Dissertation

Multifunctionality as a Principle for Urban Green Infrastructure Planning – Theory, Application and Linkages to Ecosystem Services

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Vollständiger Abdruck der von der Fakultät Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt der Technischen Universität München zur Erlangung des akademischen Grades eines

Doktor-Ingenieurs (Dr.-Ing.)

genehmigten Dissertation.

Vorsitzende: Prof. Dr. Anja Rammig

PrüferInnen der Dissertation:
1. Prof. Dr. Stephan Pauleit
2. Prof. Regine Keller
3. Junior-Prof. Dr. Christian Albert (Leibniz Universität Hannover)

Die Dissertation wurde am 30.10.2017 bei der Technischen Universität München eingereicht und durch die Fakultät Wissenschaftszentrum Weihenstephan für Ernährung, Landnutzung und Umwelt am 18.01.2018 angenommen.

Form follows function—that has been misunderstood.
Form and function should be one, joined in a spiritual union.
Frank Lloyd Wright, 1908

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CEC	The City of Edinburgh Council
CICES	Common International Classification of Ecosystem Services
EEA	European Environmental Agency
GAK	Gesamtstädtische Ausgleichskonzeption/General Urban Mitigation Plan
GREEN SURGE	Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy
ICLEI	International Council for Local Environmental Initiatives, now ICLEI-Local Governments for Sustainability
IPBES	Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services
LaPro	Landschaftsprogramm/Landscape Programme
MEA	Millennium Ecosystem Assessment
OSS	Open Space Strategy
SDG	Sustainable Development Goals
TEEB	The Economics of Ecosystems and Biodiversity
TUM	Technical University of Munich
UN	United Nations
URBES	Urban Biodiversity and Ecosystem Services

Abstract

Green infrastructure and ecosystem services have gained international attention as promising concepts to advance environmental planning, particularly in densely populated urban areas. Green infrastructure is considered to promote urban sustainability, enhance human well-being, and protect biodiversity by the means of strategic development of multifunctional green space networks. Multifunctionality is thus a core principle of urban green infrastructure planning. Moreover, ecosystem services have been suggested as a suitable concept for operationalising multifunctionality. To varying degrees, both concepts have been taken up in planning practice and research, but without much connection between the two spheres. A broad discourse on how to connect both concepts and operationalise them for planning practice is lacking. In addition, "multifunctionality" is an elusive term, understood in many different ways.

This cumulative thesis examines multifunctionality as a potential linkage between the concepts of green infrastructure and ecosystem services. By studying the theoretical foundations, as well as the current application in practice, the thesis also aims at better connecting achievements in research and in planning. The research methodology involved literature analyses and case study research. The mixed-method approach combined different semi-quantitative and qualitative case studies based on data from planning documents, interviews, and other forms of stakeholder interactions as well as desk studies of contextual information on the case study cities. Additionally, recommendations were developed based on consultation with experts from research and practice.

Research paper I suggests a theoretical framework, which illustrates different dimensions relevant for the assessment of multifunctionality. These dimensions include demand and supply of green space functions or ecosystem services, capacities of green infrastructure elements to provide these, and synergies and conflicts between different functions or services. The framework highlights that multifunctionality assessments need to be multi-dimensional.

Paper II was based on a comparative study among five cities from Europe and the US. Explicit and implicit references to the ecosystem services concept were explored. While explicit references were rare, several similarities appeared in planning documents. These include concepts, such as "ecological functions", that are related to the concept of ecosystem services. Moreover, the analysed planning documents shared an anthropocentric perspective on human-nature relations that is closely related to normative basis of the concept of ecosystem services. Regarding the services addressed, in many planning documents the scope was comparably broad. Habitat services and cultural services proved to be the most often represented categories. The results indicate that, firstly, the concept of ecosystem services can support a systematic consideration of a broad range of services in planning, and, secondly, additional aspects such as mitigation of environmental impacts or an increase of resilience to natural hazards through ecosystem services should be more strongly considered.

Paper III presents findings from an empirical analysis of the current consideration of multifunctionality in green space planning in 20 European cities. Both the analysed documents and the interviews evidenced a broad awareness of the variety of social and ecological functions provided by green spaces. However, information on how cities actually plan for securing or increasing multifunctionality was limited. In addition, three in-depth qualitative case studies in Berlin (Germany), Edinburgh

(the UK), and Aarhus (Denmark), selected as good practice cases, shed light on how different cities plan for multifunctionality: by embedding multifunctionality as a planning goal, by systematically assessing green space functions, and via designing multifunctional green spaces.

In conclusion, for planning practice, a more upfront consideration of multifunctionality is recommended. This includes adopting multifunctionality objectives in strategic (green space) planning and ensuring its proactive implementation, as well as sound assessments that capture multiple functions or services and take their interrelations into account. On the site-level, integrated solutions are needed to facilitate a broad range of functions across space and time in order to enhance synergies while avoiding trade-offs.

Researchers should be aware of the gaps between the scientific state of the art and demands in planning practice. For instance, the range of ecosystem services considered in research is too narrow and the land cover data used in assessments are too coarse to suit planners' needs for comprehensive and fine-grained, localised data. Nevertheless, potential linkages between research and practice were identified. Examples include an anthropocentric perspective, or an interest in systematic assessments of green spaces.

This thesis promotes discourse between both research and practice as it contributes conceptual frameworks as well as viable planning recommendations, combining the state of the art on both sides. It became evident that more comprehensive and integrated assessment tools for green infrastructure need to be developed that help to proactively plan for multifunctionality. Such tools need to integrate social, ecological, and potentially also economic values and capture a broad range of functions or services as well as their interrelations. Hence further research should be transdisciplinary in nature, involving researchers and planners from a range of disciplines.

Keywords: multifunctionality, green infrastructure, green spaces, ecosystem services, urban planning, strategic planning, integrated valuation

Kurzfassung

Grüne Infrastruktur und Ökosystemleistungen haben als vielversprechende Ansätze für die Umweltplanung, insbesondere in sich verdichtenden urbanen Räumen, internationale Aufmerksamkeit erlangt. Durch die strategische Entwicklung multifunktionaler Grünflächennetze soll das Konzept der grünen Infrastruktur urbane Nachhaltigkeit fördern, menschliches Wohlergehen verbessern und Biodiversität schützen. Multifunktionalität gilt somit als ein Kernprinzip für die Planung grüner Infrastruktur. Darüber hinaus werden Ökosystemleistungen als ein geeignetes Konzept diskutiert, um Multifunktionalität zu operationalisieren. In unterschiedlichem Maße wurden beide Konzepte in Planungspraxis und Forschung aufgenommen, wobei allerdings beide Sphären weitgehend getrennt voneinander agieren. Ein Mangel an eigenen theoretischen Ansätzen zur grünen Infrastruktur zeigt sich unter anderem darin, dass Multifunktionalität ein schwer fassbarer Begriff ist, der auf vielfältige Weise verstanden wird.

In dieser kumulativen Doktorarbeit wird Multifunktionalität als ein mögliches Verbindungselement zwischen den Konzepten der grünen Infrastruktur und der Ökosystemleistungen betrachtet. Durch die Untersuchung der theoretischen Grundlagen sowie der aktuellen Anwendung in der Praxis zielt die Arbeit darauf ab, den Stand der Forschung besser mit dem der Planungspraxis zu verbinden. Die Untersuchungsmethodik umfasste Literaturanalysen und Fallstudienforschung. Dabei wurde in semiquantitativen und qualitativen Fallstudien ein Methodenmix angewendet und Daten aus Planungsdokumenten, Interviews und anderen Formen der Zusammenarbeit mit Stakeholdern ausgewertet sowie aus Sekundärstudien zum Planungskontext in den Fallstudienstädten durchgeführt. Die Empfehlungen wurden zusätzlich mit Fachleuten aus Forschung und Praxis diskutiert und weiterentwickelt.

Forschungsartikel I schlägt einen konzeptionellen Rahmen vor, der die unterschiedlichen Elemente, die für die Bewertung von Multifunktionalität relevant sind, veranschaulicht. Hierzu zählen unter anderem Nachfrage und Angebot von Grünflächenfunktionen bzw. Ökosystemleistungen, die Kapazitäten von grüner Infrastruktur zur Bereitstellung dieser sowie Synergien und Konflikten zwischen verschiedenen Funktionen oder Leistungen. Der Ansatz zeigt, dass Multifunktionalität vielschichtig untersucht und bewertet werden muss.

Forschungsartikel II basiert auf einer vergleichenden Studie in fünf Städten in Europa und den USA. Es wurden explizite und implizite Hinweise auf das Konzept der Ökosystemleistungen ermittelt. Während explizite Verweise auf das Ökosystemleistungskonzept selten waren, wurden in Planungsunterlagen einige Ähnlichkeiten mit dem Konzept gefunden. Diese umfassten verwandte Konzepte wie Ökosystemfunktionen. Auch Perspektiven auf die Beziehungen zwischen Mensch und Natur, die Ähnlichkeiten mit der normativen Basis des Ökosystemleistungskonzepts aufweisen, waren präsent. Auf der inhaltlichen Ebene wurde in vielen Planungsdokumenten ein vergleichsweise breites Spektrum an Ökosystemleistungen ermittelt. Habitat- und kulturelle Ökosystemleistungen waren dabei die am häufigsten repräsentierten Kategorien. Die Ergebnisse zeigen zum einen, dass das Konzept der Ökosystemleistungen helfen kann, verschiedene Leistungen auf systematische Art und Weise in der Planung zu berücksichtigen. Zum anderen wurde deutlich, dass zusätzliche Aspekte wie die Minderung von Umweltbelastungen oder die Erhöhung von Resilienz gegenüber Naturgefahren durch Ökosystemleistungen stärker bedacht werden könnten.

Forschungsartikel III analysiert empirisch wie Multifunktionalität aktuell in der Grünflächenplanung in zwanzig europäischen Städten berücksichtigt wird. Die untersuchten Dokumente und Interviews zeigten, dass ein breites Bewusstsein für die Vielfalt der gesellschaftlichen, ökologischen und ökonomischen Funktionen von Grünflächen vorhanden ist. Allerdings waren die Informationen darüber, wie Städte tatsächlich die Sicherung oder Erhöhung der Multifunktionalität planen, begrenzt. Um diese Lücke zu schließen, wurden drei vertiefte qualitative Fallstudien in Berlin (Deutschland), Edinburgh (Großbritannien) und Aarhus (Dänemark) durchgeführt. Die drei Städte wurden als „good practice"-Fälle ausgewählt, um konkret aufzuzeigen, wie verschiedene Städte für Multifunktionalität planen: durch die Integration von Multifunktionalität als Planungsziel, die systematischen Bewertungen von Grünflächenfunktionen sowie die Gestaltung multifunktionaler Grünflächen.

Zusammenfassend wird für die Planungspraxis eine stärkere Berücksichtigung von Multifunktionalität empfohlen. Dazu gehört die Einbettung von Multifunktionalität als Ziel in der strategischen (Grünflächen-)Planung und die Sicherstellung einer proaktiven Umsetzung sowie die umfassende Bewertung der vorhandenen Grünflächen mit Bewertungsansätzen, die viele Funktionen oder Leistungen und die Beziehungen zwischen ihnen erfassen können. Auf der Ebene von Einzelflächen sind integrierte Lösungen erforderlich, mit denen ein breites Spektrum an Leistungen bereitgestellt und über Raum und Zeit verteilt, Synergien erhöht und Zielkonflikte vermieden werden können.

Forscherinnen und Forscher sollten sich der Lücken zwischen dem Stand der Wissenschaft und dem Informationsbedarf in der Planungspraxis bewusst werden. Das betrifft zum Beispiel das Spektrum der in der Forschung präsenten Ökosystemleistungen, das für die Planung zu eng gesteckt ist, und Bewertungsansätze, die auf Daten zur Landbedeckung basieren und nicht die in der Praxis benötigten ortsbezogenen, feinaufgelösten Daten bereitstellen. Zugleich zeigten sich Gemeinsamkeiten zwischen Forschung und Praxis. Beispiele sind eine anthropozentrische Perspektive oder ein Interesse an der systematischen Bewertung von Leistungen von Grünflächen.

Durch den Vergleich des Standes der Forschung mit der aktuellen Planungspraxis zielt diese Doktorarbeit darauf ab, Diskurse zwischen beiden Sphären zu fördern und sie mit konzeptionellen Grundlagen sowie praktikablen Planungsempfehlungen, die den Stand des Wissens auf beiden Seiten kombinieren, zu bereichern. Es wurde deutlich, dass umfassendere und integrierte Bewertungsansätze für grüne Infrastruktur erforderlich sind, die helfen Multifunktionalität proaktiv zu fördern. Solche Ansätze müssen soziale, ökologische und potenziell auch ökonomische Werte integrieren und nicht nur ein breites Spektrum an Funktionen oder Leistungen, sondern auch deren Zusammenhänge erfassen. Folglich muss die zukünftige Forschung transdisziplinäre Ansätze verfolgen und Expertinnen und Experten aus Wissenschaft und Planungspraxis sowie aus verschiedenen Disziplinen einbeziehen.

Schlagwörter: Multifunktionalität, grüne Infrastruktur, Grünflächen, Ökosystemleistungen, Stadtplanung, Strategische Planung, integrierte Bewertung

Cumulative Thesis

This cumulative dissertation is based on the following three peer-reviewed scientific papers. They are referred to in the text in Roman numerals. At the time of the thesis' submission two of them have already been published, one is in print.

The papers are briefly summarised in Chapter 4 and included in the Appendix with kind permission of the publishers.

Paper I

From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas

Hansen, R. and Pauleit, S.

