Living Rev. Landscape Res., **5**, (2011), 1
http://www.livingreviews.org/lrlr-2011-1

LIVING REVIEWS in landscape research

The Concept of Ecosystem Services Regarding Landscape Research: A Review

Anna Hermann
Department of Conservation Biology, Vegetation Ecology and Landscape Ecology,
Universität Wien, A-1030 Rennweg 14, Vienna, Austria
email: anna.hermann@univie.ac.at

Sabine Schleifer
Department of Conservation Biology, Vegetation Ecology and Landscape Ecology,
Universität Wien, A-1030 Rennweg 14, Vienna, Austria
email: a0402557@univie.ac.at

Thomas Wrbka
Department of Conservation Biology, Vegetation Ecology and Landscape Ecology,
Universität Wien, A-1030 Rennweg 14, Vienna, Austria
email: thomas.wrbka@univie.ac.at

Accepted on 21 February 2011
Published on 26 March 2011

Abstract

The awareness that natural and semi-natural ecosystems provide benefits to human society, which are of great economic, ecological and socio-cultural value, can be dated back to the mid-1960s and early 1970s. More recently, there has been an almost exponential growth in publications on the benefits of natural ecosystems to human society. However, despite the enhancing interest in ecosystem service research, still many open questions remain to fully integrate the ecosystem service concept in landscape research and decision making. The paper aims at providing the state-of-the-art of ecosystem service assessment regarding landscape research and to present a coherent knowledge base for further discussions. First the paper gives an overview of the different ways defining and classifying ecosystem services. Five selected typologies, very common in the literature are discussed in detail. The second main part of this review focuses on quantifying and mapping ecosystem services as well as on the different valuation approaches. As there are still a lot of challenges that have to be faced regarding quantifying, visualising as well as valuing ecosystem services the paper emphasizes the importance of further research, initiatives and projects to improve the implementation of the ecosystem service concept in environmental planning and management at all levels of decision making. To meet all these challenges research effort needs to be conducted side by side to understand underlying relationships and to improve ecological as well as socio-economic understanding.

Keywords: ecosystem services/functions, landscape services/functions, classifying, quantifying and mapping, valuation

Imprint / Terms of Use

Living Reviews in Landscape Research is a peer reviewed open access journal published by the Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Straße 84, 15374 Müncheberg, Germany. ISSN 1863-7329.

Because a *Living Reviews* article can evolve over time, we recommend to cite the article as follows:

> Anna Hermann, Sabine Schleifer and Thomas Wrbka,
> "The Concept of Ecosystem Services Regarding Landscape Research: A Review",
> *Living Rev. Landscape Res.*, **5**, (2011), 1. [Online Article]: cited [<date>],
> http://www.livingreviews.org/lrlr-2011-1

The date given as <date> then uniquely identifies the version of the article you are referring to.

Article Revisions

Living Reviews supports two ways of keeping its articles up-to-date:

Fast-track revision A fast-track revision provides the author with the opportunity to add short notices of current research results, trends and developments, or important publications to the article. A fast-track revision is refereed by the responsible subject editor. If an article has undergone a fast-track revision, a summary of changes will be listed here.

Major update A major update will include substantial changes and additions and is subject to full external refereeing. It is published with a new publication number.

For detailed documentation of an article's evolution, please refer to the history document of the article's online version at `http://www.livingreviews.org/lrlr-2011-1`.

Contents

List of Tables

1 Introduction

The concept of ecosystem services is seen as a promising approach communicating the links between ecosystems and human well-being (MEA, 2005). Although the term "ecosystem services" was primary introduced by Ehrlich and Ehrlich (1981), the concept's origin of the modern history dates back to the late 1960s and 1970s, highlighting the societal value on nature's functions (King, 1966; Helliwell, 1969; Ehrlich and Ehrlich, 1970; Dee *et al.*, 1973; Ehrlich *et al.*, 1977; Bormann and Likens, 1979). In the 1970s and 1980s, it was already started to point out societal and economic dependence on natural assets in order to attract public interest on biodiversity conservation (e.g. Westman, 1977; de Groot, 1987). Important milestones in the mainstreaming of ecosystem services were on the one hand Daily's book *Nature's Services: Societal Dependence on Natural Ecosystems* (Daily, 1997) and on the other hand the paper by Costanza *et al.* (1997) on the value of global natural capital. The monetary figures presented in the last one resulted in a high impact on both science and policy making. Especially after the release of the Millenium Assessment (MEA, 2003), which focused on the benefits people derive directly and indirectly from ecosystems, the literature concerning ecosystem services has increased exponentially (Fisher *et al.*, 2009). Since then, several authors and projects have been dealing with classifying, quantifying, mapping and valuing of ecosystem services in order to integrate the concept into decision making processes (Costanza *et al.*, 1997; Wilson and Carpenter, 1999; Heal, 2000; de Groot *et al.*, 2002; MEA, 2003; Turner *et al.*, 2003; MEA, 2005; de Groot, 2006; Fisher *et al.*, 2009; de Groot *et al.*, 2010; Rounsevell *et al.*, 2010).

As landscapes are considered to be multifunctional and are subject to a wide range of land uses, the concept of landscape functions or services, used as synonym to ecosystem services, raised much attention in the field of landscape ecology and landscape planning. 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). Because landscape sciences focus on spatial pattern and scale, they can provide useful insights into how the spatial distribution of human activities influences important landscape processes and structures from which services are derived (Jones *et al.*, 2008). Especially in Central and Eastern Europe both the analysis of landscape pattern and processes and the assessment of landscape functionality as a precondition for land use planning have a long tradition (Buchwald and Engelhardt, 1968). The idea of landscape function assessment (Bastian and Schreiber, 1994; Lee *et al.*, 1999) traces back to the multifunctionality concept of forests and green spaces (Konkoly-Gyuró, in press). Whereas the term "natural territorial potentials" (Troll, 1950; Neef, 1966) was too abstract for practical landscape planning, the concept of landscape functions arose. Bastian and Schreiber (1994) for instance, developed a framework for the assessment of landscape functions to support sustainable land use management. Based on this concept, many studies dealing with different assessment methods, especially in the German speaking community, were carried out (Haber, 1979; Niemann, 1982; Bastian, 1997; Bastian and Schreiber, 1999; Leibowitz *et al.*, 2000; Steinhardt and Volk, 2003; Palmer, 2004; Meyer and Grabaum, 2008).

However, despite the great interest in this research topic there are still remaining challenges which need to be addressed to fully integrate the concept of ecosystem services into landscape planning and decision making (de Groot *et al.*, 2010). The development of an integrative framework (Figure 1), which fully take the ecological, the economic as well as the socio-cultural values of landscapes into account, is still in process. Such a framework should be comprehensible, feasible and able to be applied at wide range of scales to different ecosystems or landscapes (Hein *et al.*, 2006). In the literature many limitations, obstacles and open questions regarding this process are documented and discussed (de Groot *et al.*, 2010). Because of the wide range of publications on the ecosystem service concept, different approaches to and implementations of the concept occur.

This paper aims at presenting the state-of-the-art of ecosystem service assessment regarding landscape research. The target is to provide a coherent knowledge base contributing to the ongoing discussion process on finding solutions for integrating the concept of ecosystem services into landscape planning and decision making. The first sections of this paper address different key definitions used within the concept of ecosystem services and different classification systems of the services. The following sections illustrate various approaches and challenges of quantifying and mapping, different aspects of valuation methods and conclude with a discussion. Although the economic aspect within the concept of ecosystem services also remains as a main challenge, it is only marginally addressed in the present paper, because a review of economic valuation would go beyond the scope of this study. For more detail on this thematic, please refer to other reviews focusing on the economic approach (e.g. Peterson and Sorg, 1987; Pearce and Moran, 1994; Gómez-Baggethun *et al.*, 2010).

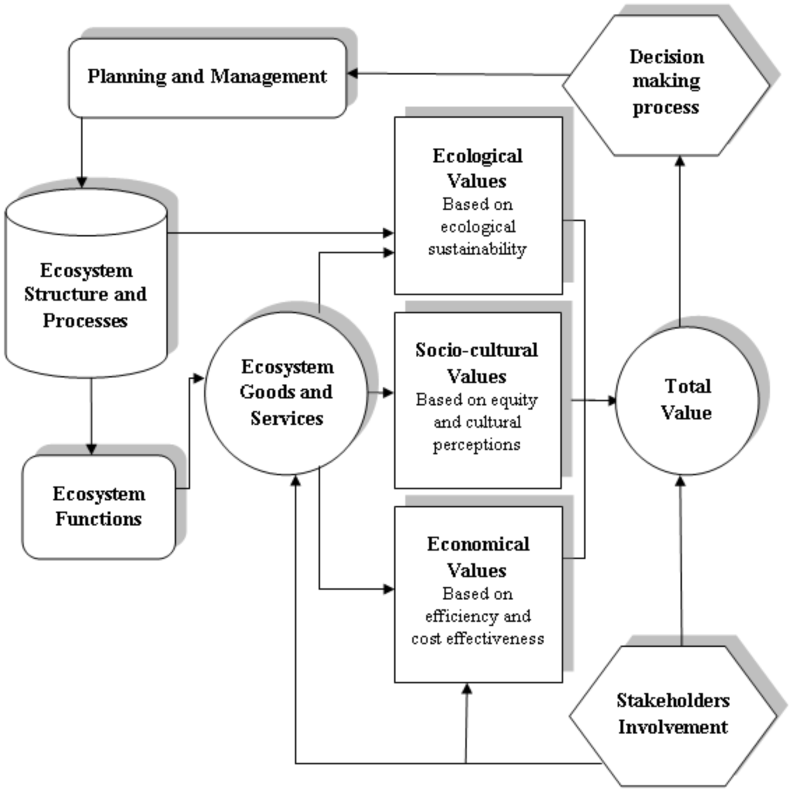

Figure 1: Valuation framework integrating the ecosystem service concept into sustainable landscape planning and management; Taking into account the total landscape value (including ecological, socio-cultural and economical values) in decision making processes effects indirectly the provision of services (adopted from de Groot, 2006).

2 Definitions of the different key terms

If the ecosystem service concept is designed to provide an effective framework for natural resource management decisions, ecosystem services have to be defined and classified in a way that allows comparisons and trade-offs amongst the relevant set of potential benefits. A number of scientists have attempted to construct typologies of ecosystem services (e.g. Daily, 1999; de Groot, 2006; Boyd and Banzhaf, 2007). However, ambiguity in the definitions of key terms – such as ecosystem processes, functions, services and benefits – makes it difficult to develop a coherent decision framework (Wallace, 2007). For meaningful comparisons across time and space, clear definitions of the key terms are required (Boyd and Banzhaf, 2007; Wallace, 2007). However, according to Boyd and Banzhaf (2007) ecology and economics have failed to standardize the definition and measurement of ecosystem services. The following brief survey of definitions reveals multiple, competing meanings of the key terms used in the literature referring to the ecosystem service concept.

Ecosystem processes. According to the Elsevier's Dictionary of Biology (Tirri *et al.*, 1998) "process" is defined as "*a series of events, reactions or operations, achieving a certain definite result*". Ecosystem processes are seen therefore as the complex interactions among biotic and abiotic elements of ecosystems, encompassing in broad terms material cycles and flow of energy (Lyons *et al.*, 2005). Although this definition is widely accepted, scientists interpret and classify processes in different ways. Balmford *et al.* (2008), for example, distinguish between "Core Ecosystem Process" (e.g. production, decomposition, nutrient and water cycling), "Beneficial Ecosystem Process" (e.g. biomass production, pollination, biological control, habitat and waste assimilation), and "Benefits" (e.g. food, fresh water).

Ecosystem functions. De Groot (1992) defines ecosystem functions as "*the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly*". Functions therefore are the subset of biophysical structures and processes that provide services (de Groot *et al.*, 2010). They can refer variously to the habitat, biological or system properties or processes of ecosystems (Costanza *et al.*, 1997). Most authors agree that goods and services are generated by ecological functions (or processes) (e.g. Costanza *et al.*, 1997; Daily, 1997; Farber *et al.*, 2006). Jax (2005) notes that the term "ecosystem function" is considered as "capability", but is often used more generally to refer to processes that operate within an ecosystem, like nutrient cycling or predation. Often the two terms ecosystem functions and ecosystem processes are commonly used as synonyms even within the same study (see Costanza *et al.*, 1997).

Ecosystem services. Ecosystem services can be simply defined as a set of ecosystem functions that are useful to humans (Kremen, 2005). They are consequences of supporting processes acting at various temporal and spatial scales (Farber *et al.*, 2006). These general definitions are widely accepted. However, when trying to classify services and applying this framework in decision making processes, several uncertainties are revealed. There exist various semantic classes of the term ecosystem services, depending on the specific goal or background (Fisher *et al.*, 2009). According to Costanza and Folke (1997) ecosystem services "*represent the benefits human populations derive, directly or indirectly, from ecosystem functions*". In Daily (1997) ecosystem services (also referred to as nature's services) are the "*conditions and processes*", as well as the "*actual life-support functions*". Following Eichner and Tschirhart (2007), those biological resources are referred to as ecosystem services, which provide inputs into both production processes and consumers' well-being. The definition in the MEA (2003), which has been widely taken-up in the international research and policy literature, highlights the strong relation of ecosystem services to the benefits people derive directly or indirectly from ecological systems. Based on the MEA approach, the TEEB

(The Economics of Ecosystems and Biodiversity) project defines ecosystem services as direct and indirect contributions of ecosystems to human well-being (TEEB, 2010).

