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Ecosystem properties, potentials and services – The EPPS conceptual framework and an urban application example

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ABSTRACT

The concept of ecosystem services is an approach widely discussed to clarify and to assess the dependence of human society on ecosystems and landscapes. In order to better differentiate between the potential performance of ecosystems and landscapes and the quality needed or demanded by society, in this paper we suggest returning to the landscape potential concept developed by landscape ecologists in the 1970s. Emerging from both concepts is the hereinafter discussed EPPS framework – ecosystem (or landscape) properties, potentials and services – which is a way to better link both potentials and services to current planning and management practice and governance schemes. The empirical part of the paper shows applications of the EPPS framework in an urban region.

1. Introduction

Ecosystem services (ES) can be defined as "the benefits people obtain from ecosystems" (MA, 2005). For about two decades the scientific concept of ecosystem goods and services has gained increasing attention and importance among scientists worldwide (e.g. Lappé, 2009; Burkhard et al., 2010).

This growing popularity of the ecosystem services concept can be seen primarily as a reaction on the interplay of firstly the long-term neglecting of biophysical and ecosystem functions – often considered *gratis* – in our economic cycles and the societal system as such and, secondly, the growing devastation and degradation of the ecosystems providing these performances (Norberg, 1999; Boyd and Banzhaf, 2007). With the publication of the Millennium Ecosystem Assessment (MA, 2005) at the latest it also became clear for the critical expert public that humankind depends on nature and ecosystems, their functions and the variety of processes and fluxes. Another example for the growing importance of ecosystem services for global policy is the TEEB (2010) which focuses on the economics of ecosystems and biodiversity. Currently, the issues of biodiversity and ecosystem services might draw policy-makers' attention: In June 2010 the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was founded in Busan, South Korea (Nature, 2010).

The attractiveness of the ecosystem services concept results on the one hand from its interdisciplinary character – it is integrated by nature – and on the other hand, it explicitly involves both natural science based and socio-economic science views and approaches (Müller and Burkhard, 2007). Neßhöver et al. (2007) call ecosystem services a missing link between ecosystems and human well-being, which is close to the view of the MA, too.

However, despite all progress in making ecosystems, their goods and services popular, we are still far from firstly, a satisfying and comprehensive scientific description of the multiple relationships and feedbacks among different ecosystem services, and secondly, a real impact of the ecosystem services approach on political decision-making (Cox and Searle, 2009; Haines-Young and Potschin, 2010). Instead, we have to state an increasing degradation of ecosystems worldwide (MA, 2005; Heinberg, 2010) along with the increase of impacts of natural hazards (floods, land slides, forest fires, heat waves) dramatically showing the declining resilience of ecosystems worldwide. One most likely reason for this impairment is the non-integration of ecosystem services in spatial and land use planning in many countries worldwide. Particularly the environmental legislation in many countries is not at all aware of the ecosystem services concept. But also science has still not met thresholds for policy impacts due to a lack of information, standards or verification (Cox and Searle, 2009). This is surprising so far as there are various traditional scientific approaches to value ecosystems and landscapes such as the framework of natural potentials and landscape diagnosis by Haase et al. (further reading Haase and Haase, 2002); or the landscape functions concept (e.g. Marks et al., 1992; Bastian and Steinhardt, 2002; Bastian and Lütz, 2006; Willemen, 2010). For example in Germany or the Netherlands, the concept of landscape functions is used in landscape planning in order to delineate protection zones or to determine priority areas

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for agricultural, forest or recreational use (ROG, 2008; Willemen, 2010). For most of the German planners – at least – it remains unclear how to bring natural science-based landscape functions together with the more valuation-centered ecosystem services (Boyd and Banzhaf, 2007; Ranganathan et al., 2008; Volk et al., 2008). What are the linkages between these two concepts (functions/services)?

At this point, we argue, that a joint view at and a combination of the variety of the approaches to assess the ecosystems or landscapes would help to better integrate the ecosystem services concept into spatial planning. In so doing, this paper presents a methodological framework which is based on the three pillars: (1) the description and analysis of ecosystems' and landscapes' properties (structure, processes and biophysical functioning), (2) the derivation of ecosystems' and landscapes' potentials to provide services, (3) the definition and valuation of services for human benefit creating. Therefore, we call this framework hereinafter EPPS (Ecosystem Properties, Potentials, and Services). In the EPPS framework, we will highlight the importance of the aspects of the 'natural potential' (in German *Naturraumpotenzial*) for ecosystems/landscapes and their functioning as it–explicitly using the term 'potential'–better differentiates between potential supply and current demands/usage of ecosystem services. The terminus 'natural' in this case means biophysical processes and structures of ecosystems and landscapes and should not be mixed up with 'pristine' or 'undisturbed'. Without ignoring the fact that ecosystem and landscape represent two quite different concepts, the EPPS framework applies to ecosystems as well as to landscapes, since both provide potentials and services.

Corresponding to its conceptual foundation, in the second part of the paper, the EPPS framework is applied to urban ecosystems and their functions, potentials and services as we find here on the one hand a particular pressure on ecosystems and natural resources but on the other hand also a high demand and potential for participation in integrative planning and land use management (Ravetz, 2000, 2004).

2. Conceptual foundations

2.1. Ecosystem properties

Ecosystem properties include the structures and processes of ecosystems and landscapes in its spatial and temporal variability (e.g. soil properties, biotic material production, nutrient cycles, biological diversity), which form the basis for the existence of society and of any kind of services utilisable by humanity. This ecological endowment does not consider potential or actual users, yet. It is assigned only to the factual level. Based on that, ecosystems (as well as landscapes) have the ability to render certain services for human society. From a (landscape-) ecological viewpoint, analysing the structures and processes of the ecosystems (or the landscape) is a basic prerequisite to approach ecosystem services. This also includes the 'functioning'; the distinction to the 'societal functions' must be considered, though (see below and Section 2.3).