Published in

AMBIO: A Journal of the Human Environment 43 (4): 516–529 (17 April 2014)

DOI 10.1007/s13280-014-0510-2

Summary

Green infrastructure and ecosystem services are promoted as concepts that have potential to improve environmental planning in urban areas. Both are considered to support a holistic understanding of the complex interrelations and dynamics of social-ecological systems. However, the scientific discourses around both concepts still lack application-oriented frameworks that consider such a holistic perspective and are suitable to mainstream green infrastructure and ecosystem services in planning practice. This literature review explores how multifunctionality as one important principle of green infrastructure planning can be operationalised by approaches developed and tested in research on ecosystem services. Specifically, approaches developed in the context of ecosystem services can help to assess the integrity of green infrastructure networks, balance supply and demand of ecosystem services and consider trade-offs. A conceptual framework for the assessment of multifunctionality from a social-ecological perspective is proposed that can inform the design of planning processes and support stronger exchange between research on green infrastructure and research on ecosystem services.

Author's contribution

The first author R. Hansen developed the conceptual idea and reviewed the literature. She undertook the literature analysis, the development of the conceptual framework, and the overall writing process under supervision of the co-author. The co-author provided scholarly advice and contributed to the language editing.

Paper II

The uptake of the ecosystem services concept in planning discourses of European and American cities

Hansen, R., Frantzeskaki, N., McPhearson, T., Rall, E., Kabisch, N.,
Kaczorowska, A., Kain, J.-H., Artmann, M. and Pauleit, S.

Published in *Ecosystem Services* 12: 228–246 (6 January 2015)
DOI 10.1016/j.ecoser.2014.11.013

Summary

Ecosystem services are gaining increasing attention as a promising concept to more actively consider and plan for the varied benefits of the urban environment. However, to have an impact on decision-making, the concept must spread from academia to practice. To understand how ecosystem services have been taken up in planning discourses, a cross-case comparison of planning documents in Berlin, New York, Salzburg, Seattle and Stockholm was conducted. The analysis has shown that explicit references to the concept of ecosystem services were rare and primarily found in documents from cities situated in countries that entered into ecosystem service discourses early, namely Stockholm and New York. However, implicit references and thus potential linkages between the ecosystem service concept and planning discourses were found frequently among all cities, particularly in Seattle. The thematic scope, represented by references to 21 different ecosystem services, is comparably broad among the cases, while cultural services and habitat provision appeared most frequently. High-level policies were shown to promote the adoption of the ecosystem service concept in planning. The results support the assumption that the ecosystem service concept holds potential to strengthen a holistic consideration of urban nature and its benefits in planning by promoting a systematic consideration of a broad range of services, covering provisioning, regulating, supporting and habitat services, as well as cultural services. The study furthermore revealed potential for the development of ecosystem service approaches with regard to mitigation of environmental impacts and improving urban resilience.

Author's contribution

The first author R. Hansen led the conceptual work and developed the study approach. The data on five cities was predominantly collected by the co-authors, the first author contributed to the analysis of documents from Berlin. The first author analysed the data provided by the co-authors and wrote the manuscript. The co-authors contributed to the manuscript by reviewing drafts, providing information about the cases for which they had collected the data, and helped to underpin the discussion of the results with case-specific information.

Paper III

Planning multifunctional green infrastructure for compact cities: What is the state of practice?

Hansen, R., Olafsson, A.S., van der Jagt, A., Rall, E. and Pauleit, S.
Published in *Ecological Indicators*: in press (online 6 November 2017)
DOI 10.1016/j.ecolind.2017.09.042

Summary

Urban green infrastructure planning aims to develop green space networks in limited space in compact cities. Multifunctionality is considered key to achieving this goal. However, little information is available on how multifunctionality is applied in urban planning practice. This paper examined its application in a semi-quantitative study in 20 European cities as well as three qualitative good practice case studies, both including interviews with local stakeholders and analyses of planning documents. The semi-quantitative study revealed a broad awareness among chief planners of the variety of social and ecological functions provided by green spaces; yet, the analysed strategic plans contained little information on how to enhance multifunctionality. Regardless of the lack of details, cities facing growth were more likely to consider promoting multifunctionality as a planning aim. The qualitative case studies in Germany (Berlin), the United Kingdom (Edinburgh) and Denmark (Aarhus) provided a detailed insight into how multifunctionality is handled on different spatial scales and revealed great differences from academic ecosystem service assessments. The findings led to five recommendations for promoting multifunctional urban green infrastructure: 1) systematic and integrated assessments of all urban green spaces and their functions; 2) standards and guidelines for multifunctionality in strategic planning; 3) design and management for multifunctionality at the site-level. Furthermore, all measures need to 4) consider synergies, trade-offs and the capacity of urban green spaces to provide functions as part of the wider green infrastructure network, and 5) depend on cooperation between different sectors and public departments.

Author's contribution

The first author R. Hansen developed the study approach and conceptual framework building on studies developed and mainly led by her and E. Rall within the GREEN SURGE project. Two of the case studies have been researched and analyzed by the co-authors A.S. Olafsson (Aarhus) and A. van der Jagt (Edinburgh), the first author and E. Rall together undertook the Berlin case study. The first author developed the manuscript and wrote most of it, the co-authors contributed to results and discussion, E. Rall also to the methods. All co-authors also contributed to the manuscript by reviewing drafts and providing scholarly advice.

Thesis

1. Introduction

1.1. Research Background

Human activities have global-scale impacts on the earth system and the speed of these alterations has led to the proclamation of the *Anthropocene* as a new geological age (Crutzen, 2002). The realization of the fundamental changes revived debates on sustainable use and resilience of natural systems (Folke et al., 2011; Steffen et al., 2011; Chapin et al., 2010). Additionally, in the first decade of the 21st century humanity also reached an urban era, with more than half of the world's population living in cities, facing on-going worldwide urbanization (UN, 2015a).

The challenges and risks arising from these developments are targeted by global policies such as the *Sustainable Development Goals* (SDGs) and the *New Urban Agenda*. While the UN's *Millennium Development Goals* gave a strong impetus to improving living conditions for humans by reducing poverty and hunger or increasing access to education, the 17 SDGs also include comprehensive environmental goals such as protection of oceanic and terrestrial ecosystems and combating climate change. As a response to global urbanization processes, the SDGs encompass a goal to "make cities inclusive, safe, resilient and sustainable" (UN, 2015b). The UN's urban policy, the New Urban Agenda calls not only for sustainable but also compact urban development (UN 2017). While compaction often puts pressure on green and open spaces, these spaces are at the same time considered fundamental for quality of life and sustainability in compact cities (Haaland and van den Bosch Konijnendijk, 2015; UN, 2015b; James et al., 2009; Jim, 2004).

The challenges of the Anthropocene such as on-going environmental degradation, human-induced climate change and loss of biodiversity (Folke et al., 2011; Rockström et al., 2009) promoted the concept of ecosystem services as an approach to illustrate and communicate how the degradation of ecosystems endangers human well-being and even impedes the attainment of the Millennium Development Goals (MA, 2005). Since the 2000s and the *Millennium Ecosystem Assessment* (MEA; ibid.), ecosystem services gained prominence as an anthropocentric paradigm suitable to emphasise the benefits people obtain from nature (Potschin and Haines-Young, 2006) and in doing so, to link biodiversity and its multiple values to the broader social-economic context (Paloniemi et al., 2012; TEEB, 2010; Liu et al., 2010; Daily et al., 2009).

Concurrently, green infrastructure has been promoted as an approach for sustainable land use and safeguarding biodiversity in urban and rural areas (Mazza et al., 2011; Ahern, 2007). The concept of green infrastructure emerged in the US in the 1990s, caused by growing concern of uncontrolled urban sprawl (Walmsley, 2006; Benedict and McMahon, 2002). It represents a shift of paradigm by treating green structures in a par with built infrastructure like transportation networks and thus valuing their importance for human well-being (ibid.).

In Europe, green infrastructure became a part of the EU's biodiversity policy and the European Commission launched a strategy titled ''Green Infrastructure—Enhancing Europe's Natural Capital'' to be considered in planning and territorial development (European Commission, 2013). In this context, green infrastructure is defined as a ''strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services'' (ibid.: 3). The connection between green infrastructure and ecosystem services has also been suggested in several academic publications (e.g. Sussams et al., 2015; Andersson et al., 2014; Lafortezza et al., 2013; Pataki et al., 2011; Tzoulas et al., 2007).

The conceptualization and operationalization of ecosystem services in an urban context is broadly discussed with numbers of academic publications steeply rising since around 2005 (Haase et al., 2014). At the time when this thesis project has been developed, ecosystem services have been suggested as a useful concept for urban planning and policy-making (Gómez-Baggethun and Barton, 2013; Colding, 2011), but had not yet entered spatial planning (Albert et al., 2014; Hauck et al., 2013; Niemelä et al., 2010).

In contrast, planning researchers and practitioners have discussed and applied green infrastructure as a holistic planning approach that combines ecological and social perspectives, mainly in the UK and the US (Rouse and Bunster-Ossa, 2013; Pauleit et al., 2011; Kambites and Owen, 2006). However, the theoretical basis for green infrastructure was fragmented and elusive and a broader debate on the actual meaning of green infrastructure, suitable frameworks and tools, as well on the implications of its uptake in planning practice was missing. First attempts to synthesise the disconnected positions and to apply a critical lens on the concept include work by Mell (2009) and Lennon (2014).

Multifunctionality is largely considered as a core principle of the green infrastructure approach (Liquete et al., 2015; Madureira and Andresen, 2013; Kambites and Owen, 2006) and seems to be a good entry point for the concept of ecosystem services being concerned with assessing the multiple green space benefits (EC DG Environment, 2012; Pauleit et al., 2011). However, multifunctionality is likewise an elusive concept and there is uncertainty about how to operationalise it (Sussams et al., 2015; Brandt et al., 2004).

1.2. Research Motivation and Questions

The motivation for this dissertation thesis is to explore the linkages between green infrastructure and ecosystem services in order to develop a combined framework. A combined approach has the potential to leverage the strengths of both concepts: The green infrastructure concept which emerged from the planning world contains logics and elements relevant for planners, while the research on ecosystem services generated a rich body of conceptual frameworks and elaborated assessment tools that, for example, help to systematise and structure the consideration of multiple ecosystem services.

By working on ways to link the two concepts and by examining the nexus between academia and planning practice, this thesis aims at developing further the theoretical basis of multifunctionality as a core principle of green infrastructure and at devising conceptual frameworks that develop relevance for planning practice. Such a research approach involves extensive analysis of the existing theory and comprehensive study of green space planning practice in different cities. For the latter, this thesis aims to explore *if* and *how* the concepts under consideration are applied using quantitative and qualitative case studies.

This study is important from a research perspective since it will help to synthesise the similar, but at the same time incongruent conceptualizations of green infrastructure, ecosystem services, and multifunctionality and subsequently improve the theoretical foundation of green infrastructure. Endeavour to link theory and application calls for empirical knowledge on how the current planning practice considers these concepts. Secondly, from the perspective of planning such a study is needed, since knowledge and tools developed in academia could help planners to better protect and develop urban green spaces under conditions of urbanization. Thirdly, empirical knowledge on the application of multifunctionality in planning can help to identify, which mechanisms or tools can help to promote multifunctional urban green infrastructure. Such knowledge can be instructive for planners in different cities.

Consequently, the **research questions** are:

(1) Can the concepts of green infrastructure and ecosystem services be linked by a framework for multifunctionality?
(2) How are multifunctionality and ecosystem services currently considered in planning practice? And what are good practices for developing a multifunctional green infrastructure?
(3) What can be recommended from the academic state-of-the-art and the applied approaches in order to support a comprehensive consideration of multifunctionality in urban green infrastructure planning?

This thesis project was related to two European research projects. First, it contributed to the project URBES (Urban Biodiversity and Ecosystem Services, 2012-2014), funded by EU-ERA-NET BiodivERsA. The project aimed to increase knowledge on the relationship between biodiversity and ecosystem services for human well-being and to strengthen the capacity of European cities to adapt to climate change and other future challenges. The thesis was connected to task 4 “Development of planning strategies and scenarios for green infrastructure planning in urban areas”.

Second, parts of this thesis have been developed within the project GREEN SURGE (Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy, 2013-2017), funded by the European Union's Seventh Framework Programme. GREEN SURGE aimed at identifying, developing and testing ways of connecting green spaces, biodiversity, people and the green economy, in order to meet major urban challenges such as climate change adaptation or social cohesion, including a sound evidence base for green infrastructure planning and implementation and its benefits to local communities. The thesis project contributed to work package 5 “Green infrastructure planning and implementation”.

1.3. Structure of the Thesis

The thesis is structured and organised according to the three research objectives and the mixed-method research approach, mainly involving literature review and case study research. Figure 1 illustrates the set-up of the different study phases, their methodological approaches, and how these interrelate.