Boyd and Banzhaf (2007) provide an alternative approach. In their definition, ecosystem services are ecological components (including ecological structure) directly consumed or enjoyed to produce human well-being. Thus indirect processes and functions are not ecosystem services, but intermediate ecological components. For instance, recreational angling is seen as a benefit with multiple inputs. Whereas the water body and the target fish population are final services, the food web and water purification land uses on which the fish population depends, are intermediate components, because they are not directly related to the benefit (Figure 2).

Benefit	**Final Services**	**Intermediate Components**
Recreational angling	The water body The bass population The riparian forest	The water body's quality
Drinking water	The water body's quality	Wetlands, natural riparian land cover

Figure 2: Final Services vs. Intermediate Components regarding the benefits "recreational angling and drinking water"; Whereas Intermediate Components are indirect processes and functions, Final Services are directly consumed or enjoyed to produce human well-being (after Boyd and Banzhaf, 2007).

In contrast to the definition above, Fisher *et al.* (2009) suggest that ecosystem services are "*the aspects of ecosystems utilized (actively or passively) to produce human well-being*". Therefore services encompass ecosystem organization and structure as well as process and/or functions if they are consumed by humanity either directly or indirectly (Figure 3).

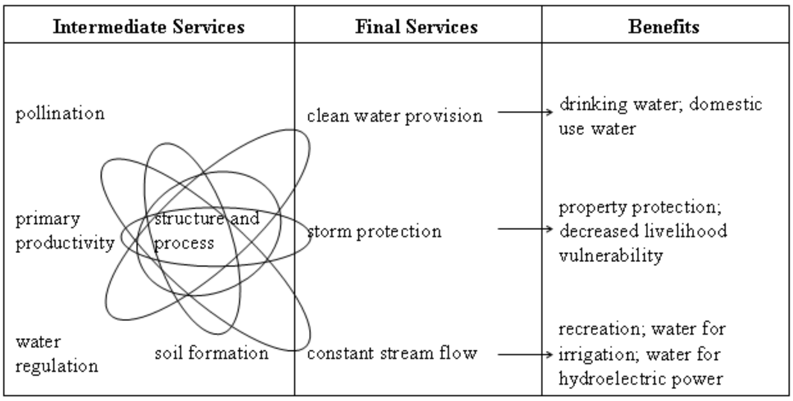

Figure 3: Conceptual relationship between Intermediate and Final Services; Structure and Processes become Intermediate Services if there are humans that benefit from them. Interactions among several Intermediate Services produce Final Services such as "clean water provision" and "storm protection" (after Fisher *et al.*, 2009).

Landscape services vs. ecosystem services. Another approach is to define functions and services at landscape scale to integrate the concept into land management decisions. The awareness that landscapes provide a multitude of functions and are subject to many possible land uses, gives rise to increasing research interest on the linkages between land use and land(sape) functions (see Bakkera and Veldkamp, 2008; Pérez-Soba *et al.*, 2008; Verburg *et al.*, 2009). Therefore, recently the terms "landscape function as well as landscape service" have become more important in the literature (Bastian and Schreiber, 1999; de Groot *et al.*, 2010; Willemen *et al.*, 2010). As "landscapes" (contrary to "ecosystem") may be more attractive to non-ecological scientific disciplines and may be associated with people's local environment, the term "landscape services" is preferred as a specification (rather than an alternative) of ecosystem services. In addition, the terms "environmental" and "green" services are used in some articles (Termorshuizen and Opdam, 2009).

Within this present paper landscape functions and services are used as a synonym to ecosystem functions and services. As the debate on the definitions is still going on and several authors have different interpretations and preferences, we don't follow specific definitions of the key terms in order to assure the provision of an overview.

Benefits. A benefit is something that directly impacts on the well-being of people (Fisher and Turner, 2008). Well-being is declared as the opposite end of a continuum from poverty, which has been defined as a "*pronounced deprivation in well-being*" (MEA, 2005). As well-being is dependent on one's situation, cultural and ecological circumstances, benefits are spatially explicit (Boyd and Banzhaf, 2007). Resources of well-being encompasses factors like aesthetic, enjoyment, various forms of recreation, maintenance of human health, physical damage avoidance, and subsistence of food (Boyd and Banzhaf, 2007). Defined this way, benefits can be seen as the link between human welfare and ecosystems, on which theoretically an economic value can be put on. The benefits humans gain from ecosystems are derived from services (Fisher and Turner, 2008). As mentioned above, the MEA (2003) and also other scientists (e.g. Costanza *et al.*, 1997; Wallace, 2007) consider services and benefits to be the same.

Recently, another scientific discourse has suggested that human well-being is not only dependent on nature, but also on other landscape elements, which have therefore to be also taken into account (Carlisle *et al.*, 2009). Especially, in affluent societies well-being can be understood as socio-cultural constructions of modernity which comply with the demands of a capitalist economic system (Eckersley, 2005). A multidisciplinary and culturally informed focus on well-being is thus necessary to be able to realise that certain aspects of "modern life" affect the physical environment on which humanity depends.

Conceptual relationship among the "key terms". Haines-Young and Potschin (2010) provide a valuation framework for linking ecosystems to human well-being, which has been used in several projects, for instance, the TEEB project (TEEB, 2010) (Figure 4). The proposed diagram makes a distinction between ecological processes and functions as well as the provided services and the outputs considered for humans as benefits. However, in the real world the relationship is not as simple and linear as illustrated in the diagram. Although the general structure of the suggested framework is widely agreed upon, the distinction between the terms "function", "service" and "benefit" is still under discussion (de Groot *et al.*, 2010). Fisher *et al.* (2009), for example, propose a different conceptual relationship between the key terms (Figure 3). It shows how joint products (benefits) can stem from individual services. Intermediate services are based on complex interactions between ecosystem structure and processes and lead to final services, which provide human welfare benefits.

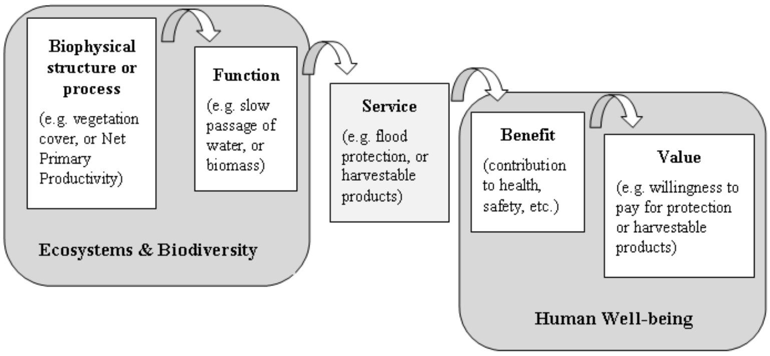

Figure 4: Conceptual relationship between Ecosystems & Biodiversity and Human Well-being (adopted from Haines-Young and Potschin, 2010).

3 Classification systems and their different typologies

3.1 Presentation of five selected classification systems

Although in the ecological literature, the key terms "ecosystem process", "ecosystem function", "ecosystem service" and "benefit" have been subject to various and sometimes contradictory interpretations, a wide range of authors have attempted to provide a systematic typology and comprehensive framework for integrated assessment and valuation of ecosystem goods and services (see Daily, 1997; de Groot *et al.*, 2002; MEA, 2005; de Groot, 2006; Boyd and Banzhaf, 2007; Fisher and Turner, 2008). However, because of the dynamic and complexity of ecosystems a single, consistent classification typology is difficult to develop (Costanza, 2008). There are many useful ways to classify ecosystem goods and services dependent on the different purposes of use.

Since a pluralism of typologies exists, we only illustrate some selected examples, which demonstrate different approaches and developments to classify ecosystem functions and services. Five different classification systems are presented, which are applied in many assessments and are used often as basis for further classification developments (Table 1). We have selected studies, which have shaped and differentiated the ecosystem service research community from the beginning (Costanza *et al.*, 1997; Daily, 1999; MEA, 2003) as well as typologies aiming at integrating the concept of ecosystem services into landscape planning and management within a European context (Bastian and Schreiber, 1999; de Groot *et al.*, 2010). In addition, two further classification approaches are presented, which show examples for further developments and adaption of the current typologies in the literature for regional as well as international integrated landscape planning projects.

Table 1: Comparison of five selected classification systems. Different typologies are presented, which are applied in many assessments and are often used as basis for further classification developments (Costanza *et al.*, 1997; Daily, 1999; MEA, 2003; de Groot *et al.*, 2010; Bastian and Schreiber, 1999).

Costanza et al. (1997)	Daily (1999)	MEA	de Groot et al. (2010)	Bastian and Schreiber (1999)
–	**Production of goods**	**Provisioning services**	**Provisioning services**	**Production (economical function)**
food production (e.g. fish, game, fruits)	food	food	food	renewable resources (herbal and animal biomass) / non-renewable resources (minerally raw materials and fossil fuel)
raw materials	durable materials (natural fiber, timber)	fibre	fiber, fuel, other raw materials	
	energy (biomass fuels)	biomass fuels		
	industrial products	–		
	pharmaceuticals	bio-chemicals, natural medicines, etc.	biochemical products and medicinal resources	
	–	ornamental resources	ornamental species and/or resources	
genetic resources	genetic resources	genetic resources	genetic materials	
water supply	–	fresh water	water	available renewable resource: water
–	**Regeneration processes**	**Regulation services**	**Regulation services**	**Regulation (ecological function)**
gas regulation	cycling and filtration processes	air quality regulation	air quality regulation	regulation of material- and energy-cycles
water regulation		water regulation	water regulation	
waste treatment		water purification and waste treatment	waste treatment	
erosion control and sediment retention		erosion regulation	erosion protection	
pollination	translocation processes (dispersal of seeds, pollination)	pollination	pollination	
–	**Stabilizing processes**	–	–	
disturbance regulation	regulation of hydrological cycle	–	natural hazard mitigation	
	coastal and river channel stability	storm protection		
climate regulation	moderation of weather extremes	climate regulation	climate regulation	
	partial stabilization of climate			
biological control	control of pest species	human disease regulation	biological regulation	regulation and regeneration of population and biocoenose
	compensation of one species for another under varying conditions			

Table 1 – *Continued*

Costanza et al. (1997)	Daily (1999)	MEA	de Groot et al. (2010)	Bastian and Schreiber (1999)
–	–	**Supporting services**	–	–
nutrient cycling	–	nutrient cycling	–	–
soil formation	–	soil formation and retention	soil formation and regeneration	–
–	–	photosynthesis	–	–
–	–	primary production	–	–
–	–	water cycling	–	–
–	–	–	**Habitat or supporting services**	–
–	–	–	genepool protection	–
refugia	–	provision of habitat	nursery habitat	–
–	**Life-fulfilling functions**	**Cultural services**	**Cultural & amenity**	**Habitat (social function)**
recreation	–	recreation and ecotourism	recreation and tourism	recreational function
–	–	–	–	human ecological function (e.g. filter- and buffer functions)
cultural	–	cultural heritage and diversity, sense of place	cultural heritage and identity	psychological function (aesthetic, ethic)
	aesthetic beauty	aesthetic values	aesthetic	
	cultural, intellectual and spiritual inspiration	inspiration	inspiration for culture art and design	
		spiritual and religious values	spiritual & religious inspiration	
	–	educational values	education & science	information function (science, education)
	scientific discovery	knowledge systems		
	serenity	–	–	–
–	existence value	–	–	–
–	**Preservation of options**	–	–	–
–	maintenance of the ecological components and systems needed for future supply	–	–	–

Costanza *et al.* (1997) tried to estimate the current economic value of renewable ecosystem services for 16 biomes, based on published studies and a few original calculations. For the purposes of this analysis the selected ecosystem services were categorised into 17 major groups. According to Costanza *et al.* (1997) ecosystem services represent the benefits humans derive, directly or indirectly, from ecosystem functions. Some ecosystem services are the product of more than one function, and one single function can contribute to two or more services. The classified ecosystem services represent the basis for further studies (e.g. de Groot *et al.*, 2002; MEA, 2005; de Groot, 2006).

According to **Daily (1999)** natural ecosystems and their related biodiversity are seen as capital assets that will yield a wide range of life-supporting goods and services over time. Benefits, which derive from ecosystems, will therefore enhance human welfare. In order to support sustainable ecosystem service management, Daily (1997) developed a conceptual framework for assessing ecosystem services and their trade-offs and revised it two years later (Daily, 1999). The "new" classification system encompasses the production of goods, regeneration processes, stabilizing processes, life-fulfilling functions, and conservation of options.

Using the definition of (Costanza *et al.*, 1997) [see Section 2 on definitions], the **Millennium Ecosystem Assessment** (MEA, 2003) provides a simple typology of services that has been widely taken-up in the international research and policy literature. Four broad types of service are suggested: "Provisioning services", "Regulating services", "Cultural services" and "Supporting services". This classification is understandably not meant to fit all purposes, which has been pointed out for contexts regarding environmental accounting, landscape management and valuation, for which alternative classifications have been proposed (e.g. Boyd and Banzhaf, 2007; Wallace, 2007; Fisher and Turner, 2008).

Following **de Groot *et al.* (2010)** ecosystem functions are intermediate between processes and services and can therefore be defined as the "capacity of ecosystems to provide goods and services that satisfy human needs, directly and indirectly (de Groot, 1992). The provided typology is mainly based on the MEA (2003) and de Groot (2006). Four broad types of services are distinguished: "provisioning services", "regulating services", "habitat or supporting services" and "cultural and amenity services". This classification concept was established aiming at integrating the concept of ecosystem services and values into landscape planning, management and decision making (de Groot *et al.*, 2010).