The term 'function' is not used consistently in literature. This is frequently leading to terminological uncertainties, misunderstanding and confusion (cf. Burkhard et al., 2010). Thus, a purely ecological interpretation is common, in the sense of the ecosystem 'functioning' as a scientifically determined organisation of structural–procedural contexts (e.g. food chains and nutrient cycles); cf. Forman and Godron, 1986 where function is "the interactions among the spatial elements, that is, the flows of energy, materials, and species among the component ecosystem". In the TEEB study (TEEB, 2010), functions are also regarded as purely ecological phenomena.

By comparison, according to Costanza et al. (1997) or the Millennium Ecosystem Assessment (MA, 2005), ecosystem functions support ecosystem services (ES). For Boyd and Banzhaf, 2007, functions are 'intermediate products' of ecosystem services. Already van der Maarel (1978) and (later) Eliáš, 1983 distinguished early between two basic groups of functions: ecological resp. internal or regulating functions (important for the existence of the ecosystems, regardless of perception by humans or specific societal claims), and societal functions satisfying human needs and demands. However, a clear distinction between both mentioned types of functions is missing there. Jax, 2003 comprehensively dealt with the different uses of the term 'function' and suggests using it exclusively when related to society, in other words, representing a service.

Ecosystem properties are a component of the natural capital (Costanza et al., 1997; Potschin and Haines-Young, 2003) resp. of the 'quality of life capital' (Santos and Martins, 2007). Thus, ecosystem properties are a prerequisite for the human well-being that is based on the natural capital of the earth from which goods and services are generated (Finvers, 2008).

In the EPPS framework, we consider the analysis of ecosystem and landscape properties as the base for the assessment steps following in the pillars 2 and 3. Functions in the sense of functioning without any expressive human perspective (e.g. nutrient cycles, pedogenesis, and litter decomposition) are belonging to the first pillar, too.

2.2. Ecosystem potentials

In European concepts and schools of landscape ecology, for example, in the German 'landscape literature', landscape potentials have been conceptualized, set into operation and were broadly discussed (see here Bastian and Schreiber, 1999; Bastian and Steinhardt, 2002; Haase and Mannsfeld, 2002; Burkhard et al., 2009; Grunewald and Bastian, 2010).

The concept of potentials assesses nature's goods from the point of view of the potential user and by means of a primarily science-driven (explicitly including natural and social sciences) mode of operation. The goal is to display the service capacities of an ecosystem (or of the bio-physical part of a landscape area) as a field of options available to society for usage. So doing, the potential-approach also considers categories as risk, carrying capacity and the capacity to capture and balance stresses (increasingly summarised today in the term 'resilience') which limit or may even exclude certain intended uses. By making ecosystem and landscape potentials scientific categories and having them ascertained according to specific parameters of biophysical processes, they can be distinguished from natural resources, which represent an economic category (Mannsfeld, 1983).

The approach of (landscape) potentials constitutes an important foundation for land use and landscape planning. Knowledge about potentials, which are available but still largely barely used can be applied to improve land use and to develop resources. This concept was introduced by Bobek and Schmithüsen (1949), initially as a 'spatial arrangement of nature-bond opportunities for development'. The scientific literature, moreover, covers such concepts as 'natural potential' (Langer, 1970; Buchwald, 1973); Lüttig and Pfeiffer (1974) drew 'maps of natural landscape potentials' (cp. Durwen, 1995; Leser, 1997). In botany, the term 'potential' appears in the form of 'potential natural vegetation', which was an integral used to indicate the totality of growth conditions at a given site (Tüxen, 1956).

Driven by his view that all social and economic processes which trigger ecological changes are detectable via the turnover of material and energy, Neef (1966) defined a '(regional) economic potential of a landscape' (in German *gebietswirtschaftliches Potenzial*) as "the sum of all energy which is latently available in a certain area, which is released and converted by economic activities in the landscape". Haase (1973, 1978) offered a way out of this hardly manageable complexity by suggesting that, instead of a summary energy standard for a theoretically conceivable overall potential, specific factors (properties, indicators) should be addressed in a particular case and so-called 'partial natural landscape potentials' defined with a clear focus on more specific socio-economic or societal goals and basic functions. This includes for example biotic yield potential and regulatory potentials, water supply and disposal potentials, construction and recreational potentials. At the same time, van der Maarel (1978) and Lahaye et al., 1979 in the Netherlands defined 'landscape potencies' which can contribute to the fulfilment of specific societal needs.

But even very recently the term 'potential' has also been used: For example, Burkhard et al. (2009) formulate "What potential do the different land cover units have to provide which ecosystem services?" and they mention ". . . the presence of trees or plants with potential use for timber" and that "the water storage potential can change with the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas." Laurijssen and Faaij (2009) deal with so-called 'biomass production potentials'. Wiggering et al. (2003) link socio-economic requirements with landscape potentials. Finally, the United Nations (2003) emphasize that "the objective of a better understanding of the relationship between economic activities and the environment requires that both the use of land by different economic activities and the potentials of land from an ecological view" is to be taken into account, and: "The potentials can be assessed from several points of view, one of them being the capacity of the landscape to sustain natural life under the pressure of human activities."