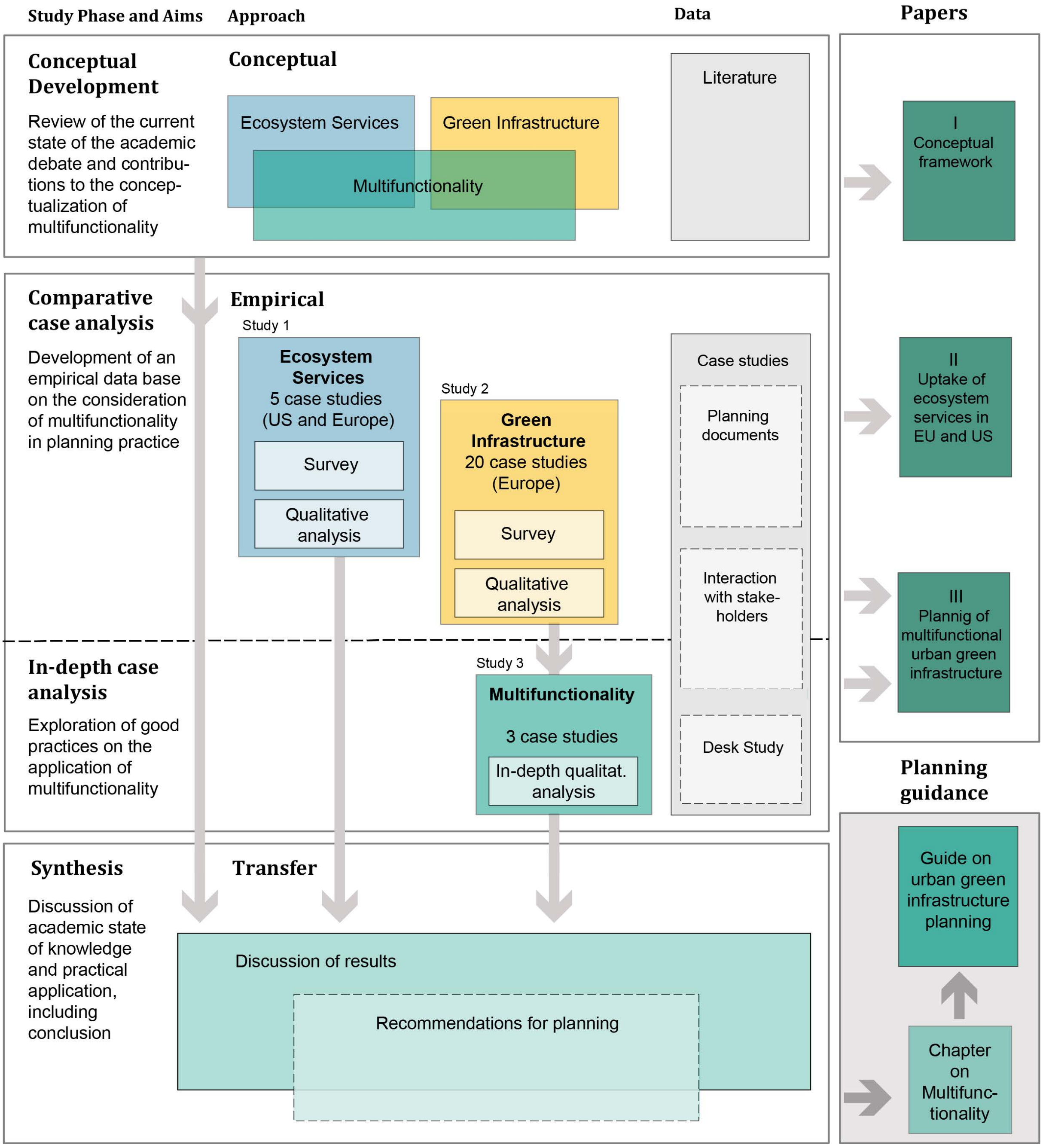

Fig. 1: Structure of the dissertation, including three academic papers. The planning guide includes results on multifunctionality from the thesis but is not part of it.

For the first research question, a meta-study of the current academic discourse addressed the theoretical foundations of green infrastructure and ecosystem services with respect to multifunctionality. The relevant literature has been reviewed systematically and synthesised into a conceptual framework for multifunctionality that represents the state of academic knowledge. This provides a first indication of how multifunctionality can be operationalised in comprehensive manner (paper I). The literature review was undertaken as part of the URBES project.

For the second research question, empirical studies based on quantitative and qualitative methods shed light on the current application of multifunctionality and ecosystem services in planning practice. Quantitative and qualitative data on the current consideration in planning practice has been gathered in two comparative studies: one on ecosystem services in five US and European cities (paper II/study 1) and one on green infrastructure, respectively multifunctionality, in 20 European cities (paper III/study 2). In a third study, based on study 2, three in-depth case studies revealed how multifunctionality is currently operationalised (also paper III/study 3). Empirical data for study 2 (paper II) was obtained during one of the several sub-studies within the URBES project, while paper III contributed to GREEN SURGE.

In the discussion part, the empirical findings are linked to the conceptual framework and translated into recommendations for promoting multifunctionality in planning (research question 3). The findings have also been used for a practitioners guide on urban green infrastructure planning (Hansen et al., 2017), which has been published as part of the GREEN SURGE project. Core recommendation and content of the guide regarding multifunctionality will be summarised in the discussion part, while the guide itself is not part of this thesis. Finally, the conclusion presents the core findings, pointing at ways forward for the research communities around urban green infrastructure and ecosystem services.

2. Background and Concepts

This chapter provides the background and defines basic concepts in order to delineate the field of research. Three concepts, namely strategic urban planning, environmental planning, and urban ecology, define the wider frame before the core topics multifunctionality, green infrastructure, and ecosystem services will be introduced, including a brief overview about their historic development and the current state of discussion.

2.1. Concepts from Planning and Ecology

2.1.1. Strategic Urban Planning

Urban areas are characterised by high spatial diversity and high density of different stakeholders with specific values, needs, and claims competing for land (Pickett et al., 2011; Ernstson et al., 2010; Colding et al., 2006; Alberti et al., 2003). Urban planning aims at organising the spatial distribution of land uses and at mitigating conflicts of interest, for instance, by means of comprehensive planning (Hall and Tewdwr-Jones, 2011; European Commission, 1997). In this thesis project, planning refers to spatial planning and, more specifically to the "plan-making function" of planning that is represented by strategies and principles for spatial organization, land use or built form arrangement (Healey and Williams, 1993). The focus lies on "strategic planning" as *"a transformative and integrative, (preferably) public sector-led [...] socio-spatial [...] process through which a vision, coherent actions and means for implementation are produced that shape and frame what a place is and might become"* (Albrechts, 2006: 1491).

Albrechts (2004) collated the historic development of strategic planning in Western countries. In brief, strategic planning applied in the 1960s and 1970s was superseded by a project-oriented approach (e.g. in the context of urban renewal) in the 1980s. However, at the turn of the century a revival of strategic planning was apparent. The realization that fragmented planning activities could neither sufficiently deal with complexity, control development nor hinder environmental degradation fuelled comprehensive long-term perspectives for cities, city-regions, and regions (ibid.).

Strategic planning is not considered as *"a technical process of producing material things but rather a process of mutual learning involving interaction between multitudes of actors. This understanding of planning as a 'soft' process is more attuned to the seemingly endless multifarious negotiations that many practising planners are constantly involved in, and to the, at best, often very indirect impact that their plans have"* (Faludi, 2000: 299). Key characteristics of strategic planning include a focus on decisions and actions, targeted at an open future, as well as problem- and process-oriented actions (ibid.; Albrechts, 2004). This requires the involvement of stakeholder and communicative planning processes (Healey, 1996).

That planning is more than a technical process has also been expressed by the term "*planning as practice of knowing*" (Davoudi, 2015). Davoudi describes different kinds of planning knowledge: *"knowing* what *(cognitive/theoretical knowledge), knowing* how *(skills/technical knowledge), knowing to* what end *(moral choices) and* doing *(action/practice)"* (ibid.: 3, based on Blackler, 2016). Together the different kinds of knowledge form the basis for *"the art of* practical judgement *(wisdom)"* (Davoudi, 2015: 3). Planners have also been considered as *bricoleurs*, a term going back to Lévi-Strauss (1966) and referring to actors that collect different forms of knowledge, tools, technologies and materials and adapt them for a specific purpose (Davoudi, 2015). Planning is also often a pragmatic activity and might adjust the planning purpose according to the availability and accessibility of resources. Not least, planning is shaped by political processes, and negotiations between different stakeholders might strongly influence plan contents (ibid.). This is especially true for problem- and process-oriented strategic planning.

Poister and Streib (2005) have empirically analysed the elements of strategic plans in municipal governments in the US. According to their study, the most common elements of strategic planning include goals and objectives, a vision for the future, review of the organizational mission, and action plans. Arts et al. (2006) developed a framework to analyse policy arrangements and identified four dimensions: discourse, actors and coalitions, rules of the game, and resources.

Based on this framework and experiences from planning research, within the GREEN SURGE project potential elements of strategic green infrastructure planning that are required to cover the process from plan development to implementation have been discussed and narrowed down to:

- **Strategy approach:** planning type (e.g. vision plan or local development plan) including core concepts, planning objectives, as well tools and methods used, e.g. for assessment and valuation of the current state or of courses of action.
- **Instruments and mechanisms for implementation:** approaches to put the strategy into action such as action plans or pilot projects.
- **Resources:** include financial and material resources, but also human resources (e.g. manpower or knowledge).
- **Actors and their roles:** involved governmental and non-governmental actors, their roles, and also their relations to each other, including cooperation and coalitions as well as participation.
- **Monitoring and evaluation:** such as reporting and reviews (Hansen et al., 2016a; based on the policy cycle by Althaus et al., 2013).

While these elements can take numerous forms, it was assumed that all of them will be required to some degrees and in different combinations for successful strategic green infrastructure planning processes and that guidance for planning practice needs to correspond to these complex processes (Hansen et al., 2017).

To evaluate different successful planning processes and the factors that supported or hindered them as well as the outcome and impacts, contextual factors (e.g. global needs and challenges, socio-economic developments or political drivers) and perceived and measured effects (ecological, social, economic and institutional) have been considered within GREEN SURGE (ibid., 2016).

2.1.2. Environmental Planning and Urban Ecology

Planning concerned with balancing human use with ecological issues and aimed at developing sustainable land use practices is often described as environmental or ecological planning (e.g. Ndubisi, 2014; Randolph, 2012; Steiner and Brooks, 1981). Natural resource depletion through human activities has already been a worry in the 19th century and raised by intellectuals such as writer and philosopher Henry David Thoreau (1817–1862), landscape architect Frederick Law Olmsted (1822-1903) or Ebenezer Howard (1850-1928), the founder of the Garden City Movement, all of which provided visions for more sustainable living, land use practices, and urban design (Ndubisi, 2014; Eisenman, 2013; Sullivan, 2009).

Fredrick Law Olmsted is also considered as an early green infrastructure planner since he aimed at improving urban living conditions through park and parkway systems in Northern American cities. Additionally, the Back Bay and Muddy River projects in Boston, part of the city's park system Emerald Necklace (see Fig. 2), have been described as pioneer projects of environmental restoration that show similarities with modern environmental planning (Eisenman, 2013; Spirn, 1984). Olmsted also represents the tradition of planning for connected green structures in cities which became an important foundation for urban green space planning and is also represented by concepts such as green belts or green wedges in numerous cities (Ahern, 2002). The idea of creating green space networks is also a core principle of the green infrastructure approach (Benedict and McMahon, 2006).

However, since the parks movement in the 19th century in Europe and Northern America, green spaces in urban areas have been developed mainly for socio-cultural and sanitary reasons detached from ecological questions (Clark et al., 2017; Schuyler, 2015).

Environmental protection and sustainable natural resource management became a global concern in the 1960s and were institutionalised in legislation and policy as well as in spatial planning in many countries across the world (Ndubisi, 2014; Randolph, 2012; Forman 2008). Ian McHarg became an icon for ecological planning and design with his book "Design with Nature" (1969) which suggested planning approaches that encompass ecological and social factors (such as surface drainage, risk of erosion, or recreation) next to factors on efficiency and costs. By layering, areas of high values for different aspects can be identified in order to make better informed planning decisions. McHarg suggested an approach for environmental planning still relevant today (BenDor et al., 2017). To date, sophisticated methods have been developed for analysing a multitude of environmental/ ecosystem components and processes, for instance in the context of landscape ecology (e.g. Chapin et al., 2011; Forman and Godron, 1986; Leser, 1978), and for operationalising them in environmental planning (e.g. Randolph, 2012).

In the field of ecology, a broader recognition of urban areas can be noted since the 1970s when effects of cities on natural environments but also natural processes taking place in cities gained attention. For instance, the Berlin School of Urban Ecology developed ecological site analyses and field botany on urban wastelands (Sukopp, 2008). In the early phase, the research was focused on exploring habitat conditions for urban flora and fauna aiming at nature conservation. Humans where merely considered as disturbance factors or users of urban nature, with a focus on recreation.

Fig. 2: Boston's Emerald Necklace, the city's park system envisioned by Olmsted in the 19th century, is still intact, with some parts such as the Muddy River area (bottom) requiring restoration and flood control improvement (own photos from 2014).

By taking up approaches from landscape ecology, chaos theory, and systems thinking, around the 1990s a turn to applied urban ecology could be noted that aimed at contributing to sustainable urban development (Weiland and Richter, 2009). The phrase "ecology *of* cities" represents a paradigm shift towards considering humans as integral part of urban ecosystems including the role of planning and decision-making, institutions, and social processes (Pickett et al., 2016).

The current understanding of cities in urban ecology portrays them as coupled complex, heterogeneous, flexible and unstable social-ecological systems (Pickett et al., 2011; Alberti et al., 2003; Grimm et al., 2000). In planning practice, the complexity of urban systems is partly mirrored by sophisticated urban planning systems present in many Western countries including comprehensive and sectorial planning. However, the high level of specialization and separate responsibilities are often also considered as impeding a holistic perspective (Kambites and Owen, 2006).

2.2. Multifunctionality

2.2.1. From Functional Diversity to Multifunctional Landscapes

Understood in its literal sense, multifunctionality implies "the condition of being multifunctional" or holding a "diversity of function" (Oxford Dictionary, online version). In the context of spatial planning and land use management, multifunctionality has been applied with different meanings and underpinned with a variety of conceptual frameworks.