Bastian and Schreiber (1999), that are well known in the German speaking community base their classification approach on a long lasted research history in landscape functioning and management. The so-called landscape functions are divided into three groups: "production functions" (economic functions), "regulation functions" (ecological functions) and "habitat function" (social function). Each group is again classified into main-functions and sub-functions so that the cause and effect chains and interactions between land-use demand on the one hand and landscape structure on the other hand are observable (Bastian, 1991, 1997; Bastian and Schreiber, 1999).

3.2 Comparison of different typologies

Whereas Costanza *et al.* (1997), the MEA (2005), and de Groot *et al.* (2010) focus on ecosystem services, Bastian and Schreiber (1999) refer to landscape functions (Table 1). Daily (1999), in comparison to them, includes in her classification both goods, processes and functions.

The typology of the ecosystem goods, services and functions is among these five broadly the same (except for the services of Costanza *et al.* (1997), which are often used as the basis for further developments). The groups "provisioning services", "production of goods" as well as "production function" represent the presence of a large variety of living biomass, which provides many goods for human consumption e.g. food, raw materials and genetic material. "Regulation" or "regeneration processes" relate to the capacity of ecosystems to regulate essential ecological processes and life support systems. Whereas Daily separates the group "stabilizing processes" from "regeneration processes", the MEA introduces the group "supporting services". In contrast to the others, de Groot *et al.* (2010) include in their system the group "habitat or supporting" services, which are limited to two services (gene pool protection and nursery habitat). Thereby it is stressed that ecosystems provide refuge and reproduction-habitat that support ecological balance and evolutionary processes. Bastian and Schreiber also include "habitat function" but in the terms of social functions, that can be compared with the "cultural services" and "life-fulfilling functions" of the other authors. Although the typologies of these selected classification systems seem to be similar, the allocation of the services is varying, due to the different definitions of ecosystem goods, services, processes and functions and due to the different purposes of the assessments.

3.3 The problem of double counting

According to Wallace (2007), most of the proposed classification systems confuse *ends* with *means*. It should probably be distinguished between the benefit people enjoy and the mechanisms that give rise to that benefit. Assessed against these properties, any classification system containing both ecosystem processes and the outcomes of those processes within the same set will produce redundancy (Wallace, 2008). The fact that different ecosystem functions can deliver similar or equal services may lead to double counting in the assessment of the total value of ecosystems. Particularly, the regulation services are often still included in other services (Hein *et al.*, 2006). For instance, "pollination", which is among others important for the maintenance of fruit production, is already included in the service "production of food". Therefore, Hein *et al.* (2006) propose to include only regulation services if they provide a direct benefit to people living in the area or/and if they have an impact outside the ecosystem of consideration. Costanza *et al.* (1997) suggest establishing a general equilibrium framework that could directly incorporate the interdependence between ecosystems functions and services. Another approach to avoid double counting is distinguishing between final and intermediate goods, when valuating the total value (see Boyd and Banzhaf, 2007). Mäler *et al.* (2008) e.g. reorganized the MEA classification so that provisioning and cultural services are merged into a new category, final services, and the supporting and regulating services are melded into the category intermediary services. The reason for this is that both the cultural and provisioning services are affecting human well-being directly, whereas the two others are doing that only indirectly.

The TEEB project, which is mainly based on the MEA classification, shifted "supporting services" such as nutrient cycling and food-chain dynamics to ecological processes. The "habitat services", instead, has been identified as a separate category to stress the importance of ecosystems to provide habitat for migratory species and gene-pool "protectors" (TEEB, 2010).

3.4 Further developments of classification systems

There exists a wide range of other useful ways to classify ecosystem functions, goods and services, like the suggestions from Costanza (2008) to classify by "spatial characteristics" or by the "excludability/rivalness" status of ecosystem services. The following presented classification systems demonstrate examples how the concept of ecosystem services can be applied to advanced international sustainability impact assessment projects as well as a comprehensive framework for analysing landscape functions in a coherent system.

The Integrated Project SENSOR (Helming *et al.*, 2008) aimed at developing ex ante Sustainability Impact Assessment Tools to support decision making on policies related to multifunctional land use in European regions and abroad. In the course of this project the concept of Land Use Functions (LUFs) (Pérez-Soba *et al.*, 2008), which are defined by the different land uses as the private and public goods and services, was developed. These functions include the most relevant economic, environmental and societal aspects of a region. Each LUF is characterised by a set of key indicators that assess the "impact issues" defined in the EU Impact Assessment Guidelines (European Commission, 2005). Nine LUFs were defined: The societal LUFs include "provision of work", "human health" as well as "recreation and cultural functions". Whereas the economic LUFs encompass "residential and land independent production", "land-based production" and "transport functions", the environmental LUFs cover "provision of abiotic resources", "support and provision of biotic resources" and "maintenance of ecosystem processes".

In comparison to other current classification systems a wide range of functions has been aggregated to three main function groups each again divided into three LUFs. On the on hand such a slim framework demonstrates a comprehensible communication tool to stakeholders, however on the other hand some loss of information has to be accepted. Great emphasis had put on reaching a balance between the main function groups within the assessments. However, this emerged very difficult as the assessments of the functions groups societal, economic and environmental are based on different methods as well as within different spatial scales.

Recently a classification based on the Land Use Function concept has been provided including two main groups, namely the active and passive landscape functions (Konkoly-Gyuró, in press). Whereas the passive functions are divided into “regulating and life sustaining functions” of the natural systems (environmental regulation, habitat protection, biomass generation) and the “potentials” (biomass, row material production and provision of territory for the different land uses and provision of information and aesthetics), the active functions are the services provided by human activities and artificial territories (settlements, infrastructure networks, recreation- and agricultural surfaces etc.). Considering the core idea of this concept, namely focusing on natural as well as human introduced landscape functions, it can be concluded that the benefits derived from non-natural landscapes transformed by human activities have also be taken into account into decision making. This coincides with the recently emerged approach that well-being can be understood as socio-cultural constructions of modernity, which often comply with the economic system (Eckersley, 2005). However, it is questionable if human transformed landscape functions are equally important as functions derived from natural ecosystems.

4 Quantifying and mapping

Dependent on data availability and spatial and temporal scales of assessments, different methods are available for quantifying and mapping landscape functions/ services. For assessments at global level as well as for rapid assessments, landscape functions and services can be determined directly by land cover or ecosystems using general assumptions from literature reviews. These methods are often applied when the economic value of the area is interesting (e.g. Naidoo and Ricketts, 2006; Troy and Wilson, 2006). However, a proper presentation of landscape functions/services would require also additional data beyond land cover observations. For example, the recreational function of a landscape is not only defined by the land cover of a specific location (e.g. natural area) but depends also on accessibility properties (e.g. distance to roads) and characteristics of the surrounding landscape (de Groot *et al.*, 2010). But in many cases this is only achievable at local or at least regional levels, because of data availability.

Kienast *et al.* (2009) present a framework for a spatially explicit landscape functions assessment at European scale, linking land characteristics with a high number of landscape functions. However, the assessments are often primarily based on area measurements and only marginally on measurements of quality (e.g. land use diversity, forest structure).

At regional or local scale a more data-driven method can be used. Function and service data are originated mainly from field observations, including census data, spatial policy documents and biophysical data. Willemen *et al.* (2008) present a methodological framework to quantify landscape functions and to make their spatial variability explicit. They distinguish three different methods depending on the measurable function: (1) linking landscape functions to land cover or spatial policy data, (2) empirical predictions using spatial indicators and (3) decision rules based on literature reviews (Willemen *et al.*, 2008). Whereas for some functions the exact location can be directly observed from the land-cover (e.g. wood for timber production), other functions such as recreation cannot be directly observed or only partially delineated and thus have to be empirically assessed based on landscape indicator analyses. If there does not exist any direct referenced information on the function’s location (e.g. leisure cycling), we have to rely on landscape data based on expert knowledge, literature reviews or process models.

A lot of studies dealt with these challenges aiming at providing spatial datasets to map landscape functions (e.g. Chan *et al.*, 2006; Haines-Young *et al.*, 2006; Gimona and Van der Horst, 2007; Egoh *et al.*, 2008; Meyer and Grabaum, 2008). However, by doing the analysis major problems encountered. Finding appropriate indicators related to the specific service providing unit and exploring how functions and services are correlated with different landscape scenarios are still unresolved questions. To investigate the capacity of landscapes to provide services, landscape complexity and configuration analysis have to be addressed. Aspects such as size, form, and the border length between neighbouring land use types as well as the spatial connectivity of landscape units have to be taken into account. However, current landscape service indicators are still limited by insufficient data and an overall low ability to convey information (Layke, 2009).

Some indicators available are inadequate in characterizing the diversity and complexity of the services provided by landscape functions, especially concerning regulation as well as cultural services, which occur at various spatial scales. Ecosystems are complex, interrelated systems, in which processes take place over a range of spatial and temporal scales (Tansley, 1935) varying from competition between individual plants at plot level, via meso-scale processes such as fire and insect outbreaks, to climatic and geomorphologic processes at largest spatial and temporal scales (Clark *et al.*, 1979; Holling *et al.*, 2002). As service supply is dependent on ecosystem processes and functions, it may occur at different scales. Some services are even relevant at more than one scale. For instance regulation services can occur both at global scale (climate regulation) and plot-scale (biological nitrogen fixation) (de Groot, 1992). Also pressures on ecosystem services can have effects at different scales. In general physical processes on small scales are often driven by the impact on long period phenomena at large scales (climate patterns, hurricanes, fires) (Limburg *et al.*, 2002). However, large scale processes are also strongly influenced by smaller scale occurrences, for example, microbes respire enough CO_2 to keep many lakes and rivers supersaturated (Levin, 1992; del Giorgio *et al.*, 1997). Hence, for the analyses of the dynamics of ecosystem service supply it is very important to consider the drivers and processes at scales relevant for ecosystem service generation.

In addition, relevant to the time frame, ecosystems can act as service provider or suppressor (Martin and Blossey, 2009). For example, wetlands dominated by *Phragmites australis* can act as source and sink for greenhouse gases, depending on time scale (Brix *et al.*, 2001). The species assimilates atmospheric carbon dioxide through photosynthesis and through sequestration of organic matter produced in wetland soils. But it also emits methane into the atmosphere in a two stage process (Beckett *et al.*, 2001). Therefore, before an ecosystem can be seen as a service supplier, a time frame has to be defined for evaluation.

5 Valuation

5.1 The ecological, economic and socio-cultural value of ecosystems

Once the multifunctionality of landscapes and their services are identified, questions arise, like: How can we measure (value) the importance of these services, to get a basis for our decision making? How robust are the estimated values of ecosystem services? To answer these questions we have to address the terms “value” and “valuation”, which have different meanings in different disciplines:

Natural sciences. Most ecologists and other natural scientists would avoid to use the term “value”, except perhaps in its common usage as a reference to the magnitude of a number – e.g. “the value of a parameter” (Farber *et al.*, 2002), because ecosystems are seen to have an “intrinsic value”, which cannot be measured (Callicott, 1989). Nevertheless, some concepts of value are important in the natural sciences, and are commonly used to talk about causal relationships between different parts of a system: For example, referring to particular tree species and their value in controlling soil erosion in a high slope area, or to the value of fires in recycling nutrients in a forest (Farber *et al.*, 2002). Therefore, the ecological importance (value) of ecosystems is determined by ecological criteria such as integrity, resilience and resistance (health). Ecological measures of value encompass parameters such as complexity, diversity and rarity (de Groot *et al.*, 2003). To integrate ecological values into landscape planning sustainable use-levels are often applied. Batabyal *et al.* (2003), for instance, propose to use a scarcity value which is described by ecological thresholds, as a measure for sustainable managing. Their study presents a formal model that explicitly analyses the connections between thresholds and ecosystem management (Batabyal *et al.*, 2003). The application of ecological modelling allows assessing the impact of environmental change and biodiversity loss on combined ecosystem services (Metzger *et al.*, 2006; Egoh *et al.*, 2008; Nelson *et al.*, 2009).

Another approach to valuate the impact of land use change on ecosystem services is the application of reference systems, e.g. the potential natural vegetation (PNV) (Tüxen, 1956). Tüxen emphasized the big value of PNV-maps for different purposes in landscape planning and nature conservation, particularly for forestry, agriculture and landscape management. However, maps of the potential natural vegetation are less useful for purposes of detailed planning on larger scales in cultural landscapes, where the reconstruction of the PNV has only hypothetical character (Zerbe, 1998).

Economy. In the economic context, the total value (TEV) of ecosystem services encompasses use values and non-use values. Use values include direct (consumptive and non- consumptive values) as well as indirect use values. Whereas direct consumptive values refer to ecosystem services like fish, fruits and some cultural services, direct non consumptive services refer for example to enjoyment of scenery or eco-tourism. Indirect use values relate to regulation services like pollination of crops, storm protection or flood prevention. The non-use values consider, for instance the importance people place on protecting nature for future use (option value) or because of ethical principles (bequest, existence and insurance value) (for more details see Pearce, 1991; Torras, 2000; TEEB, 2010).