In addition to 'potential', the term 'capacity' can also be found in literature about ecosystem functions, goods and services rather often. Thus, De Groot et al. (2002) and Willemen (2010) define 'ecosystem functions' (and 'landscape functions') as "the capacity of natural processes and components to provide goods and services which directly and/or indirectly satisfy human needs." Capacity covers both performance and capability of an ecosystem or a landscape to deliver services and is thus, compared to potential, not limited to an imagined but not necessarily demanded performance. The Millennium Ecosystem Assessment (MA, 2005) argues that the ecosystem capacity (as a function of abiotic and biotic characteristics, including geomorphology, soil quality, weather conditions and biodiversity) makes some potentially desirable ecosystem services biologically impossible (e.g. growing coffee in Canada). The state of the ecosystem capacity at the time a decision is taken sets the initial condition for the range, level, and quality of intended services that can be obtained. Additionally, MA (2005) emphasizes another, very important aspect: "the capacity of the natural system to sustain the flow of economic, ecological, social, and cultural benefits in the future."

Hence, we include the concept of ecosystem and landscape potentials as the 2nd pillar in the EPPS framework to distinguish between the potential (= capacity) to supply services and the actual or demanded/needed use of these services by humans. With the concept of potentials we address both the question of non-use or inadequate use of natural resources and the problems of overexploitation (see Section 5).

2.3. Ecosystem services

Although the concept of ecosystem services already emerged during the 1960s it had been established in the international environmental discussion in the 1990s (e.g. De Groot, 1992; Daily, 1997; Costanza et al., 1997). But still today there remains a lack of a consistent terminology. Both Costanza et al. (1997) and the Millennium Ecosystem Assessment (MA, 2005) define ecosystem services as "the benefits people obtain from ecosystems". Boyd and Banzhaf (2007), contrarily, differentiate between ecosystem services and the benefits which they generate. Fisher et al. (2009) define ecosystem services as those aspects of ecosystems which, actively or passively, provide human well-being, while TEEB (2010) sees them as the direct and indirect contributions of ecosystems to human well-being.

Boyd and Banzhaf (2007) criticise the fact that many of the 'services' listed by Daily (1997) or in the Millennium Ecosystem Assessment (MA, 2005) are actually ecosystem processes or functions. However, the simultaneous or synonymous use of the terms 'functions' and 'services' without defining either clearly or distinguishing them from one another occurs quite regularly (e.g. Vejre, 2009; Willemen, 2010). While the term 'service' has gained acceptance in the English-speaking realm, the approach of the 'societal functions' of nature and the landscape found entrance in the scientific discussion nearly exclusively in German-speaking countries (Ansink et al., 2008; Grunewald and Bastian, 2010). Spangenberg and Settele (2010) argue that "talking about ecosystem services instead of ecosystem functions" will help "to convey the message to decision-makers in a terminology they are used to and which might stimulate them to act."

While potentials describe the opportunity to use structures and processes of ecosystems and landscapes, the realization of this use is captured by the concept of ecosystem (or landscape) functions (in the sense of services, cp. Section 2.1). Niemann (1977, 1982), for instance, designed a methodology for ascertaining the degree of 'functional performance' of landscape elements and landscape units. In spatial and regional planning, functions are defined as "tasks which an area is to fulfil for the needs of life of the people" (ARL, 1995). According to Wiggering et al. (2003), the determination of the multiple ecological, social and economic functions of the landscape (multifunctionality) in their regional differentiation is the prerequisite for sustainable land use.

Consequently, we regard ecosystem services as the actually used or demanded contributions of ecosystems and landscapes to human benefits and the human well-being. They represent the 3rd pillar of the EPPS framework and include the term 'function' in its strong human perspective.

3. The EPPS framework

The EPPS framework that we propose for the analysis and the assessment of ecosystem (and landscape) services consists of three related and depending pillars – given in Fig. 1. The EPPS framework applies to ecosystems and landscapes as well. Landscape services are related to landscape elements (not necessarily ecosystems, e.g. buildings and other human-made structures), they are associated with pattern–process-relationships, and they are more relevant and legitimate to local practitioners (cp. Termorshuizen and Opdam, 2009). The left side of the diagram (pillar 1) shows the ecosystem (or landscape) properties including its structures (components) and processes (incl. functions in the sense of functioning), which form the fundamentals for the existence of society and of any services. Spatial aspects (the arrangement of parts of the system, interactions between elements as well as fluxes of matter, energy and living-beings), typification of ecosystems and landscapes, but also aspects of time (ecosystem dynamics, changes in ecosystems and landscapes) are included. In this first step within the EPPS framework, the analysis of ecosystem properties is driven by predominantly natural science methods using analytical indicators. The results represent facts and data without – for the time being – any relation to potential benefits, values or demands for services by society.

