on the right spatial scale, would increase the credibility of the contribution that science can make to collaborative landscape planning. *Salience* concerns the relevance of the information to the needs of decision makers. We assume that our concept will help to improve salience by enhancing the integration of knowledge across disciplines. Integration improves, for example, the effectiveness of scientific advice on combining functions in the same spatial structure, which reduces costs. *Legitimacy* reflects the perception that the production of information respects users' values, and is free from bias, transparent, and produced with the interests of the user in mind (Cash et al. 2003; McNie 2007). The structure–function–value chain explicitly intends to improve legitimacy by introducing value into the scientific approach.

Conclusion

"Interdisciplinary frameworks that incorporate multivariate causality, non-linear feedback, and individual-based decision-making are critical to research that explicitly incorporates humans in ecosystems" (Palmer et al. 2004). We have proposed the concept of landscape services as a common ground for knowledge production and have elaborated this concept into a framework for knowledge generation, applicable in local collaborative landscape development. With this concept we expand the pattern–process paradigm by incorporating human value to position landscape ecology as a core science for sustainable landscape development. The term "landscape services" has been used previously (without explicit definition), but we give it new significance in the context of collaborative planning processes designed to change landscapes with the purpose of generating added value. "Landscape services" is just a term; with the structure–function–value chain we intend to give it meaning for landscape development. To professional planners and local actors the chain emphasises that the demanded value requires appropriate landscape functions and physical patterns, enabling the development of sustainable landscape designs and subsequent landscape use. To scientists, we expect the concept, expressed as the chain linking knowledge found in different scientific disciplines, to enhance interdisciplinary science. Finally, we suppose that the concept will help to clarify cooperation between scientists and practitioners, which improves the user value of scientific knowledge. The concept may be seen as a contribution to interdisciplinary and probably also transdisciplinary theory (see the research questions listed below), and could stimulate the development of landscape ecology, as envisaged by Wu and Hobbs (2007), toward a hierarchical and pluralistic, interdisciplinary, and transdisciplinary branch of sustainability science.

Theory should be tested and should evoke new research questions and the development of new methods. In our view, the landscape services framework calls for challenging and innovative landscape ecological research and helps to ask the right questions. We suggest a few key questions:

- With respect to implementation of the framework:
    - How can the available knowledge in various disciplines (e.g., about landscape perception, recreation, human health) be integrated into structure–function–value chains and what are the most important gaps in knowledge?
    - What is the form of the relationships of the linkages in the structure–function–value chain and what role do they play in decision-making on limits of sustainability and cost-effectiveness?
    - Are available methods, for example policy assessment and scenario evaluation methods, suitable for application in collaborative decision-making and if not, how should these methods be adapted?
    - How can guidelines and methods for incorporating the framework into collaborative landscape planning be designed?
- With respect to the added value of the framework itself:
    - How does the framework affect the thinking and negotiation process of local actors?
    - How does the framework affect the cooperation and knowledge exchange between scientists and between scientists and practitioners?
    - Is the concept of landscape services more effective than ecosystem services in collaborative landscape development?
    - Does the framework lead to more sustainable use of landscapes?
    - In what kind of planning culture is the framework effective?
    - How does the relevance of the framework as perceived by local actors vary between intensively and extensively used landscapes?

Of course, the framework is not a solution to the problem we have identified; at most it is a means of learning how to move landscape ecology closer to sustainable development. We hope that it helps actors to visualise how landscapes can be used for sustainable development and that researchers will find it helpful and inspiring for learning how to develop adequate knowledge for sustainable landscape planning. As such, we see the framework as a tool for learning and communication. Its user value will have to be discovered in the course of a learning process involving the participation of scientists and practitioners.

Acknowledgments This study is part of the "Ecosystem and Landscape Services" research programme of Wageningen University and Research Centre and financed by the strategic research programme "Sustainable spatial development of ecosystems, landscapes, seas and regions", commissioned by the Dutch Ministry of Agriculture, Nature Conservation, and Food Quality. We thank Barbara Sterk, Laura Musacchio, and the anonymous reviewers for suggesting valuable improvements to the manuscript.

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