To provide a common metric in which to express the benefits of diverse ecosystem services, the economic approach usually uses money as a general measurement unit. There exist many ways to translate the economic values into monetary terms. For details on valuation techniques see Dixon and Hufschmidt (1986); Peterson and Sorg (1987); Pearce and Turner (1990); Tietenberg (1992); Pearce and Moran (1994); Heal (2000); Turner *et al.* (2003) and the TEEB report (TEEB, 2010). Chee (2004), for instance, shows the principal methods for the monetary valuation and points out the pro and contra of these methods.

In general, there is a distinction between direct market valuation, indirect market valuation, contingent valuation and group valuation, each with its own associated measurement issues (de Groot *et al.*, 2002; MEA, 2003). Whereas services, which are directly linked to the market, can be easily valued according to their market price, non-market services are often valued using the "willingness to pay" or "willingness to accept" compensation methods encompassing "avoiding cost", "replacement cost", "factor income", "travel cost" and "hedonic pricing" (de Groot *et al.*, 2002). In the last years "contingent valuation" and "group valuation", which are based on an open public deliberation, have also become appreciate techniques for estimating values (Jacobs, 1997; Sagoff, 1998).

All these different methods have gained increasing attention concerning ecosystem service valuation and have become an applicable tool for estimating service values. Following proponents of monetary valuation techniques, these economic methods are able to illustrate the distribution of benefits, improve understanding of problems and trade-offs and can thus facilitate decision making (e.g. Aylward and Barbier, 1992; Salzmann *et al.*, 2001; de Groot, 2006). However, economic valuation of ecosystem services has reached its limits (e.g. Heal, 2000; Farber *et al.*, 2002; Wilson and Howarth, 2002; Chee, 2004; Hein *et al.*, 2006). Although it may encourage management options, decisions makers have to take into account the overall objectives and limitations of economic valuation techniques (see Ludwig, 2000).

Socio-cultural sciences. Besides the ecological and the economical importance of ecosystems, natural and especially cultural landscapes offer a wide range of historical, national, ethical, religious and spiritual benefits, the so called socio-cultural values (MEA, 2003). However, although such cultural services play an essential part in the enhancement of human welfare, they are marginally present in the current research activities (Benayas *et al.*, 2009). This is considered as an increasing problem when the concept of ecosystem services is applied in cultural landscapes with typically long-lasting land use history, dynamic interactions of humans and nature, cultural patterns, and people's identities and values. Therefore, the ecosystem service approach should be expanded by the "cultural landscape paradigm", which includes humans as integral parts of landscapes, whereas other models in the present debate tend to see humans as impartial observers, as external drivers on ecosystems or as beneficiaries of environmental services (Matthews and Selman, 2006). Therefore, landscapes are seen as "social-ecological systems", in which social, economic and environmental components are closely interwoven (Berkes *et al.*, 2003).

While conceptual and methodological developments in monetary valuation have aimed at covering a wide range of values, including intangible ones, it can be stated that socio-cultural values cannot be fully evaluated by economic valuation techniques. A psycho-cultural perspective of valuation would strongly suggest a transdisciplinary dialogue (Rist *et al.*, 2004), aiming at cooperation between natural and social sciences research through debates on environmental ethics, tools and methods of social inquiry and socio-economic development as well as empowerment (Kumar and Kumar, 2008).

Since the last two decades many publications have dealt with different interpretations and implementations of the term "value" in the context of ecosystem services (e.g. Costanza *et al.*, 1997; Bishop, J.T., ed., 1999; Odum and Odum, 2000; Howarth and Farber, 2002; Chee, 2004; Farber *et al.*, 2006; Kumar and Kumar, 2008), which shows the big interest and importance of this topic. Following Costanza (2000) valuation is a basic need of human beings. Any choice and trade-offs between competing alternatives imply valuations, which are simply the relative weights given to the various aspects of decisions. Therefore, valuation ultimately depends on the specific goal or objective of an item (Costanza, 2000). For a long time the main focus has been on the utilitarian approach. However, individual utility maximization has become constrained when sustainability and social equity were also included as goals into the valuation concept (Costanza and Folke, 1997). According to the MEA and also to the TEEB approach the "total value" of an ecosystem and its services has to include three types of value domains, namely the ecological (environmental), economic and socio-cultural value (Toman, 1998; de Groot, 2006). For example, hunting a game gives us food (health) and income but also cultural identity (as a hunter).

A special issue on valuation of ecosystem services, published in the journal Ecological Economics, discusses in detail the background, pro and contra of these three value approaches (de Groot *et al.*, 2002; Farber *et al.*, 2002; Limburg *et al.*, 2002; Wilson and Howarth, 2002). One common problem in the valuation process is that information is often only available for some value domains and often in incompatible units.

5.2 Different valuation methods

Valuation can be conducted in many different ways (Pagiola *et al.*, 2004). The MEA (2005) and TEEB (2010) for instance focus on assessing the value of changes in ecosystem services resulting from management decisions or other human actions. This type of valuation is most likely to be directly policy relevant. The change in value can be assessed by either explicitly estimating the change value or by comparing the current value with the future value resulted by the alternative management regime. At landscape scale the (land use) change value approach proved also very useful to present all the different stakeholder positions, and their linkages, in a rather objective and clear manner to support management discussions. Depending on the goal of the valuation and on data availability, monetary as well as non-monetary valuation approaches are applicable (Gómez-Baggethun *et al.*, 2010). In the further section we introduce some examples of valuation methods, which demonstrate important steps within the ecosystem service approach. As economic valuation has been implemented in many research studies and is also the main focus of the TEEB project, we provide also some important examples based on monetary valuation methods, although we do not place great emphasis on economic valuation within this review.

Economic valuation. Economic valuation has been often applied to assess the total value of services of a particular ecosystem or landscape at a given time (e.g. Adger *et al.*, 1995; Pimentel *et al.*, 1995; Costanza and Folke, 1997; Pimentel *et al.*, 1997; Hein *et al.*, 2006). This total economic value can be seen as an economic indicator, which provide as measure of gross national product or genuine savings policy-relevant information on the state of the economy (MEA, 2003). Costanza *et al.* (1997), for instance, whose publication presented an important milestone in the valuation process, attempted in their study to find the total economic value for a range of different ecosystem services at the global (biospheric) level. The current economic value of 17 ecosystem services for 16 biomes was estimated, based on published studies and a few original calculations. In general, they estimated unit area values for ecosystem services (in \$ ha^{-1} yr^{-1}) and multiplied them by the total area of each biome. This approach has stimulated considerable debate and had not only to accept very sharp criticism from ecologists but also from economists (e.g. Opschoor, 1998; Turner *et al.*, 1998; Bockstael *et al.*, 2000; Xiaoli and Wie, 2009). Some of the core objections to Costanza's model can be summarized as follows (Xiaoli and Wie, 2009): the model did not adequately incorporate several factors which impact on ecosystem services, such as regional differences, spatial heterogeneity and social development. Neither can values estimated at one scale be expanded by a convenient physical index of area, such as hectares, to another scale, nor can two separate value estimates, derived under different contexts, simply be added together (Bockstael *et al.*, 2000). However it has to be stated, that the objective of this world wide study was not to present accurate values, but to show how valuable the natural world is (Pearce, 1998).

Since 1997, many studies were conducted to identify and quantify the value of ecosystem services. Whereas some of them based their results on Costanza *et al.* (1997) estimated values, others tried to modify Costanza's model by including new approaches (e.g. Sutton and Costanza, 2002; Williams *et al.*, 2003; Xiaoli and Wie, 2009).

To visualise that ecosystem services are spatially variable, and to identify key areas to be protected for the purpose of sustainable development, the "spatially explicit measure" represents a welcome method. It provides a mechanism for incorporating spatial context into ecosystem services evaluation (Chen *et al.*, 2009). Explicit value transfer becomes a useful method assessing ecosystems or landscapes, if valuation data is absent or limited (Bateman *et al.*, 2002; Troy and Wilson, 2006; Brenner *et al.*, 2010). Values and other data from the original study site are transferred to the designated policy site (Loomis, 1992). Troy and Wilson (2006), for example, presented in their paper a decision support system framework, which was built upon the value transfer methodology. In each case study a unique typology of land cover, to which ecosystem service estimates were available from the literature, was developed. Standardized ecosystem service value coefficients were broken down by land cover class and service type for each case study. Therefore, scenario and historic change analyses according to ecosystem services could have been conducted. However, this approach also suffers from limitations, such as availability of data, strength of the data and comparability between the source data and policy context (Troy and Wilson, 2006). Whereas some ecosystem services are easily transferable because they are provided at large scales (e.g. the avoided greenhouse gas costs of carbon sequestration), other local scale services may have limited transferability (e.g. flood control values) (Farber *et al.*, 2006).

Recognizing the limitations of value transfer, advanced research has focused more on spatially-explicit ecological and economic models, to explain the effect of human policies on ecosystem services and subsequently on human welfare (Naidoo and Ricketts, 2006; Barbier *et al.*, 2008; Polasky *et al.*, 2008; Nelson *et al.*, 2009). Such models show the spatial heterogeneity of service provision and supply a framework for regulatory analysis in the context of, for example risk assessment, non-point source pollution control, wetlands restoration and avalanche protection (Bockstael *et al.*, 1995). The application of integrated modelling supported by GIS to simulate environmental change scenarios, especially climate change, has become a useful tool to help decision-makers in selecting sustainable and economically feasible development strategies (see Bockstael *et al.*, 1995; Higgins *et al.*, 1997; Boumans *et al.*, 2002; Gret-Regamey *et al.*, 2008; Chen *et al.*, 2009). For example, in the Alpine region a study integrated into a single GIS platform several ecosystem process models simulating the provision of ecosystem services simultaneously with economic valuation procedures, in order to visualize climate change effects (Gret-Regamey *et al.*, 2008). However, modelling is costly of data and measurability requirements and therefore, studies often address relatively small spatial scales, at which it is achievable to develop ecological-economic models. In addition, most models usually focus only on a few ecosystem services and neglect the impact of biodiversity loss on combined ecosystem services. Only some authors tried to integrate the interactions between biodiversity and multiple ecosystem services in their studies (e.g. Metzger *et al.*, 2006; Egoh *et al.*, 2008; Nelson *et al.*, 2009).

The recent TEEB project, mainly based on economic valuation, concentrates on assessing the consequences of changes resulting from alternative management options, rather than for attempting to estimate the total value of ecosystems (TEEB, 2010). Within this project best practice examples from around the world are presented. However, the review of case studies undertaken by TEEB shows that, in many instances, more efficient but less precise methods have been used, hence the results must be interpreted with appropriate care. Especially, in more complex situations involving multiple ecosystems and services, and/or different ethical or cultural convictions, monetary valuations seems to be less reliable or unsuitable. Nevertheless, monetary assessments are important for internalizing so-called externalities in economic accounting procedures and in policies that affect ecosystems, especially where the alternative assumption is that nature has zero (or infinite) value (de Groot, 2006).

Non-economic valuation. Besides the economic valuation, other ways to analyse the importance of ecosystem services including environmental and socio cultural assessments are available. Assessing ecological quality the ecosystem service approach is seen as an applicable tool for supporting an environmental decision making process (Paetzold *et al.*, 2009). A specific Norwegian quality assessment, for example, evaluates current provision of services relative to their provision 100 years ago (Pereira *et al.*, 2005). Paetzold *et al.* (2009) propose to evaluate the status of an ecosystem in terms of its sustainable provision of ecosystem services in relation to the societal expectations. Thereby for each ecosystem service the quality is defined by the ratio of its sustainable provision to the expected level of service delivery. Thus, systems that provide services in a satisfactory and sustainable way can therefore be regarded as being of better quality than those that do not. One major challenge is to select, or develop appropriate indicators that, for example, assess the sustainability aspect of a service or societal expectations (McMichael *et al.*, 2005). In addition, it is difficult to obtain context-specific data on the provision and demand for many services (Chan *et al.*, 2006).

According to Martin and Blossey (2009) an ecosystem service cannot have a discrete value, because it depends on stakeholder preference and changes with quality and time frame. They suggest the following framework considering the quality of ecosystem services, the weighting, and the issue of time scale: $\mathbf{TV} = \int^t x_1 S_1 + y_2 S_2 \ldots + z_n S_n$, where $\mathbf{TV}$ is the total value of a system; S_1, S_2, and S_n are service functions; 1, 2, and n include measures of quality; x, y, and z are the respective weights of the service functions 1, 2, and n; and t is the time frame considered. Habitat quality encompasses, for example, taxonomic diversity, suitability for rare species and historic composition of the site. The weighting of services depends mainly on the background and preferences of decision makers.

In the UK the merits of a "habitat, service and place based perspective" to the assessment of ecosystem services are emphasized (Haines-Young and Potschin, 2008). The habitat perspective is based on the use of a matrix of habitats and their related services. Pressures, respectively impacts on the services are additionally identified to assess state and trends of each service associated with England's ecosystems. Since there is no commonly agreed terminology of pressures it is difficult to make such an assessment consistent. A clear advantage of using habitats as framework for representing the output of ecosystem services is that as distinct ecological units they could be seen in terms of "bundles" of services that they can deliver. It is generally known that most ecosystems are multifunctional, as structures and processes within them are capable of generating a wide range of different services (de Groot, 2006). The quality assessment of each habitat depends on the condition of their services and on the weighting of the service related indicators and their pressures. Although the habitat approach sounds very promising it also has its shortcomings, especially considering the multifunctionality of ecosystems. In most cases the links and interlinks between services might be overlooked. For policy relevance often costs-benefit analyses are conducted, because the exploitation of services usually has both costs and benefits for the society.