First of all, in forestry multifunctionality implies that forests can simultaneously provide ecological, economic, and social functions. The concept was taken up in European forestry policies since the 1970s, with a renaissance in the 1990s due to the global discourse on sustainable development (Pröbstl et al., 2008; Schmithüsen, 2007). Outside of forestry, multifunctionality gained popularity in three contexts within Europe during the early 21st first century:

- agricultural policy since 2000 as promoted by the Food and Agriculture Organisation (FAO) and the Organisation for Economic Co-operation and Development (OECD) (e.g. Wiggering et al., 2003),
- (urban) land use concepts (e.g. special issue "Multifunctional Urban Land Use" in the journal "Built Environment" in 2004), and
- landscape development concepts (e.g. "Multifunctional landscapes" book series by Brandt et al., 2004; books by the "Landscape Tomorrow" research network[1] such as Wiggering et al., 2003 and Mander et al., 2007a).

In the context of agriculture, multifunctionality has been discussed in relation to the diversity of (economic resp. market-oriented) farming activities as well as in relation to multifunctional agricultural landscapes; the latter being in line with multifunctionality as a landscape development concept (Zasada, 2011; Wiggering et al., 2003). For studying multifunctional urban green infrastructure, urban land use and landscape multifunctionality are most relevant and consequently are the focus of the following chapter.

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[1] Landscape Tomorrow was an European research network for sustainable development of multifunctional landscapes, founded 2002 (Helming 2003), last activity according to website in 2008. See http://tran.zalf.de/landtom/index.html.

2.2.2. Multifunctionality as a Land Use Concept

Multifunctionality as a spatial (urban) planning concept has been discussed in the Netherlands since the late 1990s. A general understanding of multifunctionality, in line with the lexical meaning, includes *"the combination of different socio-economic functions in the same area"* (Priemus et al., 2000 cited in ibid., 2004: 270). According to Vreeker et al. (2004), the multifunctional land use concept is focussed on socio-economic relations, e.g. transport between business sites and housing for labour forces or distance to markets within city-regions, building on strategies for efficient and integrated land use that can be tracked back to economic theories of agglomeration such as the concentric city model by von Thünen (1826), the growth pole theory by Perroux (1950), or the incubator model by Chinitz (1961). Additionally, multifunctionality has been described as being similar to mixed-use developments which have been promoted since the 1970s, and as being connected to the compact city model and the Smart Growth movement in the US. The similarities concern increasing density and efficiency as well as a mix and concentration of land use functions, whereby the emphasis on synergies has been described as a unique trait of the multifunctional land use concept (Vreeker et al., 2004).

Attempts to operationalise land use multifunctionality largely refer to Lagendijk and Wisserhof (1999 cited in Rodenburg and Nijkamp, 2004: 280) who suggested that multifunctional land use needs to meet at least one of the following criteria:

(1) intensification (increasing land use efficiency by a function),
(2) interweaving (the use of the same area for several functions),
(3) using the third dimension (underground or surface area), and
(4) using the fourth dimension (several functions in the same area within a certain time frame).

However, the usefulness of the first criterion has been questioned since it can also relate to mono-functional land use (ibid.).

Consequently, it has been suggested to characterise multifunctional land use strategies by three factors: increasing the number of functions, the degree of interweaving, or spatial heterogeneity within a given area. It further has been suggested to differentiate three types of multifunctionality:

(1) Multifunctionality by "diversity": addition of functions within one area (without dispersing them across the area)
(2) Multifunctionality by "interweaving": increasing the dispersion of functions within an area (without increasing the number of functions)
(3) Multifunctionality by "spatial heterogeneity": increasing the number of functions and dispersion within an area (ibid.).

The importance of time and spatial dimensions has been highlighted by Rodenburg and Nijkamp (2004) who noted that functions can be organised sequentially (e.g. during the day) as well as vertically (e.g. different layers in a building). Batty et al. (2004) also point to the temporal diversity of daytime and nighttime economies. These aspects can be covered under type 3.

When analysing multifunctionality of a given area, it should be considered that results will likely correlate with the spatial scale and/or time-span considered: longer time spans and larger areas (such as city or region) will usually lead to a higher degree of multifunctionality (Rodenburg and Nijkamp, 2004). Neighbourhoods or larger blocks have thus been suggested as appropriate scale for both research and planning. Further challenges occur in (statistically) analysing multifunctionality since it relates to activities such as increasing diversity of functions that can only be observed over time (ibid.).

Rodenburg and Nijkamp (2004) provide a framework for synergies between land uses and human activities (i.e. work/labour production, storage, leisure living or shopping). They compare land use by spatial functions (such as residential housing, commercial/ industrial use, cultural facilities, agriculture, as well as nature and landscape) and human activities in pairs and judge their compatibility. For green and other open spaces, they suggest that "water" is compatible with a quite large variety of human activities including work/labour production, distribution, and recreation/social activities, while "agriculture" is only compatible with work/labour production and to a certain extent with recreation/social activities. "Nature and landscape" are suggested to only provide synergies with recreation/social activities and to be largely incompatible with all other human activities. This coarse classification and identification of limited compatibilities point to the fact, that land use categories might not be sufficient for discussing multifunctionality of green spaces.

A framework to evaluate multifunctional land use systems has also been developed by Paracchini et al. (2011). This framework is targeted at the regional or even European scale and aims to support decision-making by illustrating economic, environmental, and social effects of different policy scenarios. The indicators concern each three economic, environmental and social so called "land use functions" (e.g. land-based production and infrastructure; abiotic resources and provision of habitat; work and culture). While these land use functions are still relatively coarse, the framework is complex and provides instructive ideas such as:

- definition of sustainability limits for each indictor that allow for individual assessment of each land use function, and
- combination of the different indicators into one framework that makes possible identification of trade-offs and scenarios that have the least negative impact.

The framework appears as a suitable tool to consider trade-offs that would result from land use decisions. However, it represents a monofunctional approach to land use, allowing the evaluation of different functions within a large area and implicating competition for land between them. Such a framework fails to include synergies, in particular concerning different functions within one location.

2.2.3. Landscape and Green Space Multifunctionality

Apart from land use planning, multifunctionality has been considered in landscape ecology and nature conservation. Although landscape multifunctionality is frequently mentioned, it is also often a subject of vagueness. This can be explained by the fact that obviously most (cultural) landscapes are inherently multifunctional, given they are heterogeneous enough to host a range of social, economic, and ecological functions simultaneously (Mander et al., 2007b). Consistent with this understanding, the multifunctional capacity is also considered for urban green spaces and numerous publications reproduce varying arrays of functions (e.g. Fuller and Gaston, 2009; Chiesura, 2004; Beer et al., 2003), ecosystem services (e.g. Pulighe et al., 2016; Lin et al., 2015; Niemelä et al., 2010), or values (e.g. Baycan-Levent et al., 2009) provided by natural elements in cities. However, these demonstrations of benefits represent the intent to emphasise green space values without necessarily pointing to multifunctionality as a concept.

In landscape ecology, *function* together with *structure* represents a core concept: Forman and Godron (1986: 11) define function as *"the interactions among the spatial elements, that is, the flows of energy, materials, and species among the component ecosystems."* Apart from applying it to an ecosystem *process* or *interaction*, functionality has also been related to *purpose* or *ability to work* (or *capacity* of a function) (cf. Brandt and Vejre, 2004). Without entering the complex discourse on landscape functions (cf. Jax, 2005), it seems obvious that this variety in understanding landscape functions is in particular important when opposed to functions defined within the frame of ecosystem services (see Chap. 2.4). Landscape functions are applied in planning, for example, in Germany (Bastian et al., 2012; von Haaren and Albert, 2011) and the Netherlands (de Groot, 1992).

Compared to the Dutch multifunctional land use concept, for example regarding the spatial and temporal dimension of multifunctionality or the dynamic nature of multifunctionality, very similar descriptions and characteristics can be found in literature by German scholars (e.g. Wiggering et al., 2006; Bastian, 2004; Helming and Wiggering, 2003). Bastian (2004: 79) also emphasises synergies (and their opposite) when he notes: *"Usually, there is no 'neutral coexistence' of different landscape functions, but conflicts, interferences, and synergies are common. […] In the process of landscape planning these problems must be solved, and conflicts should be defused to achieve a harmonious development including the protection of landscape in such a way, which can be supported by the major part of the human society."*

This means, for example developing land use regimes that simultaneously promote nature conservation, recreational use, and agriculture or forestry in the same area (von Haaren and Reich, 2006) or, in other words, concurrently promote ecological, social, and economic functions of a given landscape (Pauleit et al., 2011; Mander et al., 2007b). Compared to the land use approach to multifunctionality, there is a stronger emphasis on enhancing the ecological and social functions (Brandt and Vejre, 2004). When agricultural landscapes are concerned, classical agrarian economic functions and products (commodity products) are usually the starting position for discussing the enhanced provision of non-commodity products (additional services such as securing biodiversity or promoting recreational uses). This included the question of how farmers could be rewarded for the non-commodity products (Wiggering et al., 2006). However, Wiggering et al. (2003) warned that multifunctionality must not be limited to diversity in economic activities of rural land users and less environmentally harmful agriculture, forestry, and fishery practices. Landscape multifunctionality must instead be understood in a more comprehensive manner.

From a landscape perspective, multifunctionality follows the tradition of (rural) land use concepts that have been developed since the 1970s to reduce environmental degradation and to propel transformation of monofunctional land use practices into more sustainable ones. Examples include the concept of *differentiated land use* which suggests spatial arrangements of (agricultural) land uses, combined with a minimum quota of natural elements such as hedges or copses (Haber, 1971, 1989). In the same line, *integrated* versus *segregated nature conservation* has been debated (e.g. Ammer et al., 1995). Landscape multifunctionality is thus closely linked to the broader discussion on sustainable development. To highlight the potentials as a forward-looking and proactive approach for landscape development, multifunctionality has been underpinned with a variety of conceptual frameworks (Brandt et al., 2004; Helming and Wiggering, 2003). Moreover, different perceptions of multifunctionality exist in parallel (Brandt and Vejre, 2004):

- a geo- and bio-ecological (or natural science) approach concerned with the different functions provided by a certain "natural landscape", analysing matter and energy flows,
- an approach bridging biophysical and anthropocentric perspectives by considering land use types and related land cover as well as the material and immaterial values that are related to these landscape systems (similar to the ecosystem services concept),
- a policy (or social science) perspective dealing with the issues of competing and complementary land uses and related economic or juridical issues (e.g. free rider problems, ownership, regulation of conflicts),
- a cultural perspective focussed on aesthetics and cultural interpretation of landscape functionalities (related to landscape architecture and landscape planning traditions), and
- a holistic systems theory approach that aims at integrating the perspectives from above.

According to Brandt and Vejre (2004), the first four perspectives are often considered independently from each other by different disciplines. Naveh (2001) strongly advocated for the fifth understanding and pointed to the need for transdisciplinary research and holistic consideration of landscapes as complex and dynamic systems. Building on systems theory and Kuhn's "scientific revolution", he formulated "10 major premises for a holistic conception of multifunctional landscapes". These paradigms include the plea to consider multifunctional landscapes as holistic "Gestalt" systems: *"[L]andscapes are more than the sum of their measurable components. They become an entirely new entity as an ordered 'Gestalt' system. In these like in an organism (or a melody) all their parts are related to each other by the general state of the whole. Not only the natural but also the cultural components of a regional landscape, its forests, grass- and shrublands, its wetlands and rivers, its agricultural fields, its residential and industrial areas, its roads, traffic- and power-lines, and their history contribute to this truly holistic Gestalt character of the landscape. These elements comprise its various biological- and human-ecological, social, economic, psychological, spiritual, aesthetic and functional aspects"* (ibid.: 273-274).

While most studies fail to meet such an holistic claim, frameworks for assessing multifunctionality often are based on a large inventory of functions provided by landscapes (e.g. Wiggering et al., 2006; Brandt and Vejre, 2004). However, assessments of these functions reveal a strong focus on the regional level or even larger areas, working with land use or land cover data (Bolliger and Kienast, 2010), and they lack a consideration of interrelations between functions as well as of the societal demand for those functions (Wiggering et al., 2003).

Willemen et al. (2010), for example, developed an approach based on a complex understanding of relations between functions. They analysed multifunctionality on the same site based on the concept of landscape functions (understood as capacity to provide goods and services) and defined three kinds of interrelations between landscape functions:

(1) conflict: the spatial combination of two or more landscape functions reduces the capacity of a function,
(2) synergy: the combination of landscape functions leads to the enhancement of a function, and
(3) compatibility: different landscape functions co-exist on the same site without reducing or enhancing another function's capacity.

The related assessment method has, for instance, been used to identify "hot spots" and "cold spots", revealing the most and least multifunctional sites (ibid.; for a similar approach with a few functions see Gimona and van der Horst, 2007). Such an approach maps out how functions are spatially distributed and how they overlap.

Another example, focused on developing a multifunctional landscape, was the test and research landscape development project "Nature conservation-oriented suburban development at Kronsberg, Hannover" by the city of Hannover and funded by the Federal Agency of Nature Conservation in Germany. For a peri-urban agricultural area multifunctional land use types have been developed:

(1) "*tessellated multifunctionality*" with a spatial separation of different land uses/ functions within one area,
(2) "*partial multifunctionality*" by combining land uses in the same location with one or two dominating uses, and
(3) "*total multifunctionality*" with an equivalent balance of different functions on the same location (Rode, 2016; see Fig. 3).