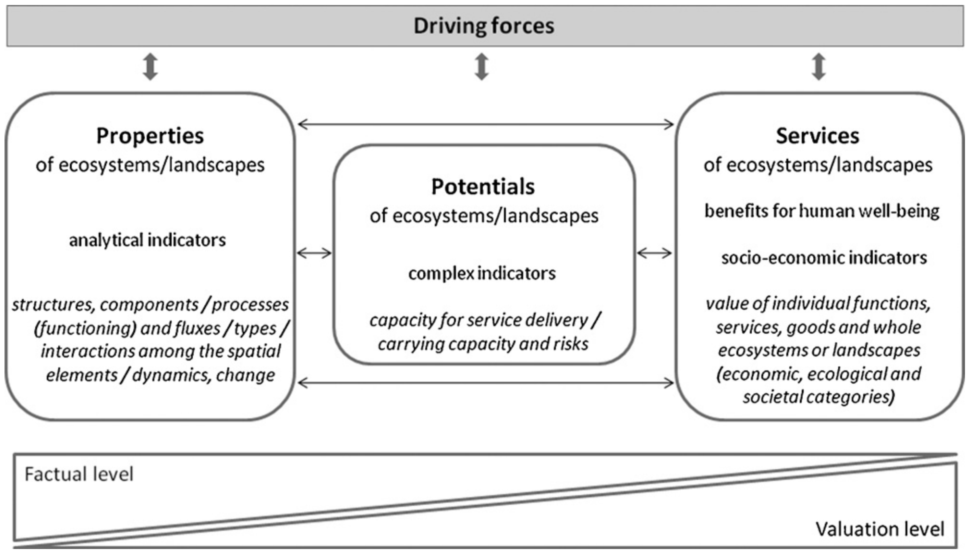

Fig. 1. EPPS framework for the analysis of ecosystem/landscape services (as explained in Section 3).

Ecosystems and landscapes provide a service potential by their way of functioning but societies' demand actually converts it into a real service. Here the 'potential' approach is of advantage: as a second pillar in the EPPS framework, potentials have consciously been included as kind of an intermediate step, so as to make a distinction between the possibility of usage and actual use. Through the analysis and assessment of potentials it is possible to assess the suitability of an ecosystem or a landscape for (different forms of) land use but also the respective carrying capacity and risks. For this reason, we consider the potentials approach to be an important constituent in planning processes, e.g. for the implementation of sustainable land use systems. As potentials are directly related to services, they can be classified in the same way like the latter (economic, ecological, socio-cultural). For the assessment of potentials, complex indicators (aggregate indicators, models) are applied.

The furthest right pillar of the diagram reflects the pure anthropocentric perspective (valuation level) looking at ecosystems and landscapes as goods and services, which are currently under use by society with the objective to gain benefits for human well-being. The analysis of ecosystem (or landscape) services always involves a valuation step, i.e., scientific cognitions (facts) are transformed into (human driven) value categories. Socio-economic indicators play an important role, here. Not only economic but also ecological and societal categories must be taken into consideration. Besides, although the EPPS framework focuses on the benefits produced, it implicitly includes also negative social or economic effects of ecosystems (and landscapes) to human well-being, so-called 'disservices' (Lyytimäki and Sipilä, 2009; Dunn, 2010). The disservices are likewise treated in the 3rd pillar of the framework, they can be regarded as services with a negative sign.

Finally, it should be considered that ecosystems (and landscapes), the potentials and services they deliver are subject to constant changes triggered by driving forces (e.g. climate change, demographic change, technological development). Reversely, properties, potentials and services of ecosystems and landscapes can affect several driving forces. The arrows between the three pillars of the EPPS framework show that there are impacts not only from the left to the right pillar but also vice versa: The use of services can modify or change the potentials and properties of ecosystems and landscapes.

With respect to the classification of ecosystem (and landscape) functions, potentials and services, there are numerous proposals, classification systems and divergent opinions. According to Costanza et al. (1997) and the Millennium Ecosystem Assessment (MA, 2005) provisioning, regulating, supporting and cultural ecosystem services can be defined. We recommend, however, a trinomial classification of ecosystem services according to the economic, ecological and societal categories of sustainability and risk. The breakdown into productive (economic), regulatory (ecological) and societal functions or services (Bastian, 1991, 1997; Bastian and Schreiber, 1999) has the advantage that it can be linked to both fundamental concepts of sustainability and risk using the established ecological, economic and social development categories. This is in line with the OECD (2008), which distinguishes between provisioning services, regulating services and cultural services. We consider supporting services as an intermediate (analytical) step. They are a prerequisite to define the other (three groups of) services, but they are more related to the first pillar of our EPPS framework (ecosystem properties). Other authors also "suggest treating them differently from the other ecosystem services which provide their benefits directly to humans. Due to thematic overlaps with regulating ecosystem services there is a high risk of double-counting particular natural processes (Burkhard et al., 2010; Hein et al., 2006).

The proposed trinomial classification of ecosystem services can also be related to the partially complementary concept of urban Quality of Life (QoL, cf. Santos and Martins, 2007) which also covers the different dimensions of sustainability from an anthropocentric point of view (Schetke et al., 2010). It also follows the three dimensions of sustainability.

4. Application: an urban case study

If ecosystem services are provided in urban areas and cities we define them as urban ecosystem services (UES; according to Bolund and Hunhammar, 1999). Not exclusively but in particular in urban regions and cities where meanwhile the majority of people is living (United Nations, 2008) ecosystems and landscapes are intensively used and appear to be more and more degraded or devastated (MA, 2005). Compared to their relative importance, UES are rarely discussed and their theoretical foundation is less specified than for rural or forest landscapes. For example, in the well-known *Nature* paper by Costanza et al., 1997, they are either coloured grey – services that do not occur or are known to be negligible – or white – open cells indicate lack of available information. A recent paper by Yang (2008) reports that settlement land was assigned no ecosystem service value derived from plants in residential and urban areas. Thus, this section's purpose is in fact twofold: to apply and demonstrate the EPPS framework by providing the urban example of the city of Leipzig, Germany. Leipzig as such is particularly interesting since it passed a dynamics phase of suburban sprawl and inner-urban shrinkage during the last 20 years after the fall of the Berlin wall (Nuissl and Rink, 2005).

According to McDonald (2009), UES are provided at different scales within an urban landscape: at the local (e.g. temperature regulation by tree shade, water and pollutant filtration at a single soil plot or timber production in a specific tree estate), at the regional (recreation, climate regulation, biodiversity) and at the global scale (carbon mitigation, contribution to the continental or worldwide gene pool and biodiversity).