A wide range of studies illustrate that multifunctional landscapes are not only ecologically more sustainable and socio-culturally preferable but frequently also economically more beneficial than landscapes that only provide few ecosystem services (Balmford *et al.*, 2002; Turner *et al.*, 2003; Naidoo and Adamowicz, 2005). Therefore, Willemen *et al.* (2010) propose to assess landscape values by referring to the total potential provision of goods and services at multifunctional locations. For each landscape the capacities of all landscape functions are normalized and summed up (see Gómez-Sal *et al.*, 2003; Gimona and Van der Horst, 2007). Finally, a weighted value can be assigned to each landscape.

In the context of environmental assessment land use management decisions are often guided by some kind of transdisciplinary process, such as suggested by the concept 'integrated planning assessment' or more specifically the 'quality of life capital' approach (Potschin and Haines-Young, 2003; Haines-Young and Potschin, 2007). Thereby a "Leitbild" is used to describe what is viable in future, with regard to ecological sustainability and to the service preferences of society. Thus, the "Leitbild" concept can be applied as a reference system for service assessment in a given landscape.

To integrate in landscape planning not only environmental but also socio cultural values, great emphasis has to be placed on the expectations of inhabitants, tourists and the general public (Hunziker *et al.*, 2008). By integrating different social groups into the valuation process both conflicting and compatible views about landscape change may arise. However, these insights are important for steering landscape development in a stakeholder-related sense and for recognising and reducing conflicts of interest (see Backhaus *et al.*, 2007; Soliva *et al.*, 2008). The underlying idea is that an integrated and multi-dimensional approach will be more likely to capture the full range of values, including those which may be context specific (local, regional, national, and global). Schama (1995), for instance, show how landscape perception is over-formed by cultural and national identity.

In general, case studies of socio-cultural assessment methods are lacking (Benayas *et al.*, 2009). Christie *et al.* (2008) give an overview of non-economic techniques for assessing the importance of biodiversity to people in developing countries. Also, Pereira *et al.* (2005) provide some interesting non-monetary assessment methods.

6 Discussion

Although a lot of research effort regarding the investigation of ecosystem services has been done in the last years, it is still an innovative research field. Scientific models, frameworks and concepts for the evaluation of the benefits people derive from ecosystems have been provided. However, implementing the concept of ecosystem services into environmental planning and management at all levels of decision making still remains a big challenge and receives a lot of criticism.

6.1 Definitions and classifications – a challenge

In spite of the work done so far, there is still much discourse about definitions and classifications. According to Wallace (2008) a wide range of ways of evaluating trade-offs and synergies exist, but they need to be based on a coherent set of ecosystem services. However, maybe we should accept that no final classification can capture the myriad of ways in which ecosystems support human life and contribute to well-being. Since linked ecological–economic systems are complex and evolving, a 'fit-for-purpose' approach may be considered in creating clear classifications. Depending on the specific aim of applying a classification system the best suitable typology should be selected. Whereas some classification systems are more simple and thus well suited for educating a broad range of stakeholders (MEA, 2003), others are more complex focusing on the various spatial–temporal aspects of ecosystem services (Fisher *et al.*, 2009). While accepting that no fundamental categories or completely unambiguous definitions exist for such complex ecosystems, and any systematisation is open to debate, it is still important to follow some basic guidelines when developing a 'fit-for-purpose' approach: (1) defining the overall aim/purpose of the assessment as well as the area of interest (2) be aware of the target addresser (3) be clear about the meaning of the core terms used (4) think about which services and their related indicators are important for the final assessment (5) avoid double counting and (6) the final typology should be comprehensible and balanced between different function/service groups.

6.2 Quantifying and mapping – their limitations

Land management decisions usually relate to spatially oriented issues. To receive support for adequate choices, information on the spatial distributions of landscape functions and services is needed. A visualisation of landscape functions should also illustrate the spatial heterogeneity in quality and quantity of services provision, which is due to differences in biophysical and socio-economic conditions at different scale levels (Wiggering *et al.*, 2006; Meyer and Grabaum, 2008). However, although recently a large number of studies have been published dealing with various assessment methods of landscape functions and services (e.g. Kienast *et al.*, 2009; Brenner *et al.*, 2010; Haines-Young *et al.*, 2006; Willemen *et al.*, 2008) information on quantity and quality of spatially explicit services for policy relevant decisions is often lacking (Pinto-Correia *et al.*, 2006; Vejre *et al.*, 2007). The information that does exist remains fragmented, not comparable from one place to another, highly technical and unsuitable for policy makers, or simply unavailable (Schmeller, 2008; Scholes *et al.*, 2008).

Regarding the state-of-the-art, this paper shows, if the ecosystem service concept should be fully integrated into landscape planning issues, a better understanding of the interactions between land cover, use and function and methods to map and quantify land use and landscape function is needed (e.g. Verburg *et al.*, 2009). In some cases the state of ecological knowledge and the data availability allow using some direct measures of services, while in other cases it is necessary to make use of proxies. However, finding the appropriate proxy still remains a challenge (Egoh *et al.*, 2008; Willemen *et al.*, 2008). By searching for appropriate indicators and proxies several issues have to be faced, especially the relationship between services and scales. Synthesizing and visualising different landscape function and services would require a spatial reference framework (Helming *et al.*, 2008), as different function groups usually occur at different scales (for instance, while provisioning functions are often restricted to a local scale, cultural or regulating functions usually operate at a broader scale). As the provision of landscape functions mainly depends both on the quantity and the spatial configuration of the landscape elements, special emphasis have to be put on defining thresholds indicating the change of function delivery when aggregating values within different spatial scales. For instance, a special function assessed on local level, cannot be assessed in the same way at landscape level. Therefore, to extrapolate function assessments to another level, special rules have to be defined. But, most of the existing assessments still tend to provide simply aggregated values for large regions, and thus data availability and disaggregation of spatial data are still one of the major limitations to the mapping of landscape functions and services.

6.3 Multifunctionality

As landscape functions do not equally interact with one another, multifunctional landscapes have different effects on service provision (Willemen *et al.*, 2010). Both negative and positive effects on ecosystem service provision can be observed. Whereas some functions seem to gain by the presence of other functions (e.g. plant habitat to tourism), others are affected negatively by multifunctionality (e.g. tourism to plant habitat). Although some research has already been done on the assessment of landscape function interactions, there are still remaining knowledge gaps (Willemen *et al.*, 2010). To analyse changes and trends in landscape function dynamics and to meet the challenges of trade-off analysis, more information on thresholds and optimum points is needed (Daugstad *et al.*, 2006; Groot *et al.*, 2007). In addition it would be very interesting to assess spatial and temporal scale effects on multifunctional areas (Hein *et al.*, 2006).

6.4 Different disciplines – advantages or hindrances?

Taking all these aspects into account the assessment of the full range of ecosystem values including the ecological, the economic and the socio-cultural, seems to be impossible. According to Norgaard (2010) scientists from different research fields are used to face complex issues within different models and most of which do not fit within a stock-flow meta-framework underlying the concept of ecosystem services. We should also be aware that different disciplines often try to attain different goals, including ecological sustainability, social fairness and the traditional economic goal of efficiency. Additionally, ecological and social phenomena happen on multiple scales and over different time periods that also match with the scalars of different social institutions (Wilson *et al.*, 1999; Folke *et al.*, 2005). However, that the three disciplines economy, ecology and applied social studies have to cooperate and produce new relations will also lead to positive effects. Economists are increasingly aware of the importance to integrate a social point of view into their ecosystem service valuation. Because the distribution of ecosystem services directly affects many people, carefully designed discursive methods, which involve small groups of citizens in the valuation process, will help ensuring the achievement of social fairness (see Farber *et al.*, 2002; Wilson and Howarth, 2002; Chee, 2004; Farber *et al.*, 2006). Whereas in former decades it has been focused on either ecological or economic modelling, in recent years an integrated approach is rising, which allows directly addressing the functional value of ecosystem services by observing long-term, spatial, and dynamic linkages between ecological and economic systems (Eichner and Tschirhart, 2007). By means of cooperation of these three different approaches every part can profit from the others, leading to an integrated ecosystem valuation concept. Economics, for example, could probably better understand the complexity of ecosystems and their effects on human well-being. While, on the other side the dynamics of markets and their information flows such as money and prices as well as the trade-offs among ecosystem services are important to understand sustainable nature conservation. Thus, approaches to trade-off analysis can include multi-criteria (decision) analysis, cost-benefit analysis as well as cost effectiveness analysis. By including socio-cultural knowledge into the valuation concept, the analysis of human behaviour in its environment and human apperception of nature, will also help to enhance human welfare (Bockstael *et al.*, 1995).

Encompassing all three disciplines into the valuation process of ecosystem services could lead to the development of a well-balanced support tool for sustainable management decisions. However, the high number of unresolved issues in quantifying and mapping of ecosystem services as well as the valuation process itself remains still as major hindrances to the implementation of the ecosystem service concept in environmental policy and management.

6.5 Valuation and the future generation

Besides the scientific discourse about the different valuation methods, the question of valuation regarding to future generation will still remain as one of the main challenges. We have to be aware that evaluation of ecosystem services can only be made within the current specific political and economic context. As predictions about future developments are still limited, we just be able to suspect which resources are important for future generations (Norgaard, 2010). Current values of ecosystem services should thus be critically analysed in concordance with global, social and political change indices (Nowotny *et al.*, 2001). Whereas at the local and regional level the ecosystem service concept can act as a decision support tool for stakeholder to reach sustainable land use management, at global scale the valuation of ecosystem services can be seen as an alerting system and could encourage rethinking the global political systems to meet future challenges, like the climate and global change effects.

In conclusion, to meet all these challenges research effort needs to be conducted side by side to understand underlying relationships and to improve ecological as well as socio-economic understanding. Model-based research activities at local scale will take significant steps towards supplying policy makers with dependable and useable results.

As the ecosystem service research community is still very young compared to other research fields it could take some time to overcome the current barriers. However, on-going research studies, initiatives and projects, for instance the TEEB project, which are dealing with the ecosystem service approach raise hope, that the gaps get filled in the future and that the concept of ecosystem services can be integrated in environmental planning and management one time. The ecosystem service approach is an overarching concept that invites scientists from different disciplines to coordinate their research and guides their efforts towards outcomes more suitable for integration. To enhance the integration by coordinating collaborative efforts on ecosystem services at the global, national and local level a communication platform has been launched (`http://www.es-partnership.org`). Several international projects, for instance, the Global Earth Observation Biodiversity Observation Network GEOBON (Scholes *et al.*, 2008) or the World Resources Institute Mainstreaming Ecosystem Services Initiative (`http://www.wri.org/project/mainstreaming-ecosystem-services/tools`) are developing tools and approaches to model, map and value particular ecosystem services based on abiotic, biotic and anthropogenic indicators, as well as knowledge of relationships between these factors.

7 Acknowledgements

This study was supported by the project TransEcoNet (Transnational Ecological Networks), which is implemented through the Central Europe Programme co financed by ERDF. We would also like to thank the project Bioserv (Biodiversity of ecosystem services as scientific foundation for the sustainable implementation of the Redesigned Biosphere Reserve "Neusiedler See") funded by the Austrian Academy of Sciences. Our personal thanks go to Stefan Schindler and Christa Renetzeder for helpful comments and revising the language.

References

Adger, W.N., Brown, K., Cervigni, R. and Moran, D. (1995), "Total economic value of forests in Mexico", *AMBIO*, 24(5): 286–296. (Cited on page 19.)

Antrop, M. (2001), "The language of landscape ecologists and planners: A comparative content analysis of concepts used in landscape ecology", *Landscape and Urban Planning*, 55(3): 163–173, [DOI]. (Cited on page 5.)

Aylward, B. and Barbier, E.B. (1992), "Valuing environmental functions in developing-countries", *Biodiversity and Conservation*, 1(1): 34–50, [DOI]. (Cited on page 17.)

Backhaus, N., Reichler, C. and Stremlow, M. (2007), *Alpenlandschaften – Von der Vorstellung zur Handlung*, Zürich (vdf Hochschulverlag). (Cited on page 21.)

Bakkera, M.M. and Veldkamp, A. (2008), "Modelling land change: the issue of use and cover in wide-scale applications", *Journal of Land Use Science*, 3(4): 203–213, [DOI]. (Cited on page 9.)

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R.E., Jenkins, M., Jefferiss, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rosendo, S., Roughgarden, J., Trumper, K. and Turner, R.K. (2002), "Economic reasons for conserving wild nature", *Science*, 297(5583): 950–953, [DOI]. (Cited on page 21.)

Balmford, A., Rodrigues, A.S.L., Walpole, M., ten Brink, P., Kettunen, M., Braat, L. and de Groot, R.S. (2008), "The Economics of Ecosystems and Biodiversity: Scoping the Science", ENV/070307/2007/486089/ETU/B2, Cambridge, UK (European Commission). (Cited on page 7.)

Barbier, E.B., Koch, E.W., Silliman, B.R., Hacker, S.D., Wolanski, E., Primavera, J., Granek, E.F., Polasky, S., Aswani, S., Cramer, L.A., Stoms, D.M., Kennedy, C.J., Bael, D., Kappel, C.V., Perillo, G.M.E. and Reed, D.J. (2008), "Coastal ecosystem-based management with nonlinear ecological functions and values", *Science*, 319(5861): 321–323, [DOI]. (Cited on page 20.)