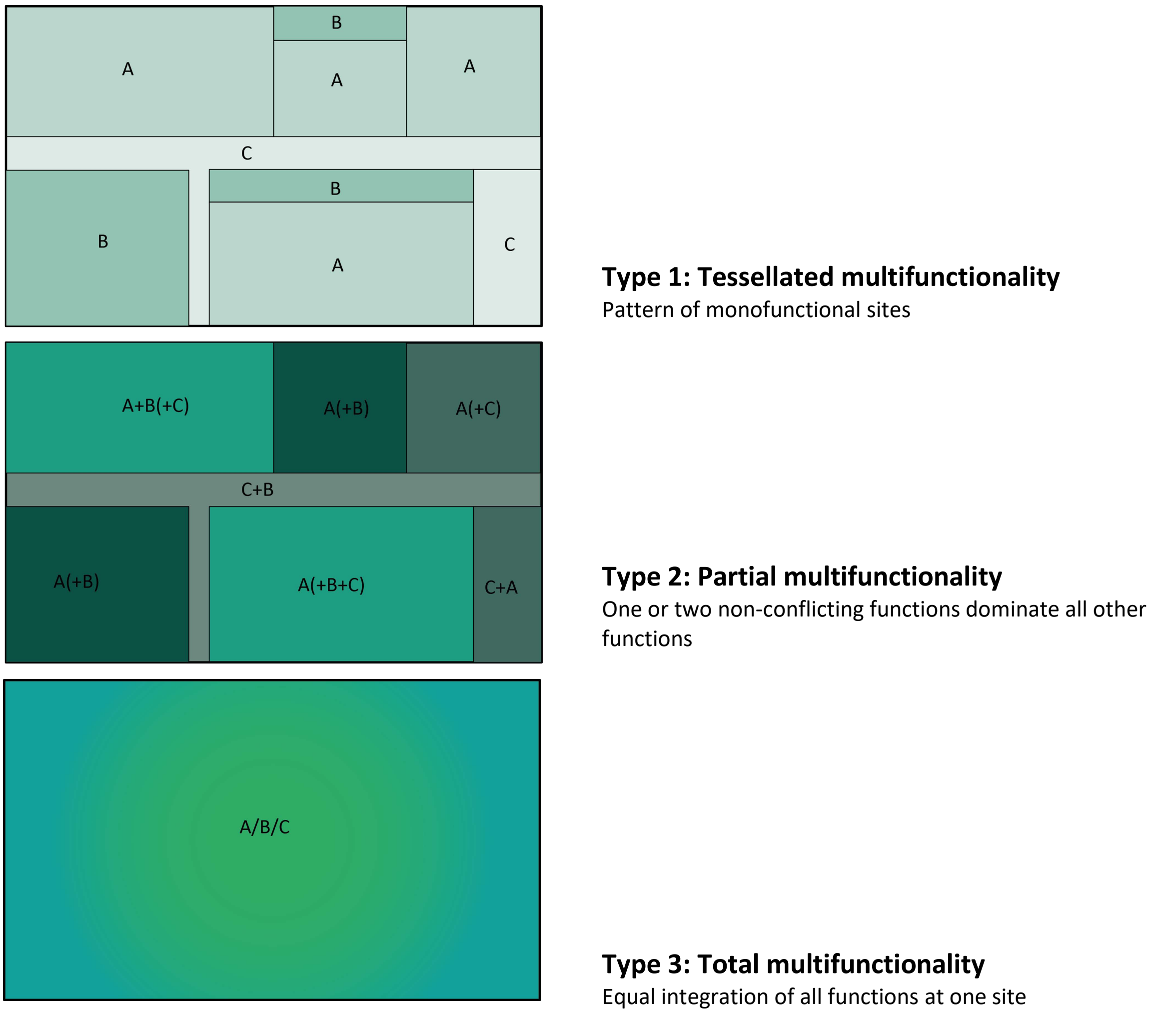

Fig. 3: Model for different types of multifunctional landscapes (A = agriculture; B = biotope function; C = recreation; based on Rode, 2016 and Brenken et al., 2003).

Specific sites for multifunctionality type 2 and 3 have been developed within the Kronsberg area such as hills from local excavation material that provide recreational users with a panoramic view and at the same time host endangered species on the dry, calcareous and nutrient poor soil. Field tracks and margins were designed to promote recreation and to contribute to biodiversity and the habitat network. This includes margins of at least 5m width that were partly planted for aesthetical reasons and as buffer zones to the arable land for rare flora. The “total multifunctionality” was tested with small orchards and a common area (“Allmende”). The Allmende was an accessible grassland between the adjacent housing zone and the agricultural land, maintained by sheep grazing and combining a high value semi-natural biotope with agricultural and recreational use (von Haaren and Reich, 2006; Rode and von Haaren, 2005, see Fig. 4).

Fig. 4: One of the look-out hills (top) within the multifunctional landscape Kronsberg and view from the hill’s top toward the city and the Allmende area with extensive grassland (bottom) (own photos from 2014).

The project was monitored by the Leibniz University of Hannover and research concerned synergies and conflicts between agriculture, recreation and nature conservation (species and biotopes). The evaluation revealed achievements in terms of increasing biodiversity and increasing attractiveness for recreation. Concerning partial multifunctionality, recreational uses and nature conservation measures could be combined in the same area without significant conflicts. Likewise, agricultural use and nature conservation could be achieved on the same site, for example with low-intensity agriculture such as sheep grazing. Total multifunctionality appeared to be difficult to implement since much compromise was needed. The Kronsberg project showed how multifunctional landscapes can be designed but also that compromises impede the individual interests of different actors groups. In particular, intensive or sensitive functions (e.g. high intensity agriculture or conservation of rare species) require partial segregation in order to be effective (Rode, 2016; von Haaren and Reich, 2006; Rode and von Haaren, 2005).

From an ecological perspective, constraints for multifunctionality become evident. For instance, Harms et al. (1995 in Brandt and Vejre, 2004) highlighted that species conservation, depending on the species concerned, requires different strategies ranging from integration, zoning, and segregation to increasing connectivity between habitats. Von Haaren (2002 based on Erz, 1980) linked the scope of action to the ecological value of a given area: in high value areas such as legally protected ones the specific conservation objectives are not negotiable and restrict the scope of action, while in areas of low value different development objectives can be considered. Hence a high level of multifunctionality – aiming, for instance, at "total multifunctionality" – is not always advisable.

Regarding strategic planning of multifunctional landscapes, Muñoz-Rojas et al. (2015: 47) suggested *"spatially-explicit policy and planning instruments and a stronger degree of coordination amongst institutions and actors operating across policy levels and spatial–temporal scales."* Altogether, landscape ecology provides concepts and experiences that are to some degree also relevant for urban regions. However, little information is available on multifunctionality of urban green spaces that are neither under agricultural use nor forests.

In the literature on urban green spaces, for cities facing pressure from urban development or for cities following the compact city ideal, strategies to increase the quality and multifunctionality of green spaces are suggested in order to use the existing space more efficiently (Haaland and van den Bosch Konijnendijk, 2015; Beer et al., 2003). Nevertheless, the issue of green spaces in dense cities has been predominantly discussed in terms of green space preservation and allocation (Haaland and van den Bosch Konijnendijk, 2015). The few publications in the international literature elaborating multifunctionality of urban green spaces have been found in the context of green infrastructure and are thus discussed in the next chapter.

2.3. The Emergence of Green Infrastructure

2.3.1. Definitions of Green Infrastructure and Classification of its Components

Since green infrastructure evolved in the US in the 1990s (see Chap. 1.1), various definitions of what it means coexist. On the one hand green infrastructure is used as synonymous for terms such as "green space" or "open space", on the other hand many of scholars highlight that it refers to a specific configuration or interrelation (such as a network) or quality of green space elements (such as being multifunctional or taking up functions of the technical infrastructure) in order to avoid that it develops into an empty buzzword (Tzoulas et al., 2007; Madureira and Andresen, 2013; Pauleit et al., 2011).

An often quoted definition by the US Green Infrastructure Work Group describes green infrastructure as a "network" of various green space types such as "*waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces"* that are supposed to have capacities to *"support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life*" (cited by Benedict and McMahon, 2006: 6). In total, these capacities could be considered as multifunctionality. The EU Green Infrastructure strategy likewise coined green infrastructure as a "*network of natural and semi-natural areas with other environmental features*" that is supposed to deliver ecosystem services, but also described it as a product of human activity as it is *"strategically planned, […] designed and managed"* (European Commission, 2013: 3).

The EEA (2011) takes up the network approach and suggests separating green infrastructure and its elements according to two main scales und purposes: urban and landscape, with the latter ranging from regional to national and transnational levels. The main objectives on the landscape level are development and protection of highly valued habitats, connected through ecological corridors (e.g. the Natura 2000 network in Europe). In urban areas, green infrastructure is seen as a network of multifunctional green spaces (Mell, 2009). However, as both approaches are interlinked and merge in urbanised city-regions, further authors emphasise the importance of a cross-scale approach (Rouse and Bunster-Ossa, 2013; Kambites and Owen, 2006).

In contrast to this broad understanding, green infrastructure has also been limited to specific purposes: green infrastructure for storm water management (see Fig. 5) is used in particular in Northern America (Fletcher et al., 2014). Examples for green stormwater infrastructure approaches range from city-wide storm water management systems supported by natural and semi-natural areas to small scale ecological engineering approaches such as decentralised storm water facilities including green roofs, rain gardens, or bioswales (e.g. Pauleit et al., 2011; Li et al., 2011; Ahern, 2010).

As a consequence of these different understandings, several attempts to systematically classify potential green infrastructure elements compete with each other (Koc et al., 2017). These classifications include types according to land use or purpose (e.g. park, greenway, nature reserve), scale (e.g. city-region, city, city-district, parcel) and location, accessibility or ownership, biotope/plant communities, surface characteristics (e.g. degree of permeability or of vegetated surfaces), or vegetation structure (e.g. parks, grassland, woodland, waterside zones), often mixing *functional, structural,* or *configurational* parameters (ibid.; Burgess, 2015).

Fig. 5: The “Street Edge Alternative” in Seattle is often referred to as an early example of green infrastructure targeted at storm water management. Roads in residential areas have been redesigned to retain stromwater, but with co-benefits such reduced traffic speed and increased aesthetic quality through reducing road widths and planting (own photo from 2013).

While such typologies per se can be instructive, to capture the ideas behind green infrastructure such as connectivity or multifunctionality, they need to be linked to complex data in order to make qualified statements about the current value and potentials for the future. The required complexity can be exemplified by Mell’s (2010) suggestion based on Ahern (1995) to classify green infrastructure elements according to form (physical characteristics of green space elements, connectivity between elements), function (provided processes and services), and context (ecological, economic and sociocultural influences on landscapes).

Next to a comprehensive analysis of the existing green space elements, the identification of untapped potentials is central for enhancing a city’s green infrastructure. Potential areas include sealed surfaces related to technical infrastructure that can be developed into combined green-grey systems (Naumann et al., 2011) as well as vacant land that can be transformed into green spaces (Schilling and Logan, 2008).

2.3.2. Green Infrastructure as a Planning Concept

When green infrastructure is understood as a planning concept, again a large variety of defining features is mentioned in the literature (e.g. Roe and Mell, 2013; Pauleit et al., 2011; Kambites and Owen, 2006). However, there is general agreement on some underlying principles: the idea that green infrastructure is to be developed as a network, and is supposed to be planned or managed to ensure multifunctionality respectively provision of multiple ecosystems services (Liquete et al., 2015; Madureira and Andresen, 2013, see Fig. 6).

Fig. 6: Barcelona in Spain as an early example for a European city that developed a city-wide green infrastructure strategy to promote biodiversity, create corridors and improve access to the adjacent mountain range for citizens, a challenge in the dense Mediterranean metropolis (own photo from 2013).

Planning of "green" in concert with "grey" infrastructure is also among the more prominent principles (e.g. Pauleit et al., 2011; Benedict and McMahon, 2002), while others emphasise transdisciplinary and participatory planning processes (Kambites and Owen, 2006). Additionally, green infrastructure is supposed to contribute to different policy objectives such as biodiversity conservation, climate change adaptation, sustainable economic development and human well-being (e.g. Sussams et al., 2015; Lafortezza et al., 2013; Rouse and Bunster-Ossa, 2013; Mazza et al., 2011).

In order to promote a unified understanding within the European context, the GREEN SURGE project has developed a definition supplemented with a set of principles and policy objectives for green infrastructure planning in urban areas. This understanding is based on the European Green Infrastructure Strategy, a literature review, and expert discussions with researchers involved in GREEN SURGE.

The project defines urban green infrastructure (UGI) planning as *"strategic planning approach that aims at developing networks of green and blue spaces in urban areas designed and managed to deliver a wide range of ecosystem services. Interlinked with [green infrastructure] planning on a landscape scale, UGI planning aims at creating multifunctional networks on different spatial levels, from urban regional to city and neighbourhood planning. Due to its integrative, multifunctional approach, UGI planning is capable of considering and contributing to a broad range of policy objectives related to urban green space such as conservation of biodiversity, adaptation to climate change, and supporting the green economy"* (Hansen et al., 2016a: 15).

The practical relevance of seven planning principles and six policy objectives has been explored within GREEN SURGE by analysing plans and interviewing city officials from 20 European cities (Davies et al., 2015). The results have been discussed in a workshop with the involved researchers and it has been decided that some of the principles will be excluded since they are either strongly linked to another principle (multi-scale is often related to connectivity) and inter- and transdisciplinarity can rather be considered as a precondition or supporting factor than a stand-alone approach. This discussion process led to a reduction to four core planning principles: green-grey integration, connectivity, multifunctionality, and social inclusion (Hansen et al., 2016a; see Tab. 1).

These principles have been embedded in a conceptual scheme, involving urban challenges that shall be tackled with the help of urban green infrastructure planning as well as means to transfer the principles into action such as green space assessments, planning and implementation instruments, and required actors (see Fig. 7).