UES are closely related to the usage of urban land as such: In particular urban green spaces – that is forests, trees, parks, allotments or cemeteries – provide a whole range of ecosystem services for the residents of a city. Firstly, they help regulating extreme day and night-time temperatures by shading, evapotranspiration and lower surface emissivity (Chiesura, 2004; Priego et al., 2008; Chang et al., 2007; Kottmeier et al., 2007). Nearly all types of urban open and green spaces provide recreational facilities. Unsealed land helps to regulate surface water flows, enhances infiltration, lowers water travel times, which help to prevent floods and related damages (Haase, 2003). To support this kind of services by unsealed land, urban water management increasingly uses 'in situ drainage sites' (Haase, 2009). In terms of carbon mitigation urban trees and urban soils contribute to the carbon uptake and thus to a partial decrease of the urban footprint. Nowak and Crane (2002) estimated that urban trees and forests balance about 1–2% of the urban C-emissions.

Example 1: Climate regulation. Starting the EPPS framework application for Leipzig with the illustrative example of climate change and heat stress, a range of studies was carried out to measure the temperature reduction potential of urban green spaces by evapotranspiration and tree shading (e.g. Gill et al., 2007; Jim and Chen, 2006; Tratalos et al., 2007; Schwarz et al., 2011). A recent study by Vogel and Haase (unpubl.) proved evidence that urban park trees lower the day-time temperature at hot summer days at a level of 2–4 K (Fig. 2). Temperature was measured at shaded and non-shaded places in a representative range of urban parks using temperature loggers. Using an urban tree GIS-data layer the shading potential of urban parks P was extrapolated to the whole city (Eq. (1); Fig. 2):

$$\frac{1}{N}\sum_{i}^{n}\left(\frac{P_{shade}}{P_{total\,area}}\right) \tag{1}$$

Referring to the EPPS framework, the ecosystem process of radiation reflectance by the leaves of the tree bears the ecosystem potential to lower the air temperature in the shadow of the respective tree. In case the tree is used by residents (to be measured in numbers or recreation time) to stay there the potential converts into an ecosystem service. At current, there are much too less such cooling spaces in the city, particularly in the densely old built-up areas (Schetke and Haase, 2008). To estimate the total ecosystem potential the measured temperature reduction potential values were extrapolated to the whole city of Leipzig using three explorative scenarios, which now show the relation of the temperature regulation potential and the urban land use change (Fig. 3): The first type of scenarios assumed (1) a linear trend of land use change in the city based on statistical data of the last decade, (2) an enlargement of the green infrastructure due to ongoing shrinkage and demolition processes and (3) the reverse process–reurbanisation combined with a transformation of urban green spaces into res-

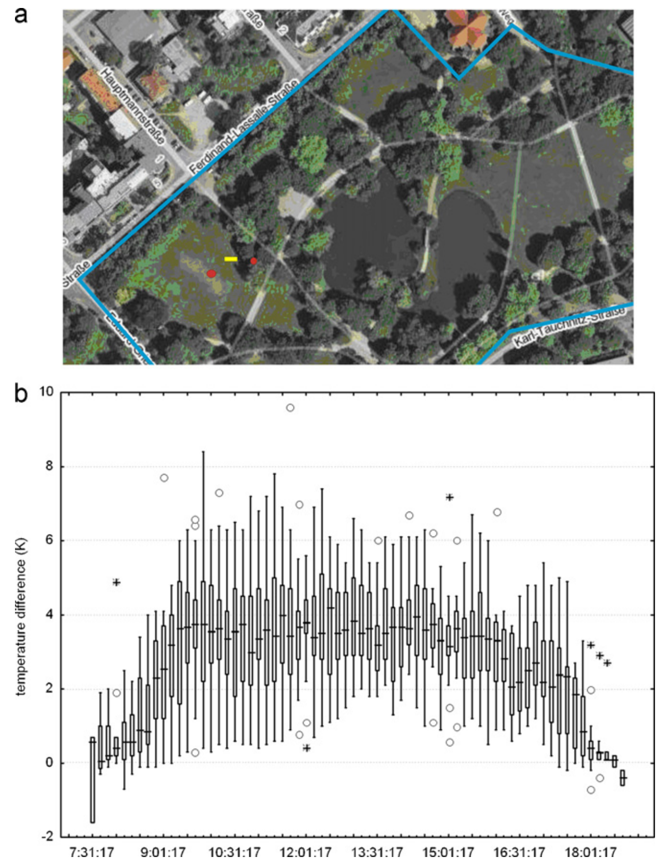

Fig. 2. (Above) temperature logging site in an urban park in Leipzig (the dark grey dots show the allocation of the temperature loggers, the white bar the location of the computerised measuring station). The box plot below shows the mean temperature lowering potential of the tree shade including the variance of the values expressed by the temperature difference of shaded and non-shaded plots (own data from August 2009, max. 36 °C air temperature).

idential land. In the second type of scenarios the total areas of green space kept stable but the tree percentage changes: it ranges from (1) the current tree proportion of about 44% over (2) a complete afforestation of all urban parks and (3) the most simple form of urban green spaces – lawns – which are considerably cheaper compared to all other types of planted green spaces.