Bastian, O. (1991), *Biotische Komponenten in der Landschaftsforschung und -planung. Probleme ihrer Erfassung und Bewertung*, Habilitation, Martin-Luther-Universität, Halle. (Cited on page 13.)

Bastian, O. (1997), "Gedanken zur Bewertung von Landschaftsfunktionen – unter besonderer Berücksichtigung der Habitatfunktion", *NNA-Berichte*, 10(3): 106–125, Schneverdingen (Alfred Toepfer Akademie für Naturschutz (NNA)). (Cited on pages 5 and 13.)

Bastian, O. and Schreiber, K.-F., eds. (1994), *Analyse und ökologische Bewertung der Landschaft*, Jena; Stuttgart (Gustav Fischer). (Cited on page 5.)

Bastian, O. and Schreiber, K.-F., eds. (1999), *Analyse und ökologische Bewertung der Landschaft*, Heidelberg; Berlin (Spektrum), 2nd edn. (Cited on pages 5, 9, 10, 11, and 13.)

Batabyal, A.A., Kahn, J.R. and O'Neill, R.V. (2003), "On the scarcity value of ecosystem services", *Journal of Environmental Economics and Management*, 46(2): 334–352, [DOI]. (Cited on page 17.)

Bateman, I.J., Jones, A.P., Lovett, A.A., Lake, I.R. and Day, B.H. (2002), "Applying Geographical Information Systems (GIS) to Environmental and Resource Economics", *Environmental and Resource Economics*, 22(1-2): 219–269, [DOI]. (Cited on page 19.)

Beckett, P.M., Armstrong, W. and Armstrong, J. (2001), "Mathematical modeling of methane transport by Phragmites: the potential for diffusion within the roots and rhizosphere", *Aquatic Botany*, 69(2-4): 293–312, [DOI]. (Cited on page 16.)

Benayas, J.M.R., Newton, A.C., Diaz, A. and Bullock, J.M. (2009), "Enhancement of Biodiversity and Ecosystem Services by Ecological Restoration: A Meta-Analysis", *Science*, 325(5944): 1121–1124, [DOI]. (Cited on pages 18 and 21.)

Berkes, F., Colding, J. and Folke, C., eds. (2003), *Navigating Social–Ecological Systems: Building Resilience for Complexity and Change*, Cambridge; New York (Cambridge University Press). Google Books. (Cited on page 18.)

Bishop, J.T., ed. (1999), "Valuing Forests: A Review of Methods and Application in Developing Countries", London (International Institute for Environment and Development). Online version (accessed 28 February 2011):
http://www.elaw.org/node/2437. (Cited on page 18.)

Bockstael, N., Costanza, R., Strand, I., Boynton, W., Bell, K. and Wainger, L. (1995), "Ecological economic modeling and valuation of ecosystems", *Ecological Economics*, 14(2): 143–159, [DOI]. (Cited on pages 20 and 24.)

Bockstael, N.E., Freeman, A.M., Kopp, R.J., Portney, P.R. and Smith, V.K. (2000), "On measuring economic values for nature", *Environmental Science & Technology*, 34(8): 1384–1389, [DOI]. (Cited on page 19.)

Bormann, F.H. and Likens, G.E. (1979), "Catastrophic disturbance and the steady-state in northern hardwood forests", *American Scientist*, 67(6): 660–669. (Cited on page 5.)

Boumans, R., Costanza, R., Farley, J., Wilson, M.A., Portela, R., Rotmans, J., Villa, F. and Grasso, M. (2002), "Modeling the dynamics of the integrated earth system and the value of global ecosystem services using the GUMBO model", *Ecological Economics*, 41(3): 529–560, [DOI]. (Cited on page 20.)

Boyd, J. and Banzhaf, S. (2007), "What are ecosystem services? The need for standardized environmental accounting units", *Ecological Economics*, 63(2–3): 616–626, [DOI]. (Cited on pages 7, 8, 9, 10, 13, and 14.)

Brenner, J., Jimenez, J.A., Sarda, R. and Garola, A. (2010), "An assessment of the non-market value of the ecosystem services provided by the Catalan coastal zone, Spain", *Ocean & Coastal Management*, 53(1): 27–38, [DOI]. (Cited on pages 19 and 22.)

Brix, H., Sorrell, B.K. and Lorenzen, B. (2001), "Are Phragmites-dominated wetlands a net source or net sink of greenhouse gases?", *Aquatic Botany*, 69(2–4): 313–324, [DOI]. (Cited on page 16.)

Buchwald, K. and Engelhardt, W., eds. (1968), *Handbuch für Landschaftspflege und Naturschutz, Bd. 4: Planung und Ausführung*, München; Basel; Wien (Bayerischer Landwirtschaftsverlag). (Cited on page 5.)

Callicott, J.B. (1989), *In Defense of the Land Ethic: Essays in Environmental Philosophy*, Albany, NY (State University of New York Press). (Cited on page 16.)

Carlisle, S., Henderson, G. and Hanlon, P.W. (2009), "'Wellbeing': A collateral casualty of modernity?", *Social Science & Medicine*, 69(10): 1556–1560, [DOI]. (Cited on page 9.)

Chan, K.M.A., Shaw, M.R., Cameron, D.R., Underwood, E.C. and Daily, G.C. (2006), "Conservation planning for ecosystem services", *PLoS Biology*, 4(11): 2138–2152, [DOI]. URL (accessed 10 March 2011):
http://dx.doi.org/10.1371/journal.pbio.0040379. (Cited on pages 15 and 20.)

Chee, Y.E. (2004), "An ecological perspective on the valuation of ecosystem services", *Biological Conservation*, 120(4): 549–565, [DOI]. (Cited on pages 17, 18, and 23.)

Chen, N.W., Li, H.C. and Wang, L.H. (2009), "A GIS-based approach for mapping direct use value of ecosystem services at a county scale: Management implications", *Ecological Economics*, 68 (11): 2768–2776, [DOI]. (Cited on pages 19 and 20.)

Christie, M., Cooper, R., Hyde, T., Fazey, I., Deri, A., Hughes, L., Bush, G., Brander, L., Nahman, A., de Lange, W. and Reyers, B. (2008), "An Evaluation of Economic and Non-Economic Techniques for Assessing the Importance of Biodiversity to People in Developing Countries", London (Department for Environment, Food and Rural Affairs (DEFRA)). Online version (accessed 28 February 2011):
http://www.defra.gov.uk/evidence/science/funding/scienceprojects/2008/09.htm. (Cited on page 21.)

Clark, W.C., Jones, D.D. and Holling, C.S. (1979), "Lessons for ecological policy design: A case-study of ecosystem management", *Ecological Modelling*, 7(1): 1–53, [DOI]. (Cited on page 16.)

Costanza, R. (2000), "Social goals and the valuation of ecosystem services", *Ecosystems*, 3(1): 4–10, [DOI]. (Cited on page 18.)

Costanza, R. (2008), "Ecosystem services: Multiple classification systems are needed", *Biological Conservation*, 141(2): 350–352, [DOI]. (Cited on pages 10 and 14.)

Costanza, R. and Folke, C. (1997), "Valuing Ecosystem Services with Efficiency, Fairness, and Sustainability as Goals", in Daily, G.C., ed., *Nature's Services: Societal Dependence on Natural Ecosystems*, pp. 49–70, Washington DC (Island Press). (Cited on pages 7, 18, and 19.)

Costanza, R., d'Arge, R., de Groot, R.S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P. and van den Belt, M. (1997), "The value of the world's ecosystem services and natural capital", *Nature*, 387(6630): 253–260, [DOI]. (Cited on pages 5, 7, 9, 10, 11, 12, 13, 14, 18, and 19.)

Daily, G.C., ed. (1997), *Nature's Services: Societal Dependence on Natural Ecosystems*, Washington DC (Island Press). (Cited on pages 5, 7, 10, and 13.)

Daily, G.C. (1999), "Developing a scientific basis for managing Earth's life support systems", *Conservation Ecology*, 3(2): 14. URL (accessed 10 March 2011):
http://www.consecol.org/vol3/iss2/art14/. (Cited on pages 7, 10, 11, 12, and 13.)

Daugstad, K., Ronningen, K. and Skar, B. (2006), "Agriculture as an upholder of cultural heritage? Conceptualizations and value judgements – A Norwegian perspective in international context", *Journal of Rural Studies*, 22(1): 67–81, [DOI]. (Cited on page 23.)

de Groot, R.S. (1987), "Environmental Functions as a Unifying Concept for Ecology and Economics", *Environmentalist*, 7(2): 105–109, [DOI]. (Cited on page 5.)

de Groot, R.S. (1992), *Functions of Nature: Evaluation of nature in environmental planning, management and decision making*, Groningen (Wolters-Noordhoff BV). (Cited on pages 7, 13, and 16.)

de Groot, R.S. (2006), "Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes", *Landscape and Urban Planning*, 75(3-4): 175–186, [DOI]. (Cited on pages 5, 6, 7, 10, 12, 13, 17, 18, 20, and 21.)

de Groot, R.S., Wilson, M.A. and Boumans, R.M.J. (2002), "A typology for the classification, description and valuation of ecosystem functions, goods and services", *Ecological Economics*, 41 (3): 393–408, [DOI]. (Cited on pages 5, 10, 12, 17, and 18.)

de Groot, R.S., Van der Perk, J., Chiesura, A. and van Vliet, A. (2003), "Importance and threat as determining factors for criticality of natural capital", *Ecological Economics*, 44(2-3): 187–204, [DOI]. (Cited on page 17.)

de Groot, R.S., Alkemade, R., Braat, L., Hein, L. and Willemen, L. (2010), "Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making", *Ecological Complexity*, 7(3): 260–272, [DOI]. (Cited on pages 5, 7, 9, 10, 11, 13, and 15.)

Dee, N., Baker, J., Drobny, N., Duke, K., Whitman, I. and Fahringer, D. (1973), "An environmental evaluation system for water resource planning", *Water Resources Research*, 9: 523–535, [DOI]. (Cited on page 5.)

del Giorgio, P.A., Cole, J.J. and Cimbleris, A. (1997), "Respiration rates in bacteria exceed phytoplankton production in unproductive aquatic systems", *Nature*, 385(6612): 148–151, [DOI]. (Cited on page 16.)

Dixon, J.A. and Hufschmidt, M.M., eds. (1986), *Economic Valuation Techniques for the Environment: A Case Study Workbook*, Baltimore (John Hopkins University Press). (Cited on page 17.)

Eckersley, R. (2005), *Well & Good: Morality, Meaning and Happiness*, Melbourne (Text Publishing), 2nd edn. Online version (accessed 28 February 2011):
`http://www.richardeckersley.com.au/main/page_books_books_page_1.html`. (Cited on pages 9 and 15.)

Egoh, B., Reyers, B., Rouget, M., Richardson, D.M., Le Maitre, D.C. and van Jaarsveld, A.S. (2008), "Mapping ecosystem services for planning and management", *Agriculture, Ecosystems & Environment*, 127(1-2): 135–140, [DOI]. (Cited on pages 15, 17, 20, and 22.)

Ehrlich, P.R. and Ehrlich, A.H. (1970), *Population, Resources, Environment: Issues in Human Ecology*, San Francisco (W.H. Freeman), 2nd edn. (Cited on page 5.)

Ehrlich, P.R. and Ehrlich, A.H. (1981), *Extinction: The Causes and Consequences of the Disappearance of Species*, New York (Random House). (Cited on page 5.)

Ehrlich, P.R., Ehrlich, A.H. and Holdren, J.P. (1977), *Ecoscience: Population, Resources, Environment*, San Francisco (W.H. Freeman). (Cited on page 5.)

Eichner, T. and Tschirhart, J. (2007), "Efficient ecosystems services and naturalness in an ecological/economic model", *Environmental and Resource Economics*, 37(4): 733–755, [DOI]. (Cited on pages 7 and 23.)

European Commission (2005), "Commission Impact Assessment Guidelines", Bruxelles (European Commission). URL (accessed 28 February 2011):
`http://ec.europa.eu/governance/impact/commission_guidelines/commission_guidelines_en.htm`. (Cited on page 14.)

Farber, S., Costanza, R., Childers, D.L., Erickson, J., Gross, K., Grove, M., Hopkinson, C.S., Kahn, J., Pincetl, S., Troy, A., Warren, P. and Wilson, M. (2006), "Linking ecology and economics for ecosystem management", *BioScience*, 56(2): 121–133, [DOI]. (Cited on pages 7, 18, 19, and 23.)

Farber, S.C., Costanza, R. and Wilson, M.A. (2002), "Economic and ecological concepts for valuing ecosystem services", *Ecological Economics*, 41(3): 375–392, [DOI]. (Cited on pages 16, 17, 18, and 23.)

Fisher, B. and Turner, R.K. (2008), "Ecosystem services: Classification for valuation", *Biological Conservation*, 141(5): 1167–1169, [DOI]. (Cited on pages 9, 10, and 13.)

Fisher, B., Turner, R.K. and Morling, P. (2009), "Defining and classifying ecosystem services for decision making", *Ecological Economics*, 68(3): 643–653, [DOI]. (Cited on pages 5, 7, 8, 9, and 22.)

Folke, C., Hahn, T., Olsson, P. and Norberg, J. (2005), "Adaptive governance of social-ecological systems", *Annual Review of Environment and Resources*, 30: 441–473, [DOI]. (Cited on page 23.)