Tab. 1: A set of four core principles constitute the urban green infrastructure planning approach developed by GREEN SURGE (Hansen et al., 2017: 4, based on European Commission, 2013; Pauleit et al., 2011; Benedict and McMahon, 2006; Kambites and Owen, 2006).

URBAN GREEN INFRASTRUCTURE (UGI) PLANNING Principles
Green-grey integration – combining green and grey infrastructure: UGI seeks the integration and coordination of urban green spaces with other infrastructure, such as transport systems and utilities.
Connectivity – creating green space networks: UGI planning for connectivity involves creating and restoring connections to support and protect processes, functions and benefits that individual green spaces cannot provide alone.
Multifunctionality – delivering and enhancing multiple functions and services: UGI planning aims at combining different functions to enhance the capacity of urban green space to deliver multiple benefits – creating synergies, while reducing conflicts and trade-offs.
Social inclusion – collaborative and participatory planning: UGI planning aims for collaborative, socially inclusive processes. This means that planning processes are open to all and incorporate the knowledge and needs of diverse parties.

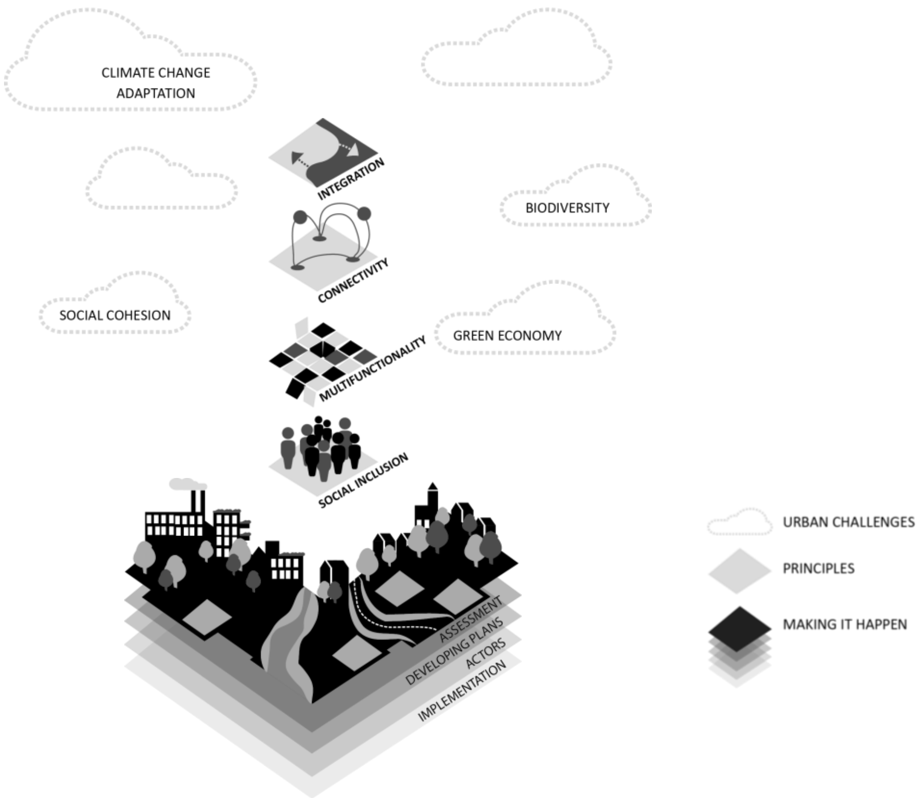

Fig. 7: Conceptual scheme illustrating the understanding of urban green infrastructure planning developed by the GREEN SURGE project. Multifunctionality is one of four core planning principles and helps cities to tackle challenges such as climate change adaptation or biodiversity protection. On the ground plans need to be based on sound assessments and developed in cooperation with different actors and implementation mechanisms (courtesy of GREEN SURGE).

2.3.3. Green Infrastructure and Multifunctionality

Definitions of multifunctionality in the literature on green infrastructure are similar to the ones provided in the prior chapters. Pauleit et al. (2011) pointed to fact that multifunctionality can be considered at different spatial levels: as multifunctionality of single green infrastructure elements or spaces and as network of interrelated green spaces that might be able to provide additional functions or a degree of functions that singular spaces cannot provide.

A relatively extensive discussion of green infrastructure and multifunctionality has been conducted by Ahern (e.g. Ahern, 2011, 2010, 2007). He argued for multifunctionality as one approach within a set of green infrastructure strategies for urban sustainability and resilience (others being e.g. redundancy, modularization, or connectivity): *"In the new urban world, planners and designers will be challenged to find new ways to provide for sustainable ecosystem services in the increasingly limited spaces within compact cities. Multifunctionality can be achieved through intertwining/combining functions, stacking or time-shifting. It is inherently efficient spatially and economically, and benefits by support from the social constituents and stakeholders associated with the multiple functions provided. Multifunctionality supports response diversity in the functions provided"* (ibid., 2011: 342). And: *"Doing more than one thing in one place is an obvious and important strategy for urban sustainability"* (ibid., 2010: 147).

The characteristics of multifunctionality such as "intertwining" functions on the same site or adding a temporal dimension by arranging different uses at different moments are similar to the concept for land use and landscape multifunctionality (see Chap. 2.2.2 and 2.2.3). Additionally, like in the context of land use planning, Ahern emphasised efficient use of space and economic benefits. Pauleit et al. (2011) suggested that multifunctionality will give urban green infrastructure added value and consequently *"broader public constituencies of support, thus making them more resistant to development pressures or changes in political leadership"* (ibid.: 273). Therefore, multifunctionality of urban green infrastructure should be assessed and communicated to the public and politicians (ibid.).

In early publications, Ahern classified functions according to the ABC-model, which stands for abiotic, biotic and cultural function, an approach that goes back to Bastedo et al. (1984), while later Ahern and his co-authors referred to ecosystem services as a useful concepts to aide urban green infrastructure planning (Ahern et al., 2014; cf. Pauleit et al., 2011). Roe and Mell (2013: 653) emphasised that different functions interact, ideally in a way that makes multifunctional landscapes *"more robust than those with single-uses. This does not necessarily mean a 'more is better' principle should be adopted and there are instances where desirable functions are mutually exclusive"*.

The limits of multifunctionality have also been mentioned by Pauleit et al. (2011) who pointed to the fact that, while many green spaces are – like cultural landscapes – inherently multifunctional to some degree, multifunctionality cannot be taken for granted but that planning needs to actively consider and promote multifunctionality. In line with this, Madureira and Andresen (2013:39) expressed concern that *"green infrastructure promotion has been considered a straightforward way to promote multifunctionality without the need to make choices among functions"*. They considered dealing with conflicts between functions a major challenge which requires comprehensive assessments (ibid.).

Similar to the range of action in relation to the ecological values provided by von Haaren (see Chap. 2.2.3), Ahern (2007) suggested four strategies for green infrastructure planning:

(1) a protective approach to secure well-functioning and intact landscapes,

(2) a defensive strategy to defend landscape elements against development pressure,

(3) an offensive one to restore or remediate functions, and

(4) an opportunistic strategy to develop and manage landscape elements in a way that enhances the provision of multiple functions.

Examples of multifunctional green infrastructure include small green elements that include decentralised storm water management systems (within the streetscape, on roofs or parking lots) or floodplain parks that contribute to recreation, water management and can also serve as wildlife habitats (ibid., 2010).

The outlined discourse on multifunctional green infrastructure depicts a normative framing for considering multifunctionality as a rationale for planning. However, despite this framing there seems to be a need for operational frameworks to support planning for multifunctionality on different planning levels (Sussams et al., 2015; Demuzere et al., 2014).

2.4. The Ascending Concept of Ecosystem Services

2.4.1. Urban Ecosystem Services

The concept of ecosystem services emerged from ecological economics in the 1990s and became a much debated concept. It is connected with the hope of ecologists and environmental economists to change policies towards reducing environmental degradation and biodiversity loss while fostering human well-being (e.g. MA, 2005; Schröter et al., 2014). Ecosystem services are generally defined as benefits humans obtain from nature such as food or timber products, storm water regulation or recreational services (MA, 2005). The often used TEEB approach differentiates four categories of ecosystems services: provisioning, regulating, habitat/supporting, and cultural services (TEEB, 2010). In this classification, supporting or habitat services are needed for the provision all other services and include, for instance, nutrient and water cycling, biomass production, habitat provision and maintenance of gene pools (ibid.).

Within the concept of ecosystem services, functions refer to biophysical functions, delivered by ecosystem structures or processes. Functions are considered as "intermediate products", while a service requires direct human beneficiaries (Fisher et al., 2009; Boyd and Banzhaf, 2007). The so called ecosystem service cascade model by Haines-Young and Potschin (2010) depicts the relation between functions and services: Biophysical structures or processes (e.g. wetlands or net primary productivity) represent the base for functions (e.g. slow passage of water). These functions can become services for humans (e.g. flood protection) and lead to human benefits and valuation (e.g. willingness to pay for wetland protection). This conceptual framework is in contrast with the multifaceted understanding of functions in landscape ecology (see Chap. 2.2.3). To overcome the limitations of an approach focused on human beneficiaries and better link with the prior concepts, frameworks such as EPPS (Ecosystem Properties, Potentials and Services) also integrate landscape potentials (Bastian et al., 2013).

In the urban context, a clear definition of what ecosystem services mean is missing. The existing definitions strongly refer to natural ecosystems, while in urban areas ecosystem services are delivered by strongly altered, managed or otherwise humanly impacted structures. Beichler et al. (2017) stress that a borderline is needed that marks which level of human modification differentiates between ecosystems and other structures in urban areas. However, usually all kinds of urban blue and green spaces are considered as providing ecosystem services, including strongly modified or constructed elements such as green roofs and walls, bioswales and canals (Cvejić et al. 2015). A broad perception will also be taken for this thesis since the research focusses on exploring how ecosystem services are considered in urban planning practice (c.f. Beichler et al., 2017).

Figure 8 illustrates all ecosystem services that potentially occur in urban areas, grouped into the four classes mentioned above. However, writers in the field describe urban ecosystem services that directly influence human health and well-being as essential. Examples include air purification, noise reduction, urban cooling, and runoff mitigation as well as cultural ecosystem services (Gómez-Baggethun and Barton, 2012; Niemelä et al., 2010; Bolund and Hunhammar, 1999).

A large body of academic research regards mapping and valuation of ecosystem services with a focus on selecting and assessing indicators for different ecosystem services (Haase et al., 2014; Seppelt et al., 2011). Moreover, a growing body of conceptual frameworks and empirical evidence on interrelations between different ecosystem services can be observed (e.g. Lee and Lautenbach, 2016; Queiroz et al., 2015; Howe et al., 2014; Mouchet et al., 2014; Haase et al., 2012; Raudsepp-Hearne et al., 2010). However, these approaches often come with the caveat that they depend on coarse land use or land cover information, such as from CORINE or Urban Atlas, and on statistics of large areas such as municipalities or regions. Such approaches are helpful to draw comparisons between cities or to monitor trends such as land use change, but there is a need for more detailed ecological, social and economic data in order to inform site-specific decisions relevant to the local planning and decision-making which is key to multifunctional urban green infrastructure development.

Provisioning Services:
material outputs from ecosystems

1) Food supply
2) Raw materials supply
3) Water supply
4) Medicinal resources

Cultural services:
non-material benefits obtained from human contact with ecosystems

1) Recreation and mental and physical health
2) Tourism
3) Aesthetic appreciation and inspiration
4) Spiritual experience and sense of place
5) Education and learning

Regulating Services:
ecosystem processes that serve as regulators of ecological systems

1) Local climate regulation
2) Air quality regulation
3) Carbon sequestration and storage
4) Noise reduction
5) Run-off mitigation
6) Moderation of extreme events
7) Waste-water treatment
8) Erosion prevention and maintenance of soil fertility
9) Pollination
10) Biological control

Habitat or supporting services:
the provision of living spaces and maintenance of plant and animal diversity (serve as the foundation for all other services)

1) Habitat for species
2) Maintenance of genetic diversity

Fig. 8: Ecosystem services in urban areas (adapted from Piwowarczyk et al., 2013; Gómez-Baggethun and Barton, 2012; TEEB, 2011; Niemelä et al., 2010; see also paper II)

2.4.2. Ecosystem Services in Planning

The practical application of the ecosystem services concept is broadly discussed in academic circles, propelled for instance by global (research) initiatives such as MEA or *The Economics of Ecosystems and Biodiversity* (TEEB). TEEB and MEA, organisations such as the *Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services* (IPBES) as well as national initiatives (see e.g. TEEB-inspired country studies on www.teebweb.org) aim at influencing policy-making on different scales in order to implement ecosystem service approaches (e.g. TEEB, 2012, 2011).

Researchers in the field suggest using ecosystem services as a tool for communication that sheds light on the importance of ecosystems and biodiversity to human well-being. By applying a language linked to dominant political and economic discourses, it might be able to influence decision-making (Luck et al., 2012). In the context of policy guidance and decision-making the concept and related valuation tools are supposed to deliver information on the ecological and socioeconomic effects of land-use decisions. As a strategic objective, ecosystem services are regarded to shape policy instruments and implementation processes (ibid.). However, when this thesis project started, a gap between the discourse in research-oriented circles and application in planning became evident in a quantitative review of studies on urban ecosystem services. Of about 200 reviewed studies, only a small minority considered practical relevance such as policy-makers' or planners' information needs, the constraints of municipal decision-making processes, or applicability of assessment tools (Haase et al., 2014).