Fig. 3 impressively shows the effects of these assumed land use changes on the ecosystem service of temperature reduction by tree shading: We see that both land use change and a modification of the tree share at prevailing green spaces have an impact on the temperature regulation potential. Most obvious is the positive impact of a green space enhancement following a demolition of inner-urban and peri-urban housing and commercial stock; here the area of an average temperature reduction potential of 2–4 K during heat waves multiplies more than tenfold. Vice versa, an increase of built-up land in the inner parts of a city declines the ecosystem service. Lawns – this became also very clear – are by far the worst form of urban green space development in terms of climate regulation (cf. again Fig. 3). In the three land use scenarios, the green infrastructure represents a potential (to reduce local air temperature). If we regard the people benefiting from it, we turn to the perspective of services.

Example 2: Carbon sequestration. While urbanisation is increasing globally with more and more people living in cities, many industrialized cities are losing population–they shrink. Concerning the ecosystem process of carbon storage by vegetation, shrinking cities are of particular interest: due to urban reconstruction they

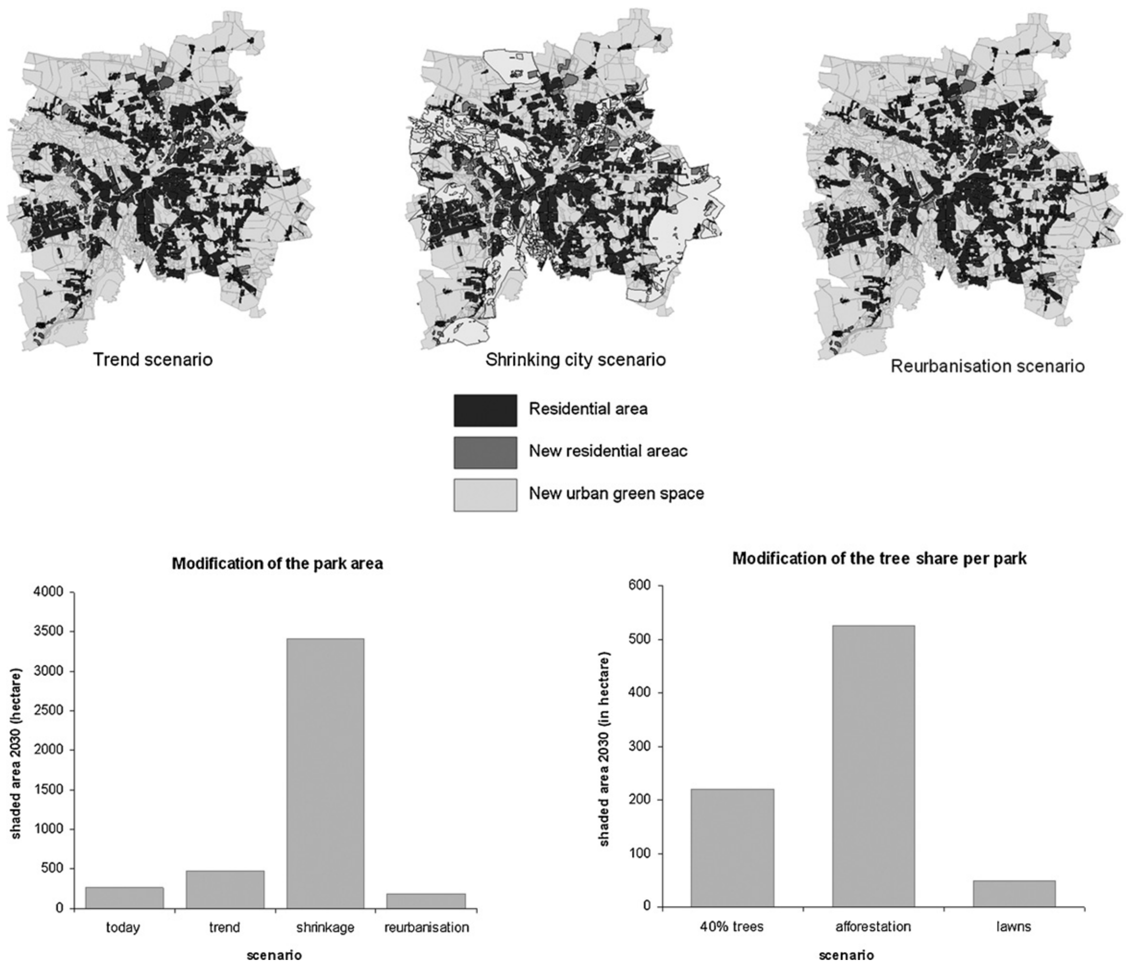

Fig. 3. Scenarios of the cumulative temperature reduction potential by tree shading (upper sequence of maps). Below, the total shaded area for (left hand side) the three scenarios 'trend', 'shrinkage' and 're-urbanisation' compared to the today's situation as well as (right hand side) the scenarios '40% trees', 'afforestation' and 'lawns' (at constant park area) is given.

hold a lot of brownfields developing into new green spaces. This is also the case in Leipzig. Fig. 4 presents the example of the carbon uptake potential of an area under an urban restructuring project which is quite typical for shrinking cities: vacant residential houses or factory buildings are demolished in favour of new (interim) green spaces which can be parks, leisure areas or even tree plantations (for more information cf. Lorance-Rall and Haase, 2011). In our example, carbon sequestration occurs by tree growth (process, belonging to the left pillar – the ecosystem properties) and was contrasted with all related carbon sources, e.g. maintenance emissions. To estimate the actual climate regulation ecosystem service provided by tree growth, this carbon sequestration potential can be set into relation to either the total or per capita CO_2-emission of the city (over time).