Gimona, A. and Van der Horst, D. (2007), "Mapping hotspots of multiple landscape functions: a case study on farmland afforestation in Scotland", *Landscape Ecology*, 22(8): 1255–1264, [DOI]. (Cited on pages 15 and 21.)

Gómez-Baggethun, E., de Groot, R.S., Lomas, P.L. and Montes, C. (2010), "The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes", *Ecological Economics*, 69(6): 1209–1218, [DOI]. (Cited on pages 6 and 19.)

Gómez-Sal, A., Belmontes, J.A. and Nicolau, J.M. (2003), "Assessing landscape values: a proposal for a multidimensional conceptual model", *Ecological Modelling*, 168(3): 319–341, [DOI]. (Cited on page 21.)

Gret-Regamey, A., Bebi, P., Bishop, I.D. and Schmid, W.A. (2008), "Linking GIS-based models to value ecosystem services in an Alpine region", *Journal of Environmental Management*, 89(3): 197–208, [DOI]. (Cited on page 20.)

Groot, J.C.J., Rossing, W.A.H., Jellema, A., Stobbelaar, D.J., Renting, H. and Van Ittersum, M.K. (2007), "Exploring multi-scale trade-offs between nature conservation, agricultural profits and landscape quality – A methodology to support discussions on land-use perspectives", *Agriculture, Ecosystems & Environment*, 120(1): 58–69, [DOI]. (Cited on page 23.)

Haber, W. (1979), "Theoretische Anmerkungen zur 'ökologischen Planung"', in Schreiber, K.-F., ed., *Verhandlungen der Gesellschaft für Ökologie*, 8. Jahrestagung, Münster, August 1978, VII, pp. 19–30, Göttingen (Goltze). (Cited on page 5.)

Haines-Young, R. and Potschin, M. (2007), "The Ecosystem Concept and the Identification of Ecosystem Goods and Services in the English Policy Context. Review Paper to Defra, Project Code NR0107", pp. 1–21, London (Department for Environment, Food and Rural Affairs (DEFRA)). Online version (accessed 28 February 2011): http://www.ecosystemservices.org.uk/reports.htm. (Cited on page 21.)

Haines-Young, R. and Potschin, M. (2008), "England's Terrestrial Ecosystem Services and the Rationale for an Ecosystem Approach. Full Technical Report, Defra Project Code NR0107", pp. 1–89, London (Department for Environment, Food and Rural Affairs (DEFRA)). Online version (accessed 28 February 2011): http://www.ecosystemservices.org.uk/reports.htm. (Cited on page 21.)

Haines-Young, R. and Potschin, M. (2010), "The links between biodiversity, ecosystem service and human well-being", in Raffaelli, D.G. and Frid, C.L.J., eds., *Ecosystem Ecology: A New Synthesis*, Ecological Reviews, pp. 110–139, Cambridge; New York (Cambridge University Press). (Cited on pages 9 and 10.)

Haines-Young, R., Watkins, C., Wale, C. and Murdock, A. (2006), "Modelling natural capital: The case of landscape restoration on the South Downs, England", *Landscape and Urban Planning*, 75(3-4): 244–264, [DOI]. (Cited on pages 15 and 22.)

Heal, G. (2000), "Valuing ecosystem services", *Ecosystems*, 3(1): 24–30, [DOI]. (Cited on pages 5 and 17.)

Hein, L., van Koppen, K., de Groot, R.S. and van Ierland, E.C. (2006), "Spatial scales, stakeholders and the valuation of ecosystem services", *Ecological Economics*, 57(2): 209–228, [DOI]. (Cited on pages 5, 14, 17, 19, and 23.)

Helliwell, D.R. (1969), "Valuation of wildlife resources", *Regional Studies*, 3(1): 41–47, [DOI]. (Cited on page 5.)

Helming, K., Pérez-Soba, M. and Tabbush, P., eds. (2008), *Sustainability Impact Assessment of Land Use Changes*, Berlin; New York (Springer). Google Books. (Cited on pages 14 and 23.)

Higgins, S.I., Turpie, J.K., Costanza, R., Cowling, R.M., LeMaitre, D.C., Marais, C. and Midgley, G.F. (1997), "An ecological economic simulation model of mountain fynbos ecosystems: Dynamics, valuation and management", *Ecological Economics*, 22(2): 155–169, [DOI]. (Cited on page 20.)

Holling, C.S., Gunderson, L.H. and Peterson, G.D. (2002), "Sustainability and Panarchies", in Gunderson, L.H. and Holling, C.S., eds., *Panarchy, Understanding Transformations in Human and Natural Systems*, pp. 63–102, Washington; London (Island Press). (Cited on page 16.)

Howarth, R.B. and Farber, S. (2002), "Accounting for the value of ecosystem services", *Ecological Economics*, 41(3): 421–429, [DOI]. (Cited on page 18.)

Hunziker, M., Felber, P., Gehring, K., Buchecker, M., Bauer, N. and Kienast, F. (2008), "Evaluation of Landscape Change by Different Social Groups: Results of Two Empirical Studies in Switzerland", *Mountain Research and Development*, 28(2): 140–147, [DOI]. (Cited on page 21.)

Jacobs, M. (1997), "Environmental Valuation, Deliberate Democracy and Public Decision-Making Institutions", in Foster, J., ed., *Valuing Nature?: Economics, Ethics and Environment*, pp. 211–231, London; New York (Routledge). (Cited on page 17.)

Jax, K. (2005), "Function and 'functioning' in ecology: what does it mean?", *Oikos*, 111(3): 641–648, [DOI]. (Cited on page 7.)

Jones, K.B., Krauze, K., Müller, F., Zurlini, G., Petrosillo, I., Victorov, S. and Li, B.-L. (2008), "Landscape approaches to assess environmental security: summary, conclusions, and recommendations", in Petrosillo, I., Müller, F., Jones, K.B., Zurlini, G., Krauze, K., Victorov, S., Li, B.-L. and Kepner, W.G., eds., *Use of Landscape Sciences for the Assessment of Environmental Security*, NATO Science for Peace and Security Series - C: Environmental Security, pp. 475–486, Dordrecht (Springer). Google Books. (Cited on page 5.)

Kienast, F., Bolliger, J., Potschin, M., de Groot, R.S., Verburg, P.H., Heller, I., Wascher, D. and Haines-Young, R. (2009), "Assessing Landscape Functions with Broad-Scale Environmental Data: Insights Gained from a Prototype Development for Europe", *Environmental Management*, 44(6): 1099–1120, [DOI]. (Cited on pages 15 and 22.)

King, R.T. (1966), "Wildlife and man", *New York Conservationist*, 20(6): 8–11. (Cited on page 5.)

Konkoly-Gyuró, É. (in press), "A tájfunkció elemzés koncepciójának kibontakozása. (Evolution of the concept of the landscape function analysis)", in *Proceedings of the MTA TAKI Workshop on Ecosystem Services*, Budapest, 24 November 2009, Budapest (Corvinus University). Online version (accessed 28 February 2011):
http://www.mta-taki.hu/hu/node/385. (Cited on pages 5 and 15.)

Kremen, C. (2005), "Managing ecosystem services: what do we need to know about their ecology?", *Ecology Letters*, 8(5): 468–479, [DOI]. (Cited on page 7.)

Kumar, M. and Kumar, P. (2008), "Valuation of the ecosystem services: A psycho-cultural perspective", *Ecological Economics*, 64(4): 808–819, [DOI]. (Cited on page 18.)

Layke, C. (2009), "Measuring Nature's Benefits: A Preliminary Roadmap for Improving Ecosystem Service Indicators", Washington DC (World Resources Institute). URL (accessed 28 February 2011):
http://www.wri.org/publication/measuring-natures-benefits. (Cited on page 16.)

Lee, J.T., Elton, M.J. and Thompson, S. (1999), "The role of GIS in landscape assessment: using land-use-based criteria for an area of the Chiltern Hills Area of Outstanding Natural Beauty", *Land Use Policy*, 16(1): 23–32, [DOI]. (Cited on page 5.)

Leibowitz, S.G., Loehle, C., Li, B.L. and Preston, E.M. (2000), "Modeling landscape functions and effects: a network approach", *Ecological Modelling*, 132(1-2): 77–94, [DOI]. (Cited on page 5.)

Levin, S.A. (1992), "The Problem of Pattern and Scale in Ecology", *Ecology*, 73(6): 1943–1967, [DOI]. (Cited on page 16.)

Limburg, K.E., O'Neill, R.V., Costanza, R. and Farber, S. (2002), "Complex systems and valuation", *Ecological Economics*, 41(3): 409–420, [DOI]. (Cited on pages 16 and 18.)

Linehan, J.R. and Gross, M. (1998), "Back to the future, back to basics: the social ecology of landscapes and the future of landscape planning", *Landscape and Urban Planning*, 42(2-4): 207–223, [DOI]. (Cited on page 5.)

Loomis, J.B. (1992), "The evolution of a more rigorous approach to benefit transfer: Benefit function transfer", *Water Resources Research*, 28(3): 701–705, [DOI]. (Cited on page 19.)

Ludwig, D. (2000), "Limitations of economic valuation of ecosystems", *Ecosystems*, 3(1): 31–35, [DOI]. (Cited on page 17.)

Lyons, K.G., Brigham, C.A., Traut, B.H. and Schwartz, M.W. (2005), "Rare species and ecosystem functioning", *Conservation Biology*, 19(4): 1019–1024, [DOI]. (Cited on page 7.)

Mäler, K.G., Aniyar, S. and Jansson, A. (2008), "Accounting for ecosystem services as a way to understand the requirements for sustainable development", *Proceedings of the National Academy of Sciences of the USA*, 105(28): 9501–9506, [DOI]. (Cited on page 14.)

Martin, L.J. and Blossey, B. (2009), "A Framework for Ecosystem Services Valuation", *Conservation Biology*, 23(2): 494–496, [DOI]. (Cited on pages 16 and 20.)

Matthews, R. and Selman, P. (2006), "Landscape as a focus for integrating human and environmental processes", *Journal of Agricultural Economics*, 57(2): 199–212, [DOI]. (Cited on page 18.)

McMichael, A.J., Scholes, R., Hefny, M., Pereira, H.M., Palm, C. and Foale, S. (2005), "Linking Ecosystem Services and Human Well-being", in Capistrano, D., Samper K, C., Lee, M.J. and Raudsepp-Hearne, C., eds., *Ecosystems and Human Well-being: Multiscale Assessment*, Millennium Ecosystem Assessment Series, 4, pp. 43–60, Washington, DC (Island Press). Google Books. (Cited on page 20.)

MEA (2003), *Ecosystems and Human Well-being: A Framework for Assessment*, Millennium Ecosystem Assessment Series, Washington, DC (Island Press). Google Books. (Cited on pages 5, 7, 9, 10, 11, 13, 17, 18, 19, and 22.)

MEA (2005), *Ecosystems and Human Well-being: Multiscale Assessment*, Millennium Ecosystem Assessment Series, 4, Washington, DC (Island Press). Google Books. (Cited on pages 5, 9, 10, 12, 13, and 18.)

Metzger, M.J., Rounsevell, M.D.A., Acosta-Michlik, L., Leemans, R. and Schrotere, D. (2006), "The vulnerability of ecosystem services to land use change", *Agriculture, Ecosystems & Environment*, 114(1): 69–85, [DOI]. (Cited on pages 17 and 20.)

Meyer, B.C. and Grabaum, R. (2008), "MULBO: Model framework for multicriteria landscape assessment and optimisation. A support system for spatial land use decisions", *Landscape Research*, 33(2): 155–179, [DOI]. (Cited on pages 5, 15, and 22.)

Naidoo, R. and Adamowicz, W.L. (2005), "Economic benefits of biodiversity exceed costs of conservation at an African rainforest reserve", *Proceedings of the National Academy of Sciences of the USA*, 102(46): 16 712–16 716, [DOI]. (Cited on page 21.)

Naidoo, R. and Ricketts, T.H. (2006), "Mapping the economic costs and benefits of conservation", *PLoS Biology*, 4(11): 2153–2164, [DOI]. URL (accessed 10 March 2011): `http://dx.doi.org/10.1371/journal.pbio.0040360`. (Cited on pages 15 and 20.)

Neef, E. (1966), "Zur Frage des gebietswirtschaftlichen Potentials", *Forschungen und Fortschritte*, 40: 65–79. (Cited on page 5.)

Nelson, E., Monoza, G., Regetz, J., Polasky, S., Tallis, J., Cameron, D.R., Chan, K.M.A., Daily, G.C., Goldstein, J., Kareiva, P.M., Lonsdorf, E., Naidoo, R., Ricketts, T.H. and Shaw, M.R. (2009), "Modelling muliple ecosystem services, biodiveristy conservation, commodity production, and tradeoffs at landscape scale", *Frontiers in Ecology and the Environment*, 7(1): 4–11, [DOI]. (Cited on pages 17 and 20.)

Niemann, E. (1982), *Methodik zur Bestimmung der Eignung, Leistung und Belastbarkeit von Landschaftselementen und Landschaftseinheiten*, Wissenschaftliche Mitteilungen, Sonderheft 2, Leipzig (Institut für Geographie und Geoökologie der Akademie der Wissenschaften der DDR). (Cited on page 5.)

Norgaard, R.B. (2010), "Ecosystem services: From eye-opening metaphor to complexity blinder", *Ecological Economics*, 69(6): 1219–1227, [DOI]. (Cited on pages 23 and 24.)