Some tools for ecosystem service assessments such as InVEST have been tested in different policy contexts and for spatial planning with varying impacts (Ruckelshaus et al., 2015), but are considered as too costly and time-consuming for widespread application in decision-making (Bagstad et al., 2013). Further barriers for uptake in planning may exist on the side of the practitioners: some studies have shown that regional as well as urban planners are interested in the concept of ecosystem services but also express hesitance and doubt if the concept would bring advantages compared to established approaches (Albert et al., 2014; Hauck et al., 2013; Niemelä et al., 2010). This scepticism points to the need to deliver persuasive arguments and application oriented tools that assure planners of the usefulness of the concept.

2.5. Interim Conclusions: Multifunctionality in the Context of Green Infrastructure and Ecosystem Services

The preceding chapter established the theoretical basis for strategic planning of urban green infrastructure. Multifunctionality can be connected to urban development strategies such as mixed-use or the compact city ideal. Against this backdrop, multifunctionality emphasises spatial constellations that promote synergies between the different functions. In the landscape ecology context, multifunctionality is considered as a holistic concept that relates to the perspective of sustainability and thus considers the social, ecological, and economic dimension in concert. If understood in a comprehensive manner, multifunctionality appears to be a promising concept to aid protection and development of urban green spaces within complex social-ecological systems. While the research activities around multifunctional landscapes appear to have had their momentum, the rise of the ecosystem services concept can uplift the discussion about multifunctionality in the context of green infrastructure.

It can be assumed that multifunctionality on the one hand might be often taken for granted while on the other hand approaches for operationalization are missing. Although, researchers developed a number of frameworks and assessment approaches that each cover specific aspects of multifunctionality, the need for approaches capable of dealing with a phenomenon that is multidimensional, dynamic in space and over time, and often requires fine-grained site-specific data became evident. Connecting both concepts of green infrastructure and ecosystem services is a promising venture since they provide conceptual elements that could be synthesised and developed in recommendations for planners that correspond to planning logics and procedures and likewise help to gather sound knowledge on functions or services, their limits and conflicts.

From this review of foundational concepts, the following assumptions can be derived:

- There is a need for better conceptual frameworks to help capture multifunctionality in a comprehensive manner.
- Such frameworks and related evaluation approaches for multifunctionality must be adapted to urban contexts taking the complexity of urban systems into account.
- Three fields of application for multifunctionality within the frame of strategic green infrastructure planning are plausible:
  (1) multifunctionality as a planning principle that guides all planning activities related to urban green spaces within a city (see in particular Chap. 2.2.2 and 2.3.3);
  (2) multifunctionality assessments to explore which areas provide which functions and to make sound planning decisions that promote multifunctionality (see in particular Chap. 2.4); and
  (3) design and management of multifunctional green spaces on different levels ranging from peri-urban landscapes to local stormwater management features (see in particular Chap. 2.2.3).
- More knowledge is needed on how multifunctionality is currently actioned in planning and how the assessment approaches developed in research can more strongly relate to the logics of (strategic) green infrastructure planning and consequently be better integrated in planning practice.
- For different urban green space types, real-life application needs to be analysed in order to gain empirical evidence on how multifunctional spaces can be promoted and managed.

3. Methodology and Data

The following chapter outlines the general research approach and describes the research design and methods applied in the different study parts. Additionally, this chapter provides an overview of the different case study areas.

3.1. Research Design and Rationale

While studying multifunctionality within urban green space planning builds on theoretical concepts and frameworks from (landscape) ecology as outlined in the prior chapter, it furthermore requires actual planning research. Due to the complex nature of strategic planning and planning as a practice of knowledge (see Chap. 2.1.1), the research strategy for this thesis was based on a pragmatic paradigm which accepts multiple social realities (opposed to the positivistic paradigm) and mixes research methods (Du Toit, 2016). Mixed method research aims at integrating quantitative and qualitative data in order to facilitate a more complete understanding of the research problem (Creswell, 2013).

The thesis followed the descriptive tradition as it first established empirical data on the question if both multifunctionality and ecosystem services have been considered in current planning practice at all. Since reasons for differences in findings between cities were explored with the help of contextual data, the analysis was also mixed with explanatory elements (paper II and III).

In all study phases, interpretative research was a core approach. Methods such as discourse and content analysis were applied to explore how multifunctionality and ecosystem services have been discussed in academia (mainly paper I) and how both have been conceptualised and operationalised in planning (paper II and III).

For interpretative study elements, case studies are a vital resource since they allow concrete, practical and context-dependent knowledge (Flyvbjerg, 2006). The empirical part of the thesis was thus based on comparative/multiple case study research (see Chap. 3.3; cf. Yin, 2010). Interpretative meta research concerned the literature review and conceptual analysis (paper I) as well as the research synthesis (see Chap. 3.4; cf. Du Toit, 2016). The formative elements concerned the development of recommendations on how to consider multifunctionality in the context of green infrastructure planning in urban areas (see Chap. 3.4).

3.2. Literature Review Approach

To answer research question 1 on conceptual linkages, the systematic literature review (paper I) was focused on exploring the theoretical foundation of multifunctionality in the context of green infrastructure and ecosystem services.

The search term "green infrastructure" was combined with "planning"; "framework"; or "strategy" in the scientific citation search engine Web of Knowledge (currently named Web of Science) to find peer reviewed articles, published in international journals. The focus was on literature discussing green infrastructure approaches for urban areas. Fundamental theories or conceptual approaches from non-urban literature were not generally excluded. However, papers were excluded from the results if

(1) green infrastructure was only named in the keywords or abstract without any further reference in the main text, or
(2) green infrastructure was used in the text without explanation.

On the other hand, chapters of landmark environmental planning and urban ecology textbooks as well as policy guidance reports dealing with theory on green infrastructure were included.

Due to the exponential increase of relevant literature in the last decade (see Chap. 2.4), the review on ecosystem services needed to be more selective. The quantitative review on urban ecosystem service literature by Haase et al., (2014) was used as a starting point. The review was then complemented by articles on ecosystem services with a non-urban focus in case their focus was closely related to the multifunctionality concept such as literature on interrelations between services or supply-demand issues. Using a snowball approach, finally literature referenced in the reviewed papers was added to the analysis in case those had a relevant focus (Wohlin, 2014).

The findings were hence used to construct a comprehensive tentative framework for assessing multifunctionality that combined state of the art from both research fields.

The literature review started end of 2012 and was frequently updated until the final submission of paper I, end of 2013. The final list of 193 reviewed publications can be found in the Electronic Supplementary Material, Appendix S1 of paper I.

3.3. Case Study Approach

To explore if and how multifunctionality, green infrastructure and ecosystem services have been considered in planning practice (research question 2), the empirical part of the thesis involved three studies based on case studies: **two semi-quantitative studies** on consideration of ecosystem services (**study 1**) and of green infrastructure and multifunctionality (**study 2**) as well as a qualitative study (**study 3**) on the operationalization of multifunctionality in good practice cases. In the following, the commonalities as well as the differences of the three studies are described.

3.3.1. Study Design and Case Selection

In broad terms, according to Yin (2010), multiple case study research involves:

(1) a **definition and design phase:** development of the theory, selection of cases and establishment of a data collection protocol,
(2) a **data preparation, collection and analysis**: all case studies need to be conducted in the same manner following the data collection protocol and the results have to be resumed in a report/narrative, and
(3) a **cross-case analysis and conclusion**: to draw conclusions the cases are compared to each other. Further results include modification of the initial theory or policy implication. All are combined to a cross-case report.

For the first two phases, Table 2 provides an overview of the three studies, comparing their aims and scopes. The design varied from holistic (single unit of analysis) case studies (study 1) – focussed on content analysis of planning documents – to embedded (multiple units of analysis) case studies which additionally involved interview data (study 2 and 3) (cf. Yin, 2010).

All cases used in the studies were selected in a systematic manner in correspondence with the research questions and in order to represent variety (Marshall and Rossman, 2006). The selection was based on different levels of exposure to the ecosystem services concept (study 1), different planning systems, and (due to size) different capacities for green space planning (all studies), different economic situations, and bio-geographic contexts (in particular study 2; see Chap. 3.5).

Due to the amount of case studies and the required language skills, the data for the case studies was collected by different researchers involved in the URBES or GREEN SURGE project (see Chap. 1.2), including the thesis author[2]. These researchers are hereafter called study contributors. For all studies, study leaders developed detailed data collection and documentation procedures[3]. After a test run and subsequent improvements by the study leaders, templates were shared with the study contributors, including the test example, and the case studies were executed by the study contributors. For all cases, results were documented in spreadsheets and case narratives (for study 2 case narratives were published by Hansen et al., 2016a; for study 1 partly in paper II).

[2] An overview of the case studies can be found in Chapter 3.5. The thesis author contributed to the case studies of Barcelona, Berlin, Halle, Linz, New York City, and Seattle.

[3] For study 1 the thesis author was the study leader, study 2 and 3 were led by the thesis author together with a small team of one to two fellow researchers.

Tab. 2: Study design of the three studies

Study	**1 - Theme: Ecosystem services**	**2 - Theme: Green infrastructure and multifunctionality**	**3 - Theme: Good practices for multifunctionality**
Study aims	Uptake of the concept of ecosystem services in cities: Conceptual level (explicit and implicit) Content level	State of the art of urban green space planning in Europe: Consideration of multifunctionality in planning documents and by planners	Good practice approaches for multifunctionality: Real-world application of multifunctionality in urban green space planning
Developed theory	Definition of concepts (ecosystem services and related topics; human-nature relations) Classification of ecosystem services	Definition of concepts (multifunctionality as a principle for urban green infrastructure planning)	Builds on theory for study 2 Different fields of application of multifunctionality
Study approach	Comparative Quantitative survey combined with qualitative elements	Comparative Quantitative survey combined with qualitative elements	In-depth Qualitative
Selected cases	5 cities (2 from the US, 3 from Europe)	20 European cities	3 green space plans/projects in 3 different European cities
Study units	Planning documents (5-7 per city, in total 33) (plus contextual data)	Planning documents (1-2 per city; in total 32) Structured interviews with local experts (plus contextual data)	Planning documents (1 core document and related documents) Semi-structured interviews with local experts Contextual data
Data collection protocols	Coding protocols and spreadsheets (see paper II, Appendix A.2, A.3) Case narrative: template for case portrait	Overall: guideline document with detailed instructions and webinar with all participating researchers For document analysis: coding protocol and spreadsheet (see Davies et al., 2015, Appendix 5) For interviews: questionnaire (see ibid., Appendix 3) Case narrative: Template for case portrait (see ibid, Appendix 6)	Overall: guideline document with detailed instructions and research questions For interviews: guideline document with interview questions Case tables for summarising findings from all sources (see Hansen et al., 2016a) Case narrative: Template for detailed narrative (see ibid., Appendix)
Time frame (data collection)	April-August 2013	May-October 2014	February-October 2015; updates April-July 2016

While aims, study approach (quantitative or qualitative), study units, and protocols differed to varying degrees for all three studies, **triangulation** was a joint approach. In case study research, triangulation of different data sources – such as documents, interviews or observations – increases validity, supports testing the consistency of findings within one case, and also helps to explore the data. As a research technique triangulation aims to *"reveal different aspects of empirical reality"* (Patton, 2009: 555) and promotes an in-depth understanding rather than generalization (Yin, 2010). Triangulation highlights complementarity and convergence rather than congruence (Flick, 2012).

Since investigator triangulation can reduce personal biases (Patton, 2009), all three studies involved different researchers[4]. The involvement of researchers as study contributors with local expertise and study leaders with an overview of all cases was also an important quality check in both directions. This included a review and cross-case analysis by study leaders as well as reviews of the results by study contributors. The review process and cross-case comparison helped to increase comparability between cases since the coding often needed to be synthesised. This was, for instance, caused by literal translations from the original language into English, which led to inconsistent terminologies. Overall, the analysis process involved several iterations of data review between study contributors and study leaders.

To interpret the collected data from different study units, such as planning documents or expert interviews within the local context, additional data of each city was collected on the current situation (regarding spatial planning, but also social, economic or ecological developments). The type of data collected in desk studies varied between the studies, e.g. based on published and grey literature, websites or census data (see Chap. 3.5).

It is important to note, that the case study approach does not claim to represent an objective reality, but needs to meet quality criteria (Flyvbjerg, 2006). Triangulation and desk studies helped to ensure **internal validity.** Data triangulation (documents and interviews) was applied to explore the consistency of the findings within one case (in particular study 3, to a lesser degree study 2). Additionally, the insights from the desk studies have been used to critically reflect on the findings in relation to the local context (all studies). Furthermore, the cross-case analysis and investigator triangulation helped to reveal outliers that could then be discussed with the study contributors to clarify possible misunderstandings or mistakes (all studies).

Additional criteria to ensure case study research of high quality and soundness include: construct validity, external validity, and reliability (Yin, 2010). To ensure **construct validity,** theoretical concepts have been developed based on the literature (see Chap. 2), data has been collected from different sources, and the results of the analyses (case narratives/ reports) have either been reviewed by key information for planning practice (study 2 and 3) and/or by primary researchers that were familiar with the local planning context (all studies).

To promote **external validity,** multiple cases (study 1 and 2) have been analysed to detect replication of results across cases. However, generalizations have been handled very cautiously or avoided (all studies). For **reliability,** all three studies followed detailed protocols and documentation procedures (see Tab. 2). Additionally, the findings have been supported by a detailed narrative with clear

[4] 1-2 study leaders and usually 1-2 study contributors per case; in study 2 some researchers undertook more than one case study.

argumentation (study 2 and 3). To ensure transparency within the document analysis in study 1 and 2, not only a code but also quotes from the analysed documents have been included.