Example 3: Recreation. Perhaps one of the highest valued ecosystem services in cities is recreation, which bases on the provision of recreation opportunities (= potential) by ecosystems or landscapes to urban residents. To a high extent, this potential bases on the biological process of plant growth and animal life. There is a range of studies on analysing and measuring the recreation potential or, when related to the number of people using the green spaces, the recreation ecosystem service (e.g. Handley et al., 2003; De Vries et al., 2003; Chiesura, 2004; Li et al., 2005; Jim and Chen, 2006; Comber et al., 2008; Mazuoka and Kaplan, 2008). The example in Fig. 5 shows urban green space (UGS) supply and demand per capita. The overlay of both graphs along the urban-to-rural gra-

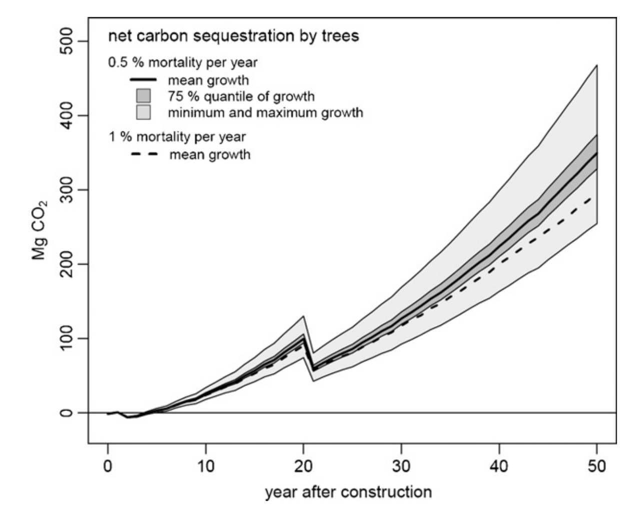

Fig. 4. Carbon sequestration of the reconstruction project in 50 years lifetime. Emissions from construction and management are balanced against sequestration from tree growth. Construction means here the urban renewal measure of demolition (of vacant houses) and subsequent tree plantation at the place. Tree growth is modelled for a range of growth rates. After 5 years of tree growth the balance becomes positive. After 20 years 182 of the initially 461 trees are thinned out, hence the bend in the line (Strohbach et al., 2010).

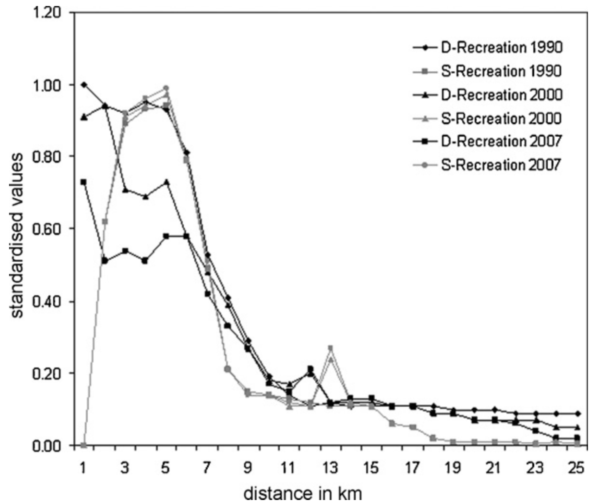

Fig. 5. Standardised values illustrating the recreation ecosystem service supply (S) and demand (D) along the urban (0) to rural (25) gradient of Leipzig (Germany). The different years represent the three available Corine land cover data time snap shots of 1990, 2000 and 2007 (http://www.eea.europa.eu/publications/COR0-landcover). A large undersupply in the inner city areas can be mirrored by a partial oversupply in the floodplain areas in 2–7 km distance from the city centre. In the peri-urban areas demand and supply outweigh each other (Haase, 2010).

dient shows the dissimilarity in distribution of both supply (= the potential) and demand (for the service). Particularly the densely old built-up areas in the city centre and the 19th century-time ring are under-supplied by urban green whereas neighbourhoods close to the floodplains provide high green space availability which exceeds Leipzig's target level of 7 m^2 per capita by far.

Compared to carbon sequestration by urban vegetation, recreational green space supply and tree shade represent local urban ecosystem services in terms of where they are supplied and consumed (McDonald, 2009).

As we could show, the EPPS framework can be useful in urban areas, too. In particular, the analysis and modelling of ecosystem structures and processes (1st pillar of the EPPS framework) gives an idea of the potentials of urban ecosystems residents could benefit from (2nd pillar). All three examples were linked to specific land use management and planning strategies which are basing on service valuations belonging to the 3rd pillar of the EPPS framework. The three examples represent three best practice measures and indicators that would suit as standards for ecosystem services valuation and monitoring (cf. Cox and Searle, 2009). Moreover, we have shown how ecosystem services modelling can be linked to land use relevant scenario and gradient techniques. In particular the latter, the urban-to-rural gradient is a suitable method to quantify, analyse and understand complex processes of land use change over long periods of time. It facilitates to get the 'broad picture' of urbanisation and ecosystem degradation in an area and – based on this knowledge – to more comprehensively support spatial planning for future land management. It provides a means for decision-makers and planners when they are to judge on urbanisation, land consumption and sprawl-like developments in their jurisdiction (Haase and Nuissl, 2010).

5. Discussion

The concept of ecosystem services was launched to raise awareness of economists, politicians, planners and the wider public for the benefits society obtains from ecosystems. The practical consequence and purpose of this is – logically – to implement the performances of ecosystems into economic systems and cycles, policy decision-making and planning processes.