Nowotny, H., Scott, P. and Gibbons, M. (2001), *Re-Thinking Science: Knowledge and the Public in an Age of Uncertainty*, Cambride (Polity Press). Google Books. (Cited on page 24.)

Odum, H.T. and Odum, E.P. (2000), "The energetic basis for valuation of ecosystem services", *Ecosystems*, 3(1): 21–23, [DOI]. (Cited on page 18.)

Opschoor, J.B. (1998), "The value of ecosystem services: whose values?", *Ecological Economics*, 25(1): 41–43, [DOI]. (Cited on page 19.)

Paetzold, A., Warren, P.H. and Maltby, L.L. (2009), "A framework for assessing ecological quality based on ecosystem services", *Ecological Complexity*, 7(3): 273–281, [DOI]. (Cited on page 20.)

Pagiola, S., von Ritter, K. and Bishop, J. (2004), "Assessing the Economic Value of Ecosystem Conservation", *Environment Department Paper*, 101, 30887, Washington DC (The World Bank). URL (accessed 28 February 2011):
http://go.worldbank.org/0S5TI6YE30. (Cited on page 18.)

Palmer, J.F. (2004), "Using spatial metrics to predict scenic perception in a changing landscape: Dennis, Massachusetts", *Landscape and Urban Planning*, 69(2-3): 201–218, [DOI]. (Cited on page 5.)

Pearce, D. (1998), "Auditing the Earth: The Value of the World's Ecosystem Services and Natural Capital", *Environment*, 40(2): 23–28, [DOI]. (Cited on page 19.)

Pearce, D.W. (1991), "An economic approach to saving the tropical forests", in Helm, D., ed., *Economic Policy Towards the Environment*, pp. 239–262, Oxford (Blackwell). (Cited on page 17.)

Pearce, D.W. and Moran, D. (1994), *The Economic Value of Biodiversity in Association with the Biodiversity Programme of IUCN*, London (Earthscan Publications). (Cited on pages 6 and 17.)

Pearce, D.W. and Turner, R.K. (1990), *Economics of Natural Resources and the Environment*, Baltimore (Johns Hopkins University Press). (Cited on page 17.)

Pereira, H.M., Reyers, B., Watanabe, M., Bohensky, E., Foale, S., Palm, C., Espaldon, M.V., Armenteras, D., Tapia, M., Rincón, A., Lee, M.J., Patwardhan, A. and Gomes, I. (2005), "Condition and Trends of Ecosystem Services and Biodiversity", in Capistrano, D., Samper K, C., Lee, M.J. and Raudsepp-Hearne, C., eds., *Ecosystems and Human Well-being: Multiscale Assessment*, Millennium Ecosystem Assessment Series, 4, pp. 171–203, Washington, DC (Island Press). Google Books. (Cited on pages 20 and 21.)

Pérez-Soba, M., Petit, S., Jones, L., Betrand, N., Briquel, V., Omodei-Zorini, L., Contini, C., Helming, K., Farrington, J.H., Mosselo, M.T., Wascher, D., Kienast, F. and de Groot, R.S. (2008), "Land use functions – a multifunctionality approach to assess the impact of land use change on land use sustainability", in Helming, K., Pérez-Soba, M. and Tabbush, P., eds., *Sustainability Impact Assessment of Land Use Changes*, pp. 375–404, Berlin; New York (Springer). (Cited on pages 9 and 14.)

Peterson, G.L. and Sorg, C.F. (1987), "Toward the measurement of total economic value", *General technical report RM*, 148: 1–44, US8918310, Fort Collins, CO (USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado). (Cited on pages 6 and 17.)

Pimentel, D., Harvey, C., Resosudarmo, P., Sinclair, K., Kurz, D., McNair, M., Crist, S., Shpritz, L., Fitton, L., Saffouri, R. and Blair, R. (1995), "Environmental and Economic Costs of Soil Erosion and Conservation Benefits", *Science*, 267(5201): 1117–1123, [DOI]. (Cited on page 19.)

Pimentel, D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., Tran, Q., Saltman, T. and Cliff, B. (1997), "Economic and environmental benefits of biodiversity", *BioScience*, 47(11): 747–757, [DOI]. (Cited on page 19.)

Pinto-Correia, T., Gustavsson, R. and Pirnat, J. (2006), "Bridging the gap between centrally defined policies and local decisions – Towards more sensitive and creative rural landscape management", *Landscape Ecology*, 21(3): 333–346, [DOI]. (Cited on page 22.)

Polasky, S., Nelson, E., Camm, J., Csuti, B., Fackler, P., Lonsdorf, E., Montgomery, C., White, D., Arthur, J., Garber-Yonts, B., Haight, R., Kagan, J., Starfield, A. and Tobalske, C. (2008), "Where to put things? Spatial land management to sustain biodiversity and economic returns", *Biological Conservation*, 141(6): 1505–1524, [DOI]. (Cited on page 20.)

Potschin, M.B. and Haines-Young, R.H. (2003), "Improving the quality of environmental assessments using the concept of natural capital: a case study from southern Germany", *Landscape and Urban Planning*, 63(2): 93–108, [DOI]. (Cited on page 21.)

Rist, S., Zimmermann, A. and Wiesmann, U. (2004), "From epistemic monoculture to cooperation between espistemic communities – lessons learnt from development research", Paper presented at the conference 'Bridging Scales and Epistemologies: Linking Local Knowledge and Global Science in Multi-Scale Assessments', held in Alexandria, Egypt, April, 17 – 20 March, 2004, conference paper. (Cited on page 18.)

Rounsevell, M.D.A., Dawson, T.P. and Harrison, P.A. (2010), "A conceptual framework to assess the effects of environmental change on ecosystem services", *Biodiversity and Conservation*, 19 (10): 2823–2842, [DOI]. (Cited on page 5.)

Sagoff, M. (1998), "Aggregation and deliberation in valuing environmental public goods: A look beyond contingent pricing", *Ecological Economics*, 24(2-3): 213–230, [DOI]. (Cited on page 17.)

Salzmann, J., Thompson Jr, B.H. and Daily, G.C. (2001), "Protecting Ecosystem Services: Science, Economics and Law", *Stanford Environmental Law Journal*, 20: 309. (Cited on page 17.)

Schama, S. (1995), *Landscape and Memory*, London (Harper Collins). (Cited on page 21.)

Schmeller, D. (2008), "European species and habitat monitoring: where are we now?", *Biodiversity and Conservation*, 17(14): 3321–3326, [DOI]. (Cited on page 22.)

Scholes, R.J., Mace, G.M., Turner, W., Geller, G.N., Jürgens, N., Larigauderie, A., Muchoney, D., Walther, B.A. and Mooney, H.A. (2008), "Toward a Global Biodiversity Observing System", *Science*, 321(5892): 1044–1045, [DOI]. (Cited on pages 22 and 24.)

Soliva, R., Ronningen, K., Bella, I., Bezak, P., Cooper, T., Flo, B.E., Marty, P. and Potter, C. (2008), "Envisioning upland futures: Stakeholder responses to scenarios for Europe's mountain landscapes", *Journal of Rural Studies*, 24(1): 56–71, [DOI]. (Cited on page 21.)

Steinhardt, U. and Volk, M. (2003), "Mesoscale landscape analysis on the base of investigations of water balance and water-bound material fluxes: problems and hierarchical approaches for their resolution", *Ecological Modelling*, 168: 251–265, [DOI]. (Cited on page 5.)

Sutton, P.C. and Costanza, R. (2002), "Global estimates of market and non-market values derived from nighttime satellite imagery, land cover, and ecosystem service valuation", *Ecological Economics*, 41(3): 509–527, [DOI]. (Cited on page 19.)

Tansley, A.G. (1935), "The use and abuse of vegetional concepts and terms", *Ecology*, 16: 284–307, [DOI]. (Cited on page 16.)

TEEB (2010), "The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations", Kumar, P., ed., London (Earthscan). (Cited on pages 8, 9, 14, 17, 18, and 20.)

Termorshuizen, J.W. and Opdam, P. (2009), "Landscape services as a bridge between landscape ecology and sustainable development", *Landscape Ecology*, 24(8): 1037–1052, [DOI]. (Cited on page 9.)

Tietenberg, T.H. (1992), *Environmental and Natural Resource Economics*, New York (Harper Collins). (Cited on page 17.)

Tirri, R., Lehtonen, J., Lemmetyinen, R., Pihakaski, S. and Portin, P. (1998), *Elsevier's Dictionary of Biology*, Amsterdam (Elsevier). (Cited on page 7.)

Toman, M. (1998), "Why not calculate the value of the world's ecosystem services and natural capital", *Ecological Economics*, 25: 57–60, [DOI]. (Cited on page 18.)

Torras, M. (2000), "The total economic value of Amazonian deforestation, 1978-1993", *Ecological Economics*, 33(2): 283–297, [DOI]. (Cited on page 17.)

Troll, C. (1950), "Die geographische Landschaft und ihre Erforschung", *Studium Generale*, 3. (Cited on page 5.)

Troy, A. and Wilson, M.A. (2006), "Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer", *Ecological Economics*, 60(2): 435–449, [DOI]. (Cited on pages 15 and 19.)

Turner, R.K., Adger, W.N. and Brouwer, R. (1998), "Ecosystem services value, research needs, and policy relevance: a commentary", *Ecological Economics*, 25(1): 61–65, [DOI]. (Cited on page 19.)

Turner, R.K., Paavola, J., Cooper, P., Farber, S., Jessamy, V. and Georgiou, S. (2003), "Valuing nature: lessons learned and future research directions", *Ecological Economics*, 46(3): 493–510, [DOI]. (Cited on pages 5, 17, and 21.)

Tüxen, R. (1956), "Die heutige potentielle natürliche Vegetation als Gegenstand der Vegetationskartierung: mit 10 Tabellen", *Angewandte Pflanzensoziologie*, 13, Stolzenau (Bundesanstalt für Vegetationskartierung). (Cited on page 17.)

Vejre, H., Abildtrup, J., Andersen, E., Andersen, P., Brandt, J., Busck, A., Dalgaard, T., Hasler, B., Huusom, H., Kristensen, L., Kristensen, S. and Præstholm, S. (2007), "Multifunctional agriculture and multifunctional landscapes – land use as an interface", in Mander, Ü., Wiggering, H. and Helming, K., eds., *Multifunctional Land Use: Meeting Future Demands for Landscape Goods and Services*, pp. 93–104, Berlin; New York (Springer), [DOI]. (Cited on page 22.)

Verburg, P.H., van de Steeg, J., Veldkamp, A. and Willemen, L. (2009), "From land cover change to land function dynamics: A major challenge to improve land characterization", *Journal of Environmental Management*, 90(3): 1327–1335, [DOI]. (Cited on pages 9 and 22.)

Wallace, K. (2008), "Ecosystem services: Multiple classifications or confusion?", *Biological Conservation*, 141(2): 353–354, [DOI]. (Cited on pages 14 and 22.)

Wallace, K.J. (2007), "Classification of ecosystem services: Problems and solutions", *Biological Conservation*, 139(3-4): 235–246, [DOI]. (Cited on pages 7, 9, 13, and 14.)

Westman, W.E. (1977), "How much are natures services worth", *Science*, 197(4307): 960–964, [DOI]. (Cited on page 5.)

Wiggering, H., Dalchow, C., Glemnitz, M., Helming, K., Muller, K., Schultz, A., Stachow, U. and Zander, P. (2006), "Indicators for multifunctional land use – Linking socio-economic requirements with landscape potentials", *Ecological Indicators*, 6(1): 238–249, [DOI]. (Cited on page 22.)

Willemen, L., Verburg, P.H., Hein, L. and van Mensvoort, M.E.F. (2008), "Spatial characterization of landscape functions", *Landscape and Urban Planning*, 88(1): 34–43, [DOI]. (Cited on pages 15 and 22.)

Willemen, L., Hein, L., van Mensvoort, M.E.F. and Verburg, P.H. (2010), "Space for people, plants, and livestock? Quantifying interactions among multiple landscape functions in a Dutch rural region", *Ecological Indicators*, 10(1): 62–73, [DOI]. (Cited on pages 9, 21, and 23.)

Williams, E., Firn, J.R., Kind, V., Robers, M. and McGlashan, D. (2003), "The Value of Scotland's Ecosystem Services and Natural Capital", *European Environment*, 13(2): 67–78, [DOI]. (Cited on page 19.)

Wilson, J., Low, B., Costanza, R. and Ostrom, E. (1999), "Scale misperceptions and the spatial dynamics of a social-ecological system", *Ecological Economics*, 31(2): 243–257, [DOI]. (Cited on page 23.)

Wilson, M.A. and Carpenter, S.R. (1999), "Economic valuation of freshwater ecosystem services in the United States: 1971-1997", *Ecological Applications*, 9(3): 772–783. (Cited on page 5.)

Wilson, M.A. and Howarth, R.B. (2002), "Discourse-based valuation of ecosystem services: establishing fair outcomes through group deliberation", *Ecological Economics*, 41(3): 431–443, [DOI]. (Cited on pages 17, 18, and 23.)

Xiaoli, S. and Wie, W. (2009), "Modification of Costanza's model of valuing ecosystem services and its application in China", *Ecological Economics*, 5: 341–348. (Cited on page 19.)

Zerbe, S. (1998), "Potential Natural Vegetation: Validity and Applicability in Landscape Planning and Nature Conservation", *Applied Vegetation Science*, 1(2): 165–172, [DOI]. (Cited on page 17.)