The specific of the EPPS framework proposed in this paper is the incorporation of the approved concept of ecosystem/landscape potentials into the ecosystem services concept as kind of amplification so as to consider more strongly the bio-physical prerequisites and conditions of ecosystems and distinguish between a potential and requested or real use of ecosystem services. In other words, the capacity of ecosystems and landscapes to supply goods and services can be evaluated regardless the actual use of these services. Thus, the EPPS framework consists of three pillars: (1) ecosystem/landscape properties, (2) potential and (3) services. But it is not always necessary to consider all three pillars – not for the assessment of the ecosystem functioning and service potential, and not for each planning process. The decision to look at the demanded service depends on the specific task and the focus of the stakeholder: If only information about the potentials is needed, the third pillar of the EPPS framework – utilization/management of services – can be left out. But also the second pillar – potential benefits/service – can be skipped if the actual use of services is of interest, only. Vice versa, potential (additional) services (2nd pillar) can be further investigated also in case current requirements are fulfilled (3rd pillar).

The differences between processes (in the sense of ecosystem functioning), potentials and services provided by ecosystems and landscapes must be considered in the methodical approach, i.e., the indicators, their aggregation and the models applied. The human perspective is decisive, i.e., the affiliation to the data level or to the valuation level. To give an example, groundwater recharge can be regarded as a predominantly physical process independent from any human perception, evaluation or interests of usage. If this process is regarded in terms of a possible usage it becomes an ecosystem or landscape potential that is transferred into a service by an actual use or at least a demand or a need.

The concept of potentials can be applied not only in a static way but it is also very helpful for the documentation and the assessment of changes in land use, ecosystems and landscapes (Bastian and Röder, 1999). Neef (1966) referred early to the changes in the 'overall economic potential of landscape' by human impacts: "All measures concerning nature lead to changes (loss, decline or increase) in the potentials, too. These changes must be taken into account in planning."

Following these ideas, the concept of potentials within the EPPS framework offers opportunities for land use management and landscape planning, which are not considered so far. The potentials mark a field of options showing currently unused or barely used services but also over-exploited services and disservices according to Lyytimäki et al. (2008). Appropriate land use patterns and forms can be approached by comparing these potentials: either to identify the most appropriate use(s) for a specific area, or the most suitable area for a specific land use demand. Thus, crucial questions in planning processes can be better answered, e.g. "Where are optional areas for specific land use that have not been realized so far?" Or "Where are actual land use patterns not being conform with the ecosystem potentials given?" This is of great socio-economic significance and helps to strengthen the reputation of landscape and ecological planning and management in society. The differentiated view (potentials versus services) suggested in the EPPS framework, particularly the weighting of different options of developments, finally can lead to a higher degree of public and stakeholder participation in land use planning and introduces a new way of landscape or land use governance.

While the cascade model of Haines-Young and Potschin (2010) that inserts the 'functions' as an intermediate step between the 'biophysical structures and processes' and the 'services', the EPPS framework makes a distinction between the function(ing)(belonging to the 1st pillar) and the functions used by the society (societal functions in the sense of services, 3rd pillar), and it emphasizes especially the potentials (2nd pillar) as an intermediate step between biophysical processes and real services.

Especially in urban landscape planning, stakeholder-oriented in nature, the EPPS framework including the concept of potentials can be helpful: integrative planning thereby means the removal of sectoral thinking and actions in favour of more holistic concepts of regional and local regeneration and adaptation (Ravetz, 2000, 2004). Accordingly, expert-driven formal planning will be enhanced and accompanied by participatory processes to ensure a better integration within a city. For example, not exclusively but most notably in shrinking cities concepts of 'green and blue services' provide potential to move from a simple 'land use view' of green and water areas in cities towards a valuation of ecosystem processes and spatial potentials of each piece of land.

By including various groups of stakeholders in decision-making during planning processes, the concept of potentials shows close relations to different forms of governance, which can be seen as soft forms of steering (e.g. Fürst, 2003; Fürst et al., 2008) or as "a process of coordination of actors, social groups and institutions in order to attain appropriate goals that have been discussed and collectively defined in fragmented, uncertain environments" (Le Galès, 1998; Wirth et al., 2010).

There are several examples of relations between ecosystem services and governance in the literature, e.g. Haslett et al. (2009) who argue that a "focus on governance and institutions and increased communication and integration across the different sectors" is a supposition "to incorporate an ecosystem services approach." Other authors (Norgaard and Jin, 2008; Tallis et al., 2009; TEEB, 2010) deal with trade and the governance of ecosystem services. According to Termorshuizen and Opdam (2009), in systems of governance planning ('collaborative planning' or 'collaborative management') decision-making on landscape changes is becoming the domain of various groups of actors at regional and local scales where different demands on the landscape exist and, accordingly, different perceptions of the benefits those landscapes must deliver to society are held. The relation between the concept of potentials on the one hand and the different governance schemes on the other hand are not investigated thoroughly, yet.

6. Conclusions

There is a large variety of terms, topics, theoretical foundations and methodological approaches in the area of ecosystem services. The attempt to better adopt the concept of ecosystem services for planning purposes and to put more emphasis on the difference between the capacity of ecosystems and landscapes to supply goods and services on the one hand, and of the actual use of these services on the other hand, inevitably leads to the concept of ecosystem and landscape potentials, which was elaborated already in the 1970s. The potentials can be regarded as one of three pillars of the EPPS framework proposed in this paper that ranges from the properties of ecosystems and/or landscapes across its potentials to services they supply. The theoretical concept was applied to urban ecosystems to show the way it works. The concept of ecosystem and landscape potentials is able to improve the implementation of the ecosystem services approach in planning processes, e.g. by weighting alternative land use development options. This ultimately can lead to more participation in land use and landscape planning and better governance schemes for conserving ecosystems, particularly in intensively used dense urban areas of which an example was shown in this paper.

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