3.3.2. Specific Approach in Study 1

To answer research question 2 on the uptake of the studied concepts in planning practice, the current application of ecosystem service concept was explored. When study 1 was developed, few prior studies on the application and operationalization of the ecosystem services concept in urban planning existed (Frantzeskaki and Tilie, 2014; Wilkinson et al., 2013; Piwowarczyk et al., 2013). Compared to these, the study aimed at exploring the application of the concept of ecosystem services in a larger number of cities in different planning contexts. The study furthermore focused on capturing the variety of planning instruments in these cities. To explore the variation between cities, the selection of cases has been aimed at contrasting cases (cf. Yin, 2010). It was anticipated that national/federal policies and planning traditions largely influence the consideration or absence of such emerging concepts. Two cities from the US have been selected as potential forerunners and were compared to three European cities. One of the European examples also stems from a country that could be considered as forerunner within Europe (see Chap. 3.5).

A further hypothesis of study 1 was, that while explicit references to ecosystem services might be rare, related concepts such as landscape functions or ecological functions might be present. Furthermore, plans might reveal an understanding of human-nature relations that can either support or defy the concept of ecosystem services. It was also assumed that a lack of explicit references to ecosystem services might not mean, that specific ecosystem services such as stormwater regulation, are not considered.

Thus, the research aims included:

(1) exploration of explicit references to the concept of ecosystem services as well as presence of other related concepts in planning documents, including perspectives on human-nature relations, and
(2) analysis of the content of different planning documents regarding application of specific ecosystem services as well as the range of considered services.

For each of the three European and five US cities, 5-7 strategic planning documents from regional and city-wide spatial planning have been analysed per case, in total 33 documents. For a comprehensive representation of each planning system, plans from three broad categories of documents were considered:

(1) comprehensive plans, and
(2) sectoral plans for green spaces, landscapes, biodiversity, or
(3) more generally the environment and technical infrastructure.

The documents were researched on the city's official websites and with the help of local planning officials. Only plans in action and of relevance for the future development of urban green spaces were included.

To contextualise the findings, for each case a portrait was developed based on bio-geographical/ historic context, main social, economic, and ecological drivers of change, policy and planning context, and the national discourse on ecosystem services. In a desk study, published and grey literature, websites, census and land use data were collected. Additional information was gained from stakeholder interaction during the URBES project and a research stay of the thesis author in Seattle (interviews, discussion groups, workshops, and observation of decision-making processes; see e.g. Kabisch, 2015; Kaczorowska et al., 2015; McPhearson et al., 2014).

The hermeneutic content analysis explored the conceptual level (references to the ecosystem service and related concepts, expression of human-nature relations) and content level (consideration of specific ecosystem services and the degree of consideration). The approach included a search for explicit references to ecosystem services and other concepts as well as implicit references (references to specific ecosystem services types). The data analysis included quantitative elements (presence/ absence of concepts or content on specific ecosystem services) as well as qualitative aspects (description of human-nature relations, ranking according to degree of consideration of specific ecosystem services) and aimed at a comparison between cities and regions.

3.3.3. Specific Approach in Study 2

To add insights on the consideration of multifunctionality – research question 2 – data from 20 cities across 14 European countries has been collected. The aim of this extensive study was to compare the current state of green space planning practice under the light of the green infrastructure concepts and its underlying principles (Davies et al., 2015).

Research on strategic planning should consider the planning process and how this process promoted a mutual learning among the actors and might have impacted decisions, even in subtle ways (Faludi, 2000). Thus it was hypothesised that the actual planning documents might only represent a part of the outcomes of current green space planning practice. Consequently, interviews have been used as an additional source. 32 documents (up two to per city, depending upon availability) have been analysed, including two questions related to multifunctionality. The plans included the most important plan and the most innovative plan regarding urban green spaces, selected by researchers with local knowledge in cooperation with municipal planning experts. Since this study was part of a larger survey, only one question on multifunctionality could be included in the interview with a chief (green space) planner in each city. Desk study and narrative helped to gain an understanding of the contextual factors in each city (paper III).

The data has been analysed in a semi-quantitative manner with simple statistics, supplemented with qualitative data from the document analysis. Socio-economic data have been used to identify trends towards considering multifunctionality among cities that share similar developments.

3.3.4. Specific Approach in Study 3

To answer the second part of research question 2 – What are good practices for developing a multifunctional green infrastructure? – cases were identified that allow an in-depth study of different approaches to multifunctionality. The qualitative study involved content analysis of planning documents but also semi-structured interviews with local experts involved in the plan or project under investigation (two to four per case, see paper III, Appendix 2). A desk study with supplementary material helped to gain contextual information.

The case analysis was based on the identified strategy elements described in Chapter 2.1.1. The strategy elements were to capture factors that are needed to cover a comprehensive approach for multifunctionality (see Chap. 2.5).

These elements comprised, amongst others, a separate analysis of assessment and valuation methods. This approach led to the consideration of the following factors for each case:

- strategic approach (type of planning process),
- planning concept, including definition, and objectives,
- assessment and valuation methods,
- actors and their roles,
- implementation mechanisms and resources, and
- supporting conditions and limitations.

The data was analysed by using case tables that categorised data from all sources for each case in the same manner. Furthermore, a narrative was included that summarised the information. This narrative emphasised linkages between factors within each case that are not supported by a categorical representation of data in the case tables. The content analysis approach was used to reveal both variation and common factors across cases (for details see Hansen et al., 2016a).

3.4. Synthesis Approach and Development of Planning Recommendations

In a final step, the results from all three papers (paper I-III) were synthesised and summarised as planning recommendations (see Fig. 9). This process was connected to the wider frame of the GREEN SURGE project. GREEN SURGE was based on an iterative exchange between researchers and city stakeholders, aiming at mutual learning and co-development of planning strategies and tools. Workshops with urban stakeholders and a review process took place to discuss research results such as planning strategies and tools, their potential value for urban planning and their further development according to planners needs.

Preliminary recommendations for multifunctionality were discussed during

- a workshop with stakeholders from different European cities in Brussels,
- a workshop with stakeholders from the city of Malmö, and
- a work meeting with a small group from the city of Malmö[5].

The full-day workshop in Brussels (October 13 2015) was a so called Stakeholder Dialogue Forum, organised and implemented by ICLEI – Local Governments for Sustainability together with the Technical University of Munich (TUM) and the University of Wageningen. The Stakeholder Dialogue Forum series within GREEN SURGE aimed to promote the dialogue between researchers, local government planners, and other stakeholders, dealing with urban green infrastructure.

[5] For all three events, the thesis author presented findings on multifunctionality and contributed to their discussion.

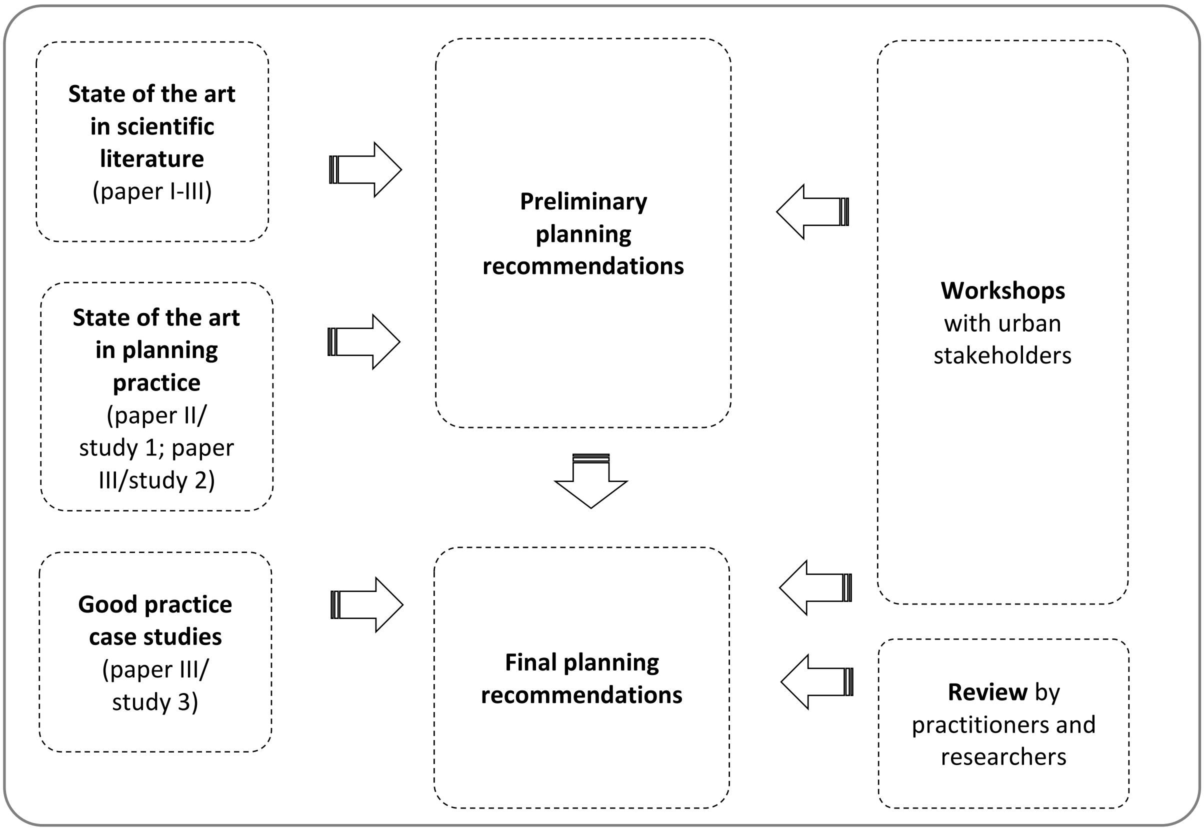

Fig. 9: Development of planning recommendations for multifunctionality based on the synthesis of research findings and insights from interaction with planning practitioners and other experts.

The workshop took place as an official side event of the Open European Days 2015 and had the topic "Green Infrastructure for and with citizens: How can local governments make it happen?" The participants deliberated how cities can plan multifunctional green infrastructure and promote socially inclusive planning approaches. Furthermore, cooperation between city administrations and citizens for green infrastructure development as well as between urban stakeholders and researchers was discussed. 26 experts from local governments, research institutes, the European Commission, non-governmental organisations and GREEN SURGE partners participated (Reil, 2015). Within this workshop, first ideas on how to plan for multifunctional green infrastructure were discussed.

The two-day workshop (September 22-23 2016) in Malmö was a so called ULL workshop, organised and implemented by the City of Malmö and the Swedish University of Agricultural Sciences together with the TUM and the University of Wageningen. The ULL workshops within GREEN SURGE aimed at cooperative development of planning tools and strategies. Before the workshop, a web-based meeting took place to agree the workshop agenda between the GREEN SURGE partners and city stakeholders that fits needs from both sides.

During the first workshop day issues related to urban green infrastructure planning were discussed, including on the one hand result from the GREEN SURGE project (such as a checklist for urban green infrastructure planning), on the other hand current planning processes and related questions in Malmö. The second day was focussed on participatory governance of green infrastructure. On the first day, a session was focussed on multifunctionality. Local stakeholders from different city departments including city planning, leisure, streets and parks, environment, culture, and education as well as GREEN SURGE partners and few other researchers participated. With varying presence, overall 42 persons joined the workshop (Rolf et al., 2016).

The work meeting in Malmö (February 22 2017) took place between two green space planners from Malmö and the thesis author. They discussed a current green infrastructure planning process and evaluated this process with a checklist (test version) developed within GREEN SURGE. Multifunctionality was one of the focal themes.

Additionally to these events, results, in the form of guide for urban green infrastructure planning (a so called Field Test Version, Hansen et al., 2016b), were reviewed by stakeholders involved in GREEN SURGE and research partners to ensure that the suggestions are inspiring and useful for planners in different cities. After an extensive revision based on the feedback on the Field Test Version, the final recommendations were published as a guide for urban green infrastructure for planning practitioners including a checklist (Hansen et al., 2017). This guide is supposed to convey the insights from GREEN SURGE and make them available for stakeholders in other cities. It includes a chapter on multifunctionality developed by the thesis author.

3.5. The Study Areas

To comply the diversity of cities in Europe and beyond, 24 cities in total, from different geographic regions and with different population sizes were studied within this thesis:

- five cities with less than 200 000 inhabitants,
- six with less than 400 000,
- four with less than 600 000, and
- nine with more than 600 000 inhabitants, including Berlin hosting more than 3 million inhabitants and New York City with more than 8 million people.

The geographical distribution of the case study cities and their population numbers can be observed in Figure 10 and Figure 11. The figures reveal that size of the city area and population numbers do not necessarily correspond. For instance, Lisbon or Barcelona on the one hand have relatively small municipal areas. Barcelona, however, has an overall population of more than 1,5 million. Cities such as Aarhus or Szeged, on the other hand, encompass large agricultural lands and only have a population below 400 000 inhabitants concentrated in the urban core (Aarhus) or even have one of the smallest populations among all case study cities (Szeged). The bar chart shows that cities such as Ljubljana, Berlin or Helsinki include a high proportion of green spaces, while cities such as Bari or Oradea have the smallest green space share[6]. Most of these cities faced population growth in recent years, and only few experience decline (see paper II). Differences regarding the socio-economic context, biophysical features and geographic locations and planning systems are briefly outlined in the following section.

[6] It has to be taken into account that this spatial information stems from the European Environmental Agency's (EEA) Urban Atlas 2006 (http://land.copernicus.eu/local/urban-atlas/urban-atlas-2006). The EEA provides comparable data for all European cities above a certain population size but is usually not congruent with the official land use data offered by the cities. Deviations with the municipal land use statistics occur for instance because the Urban Atlas only maps green areas that are presumably public and bigger than 250 m^2 (European Union 2011).

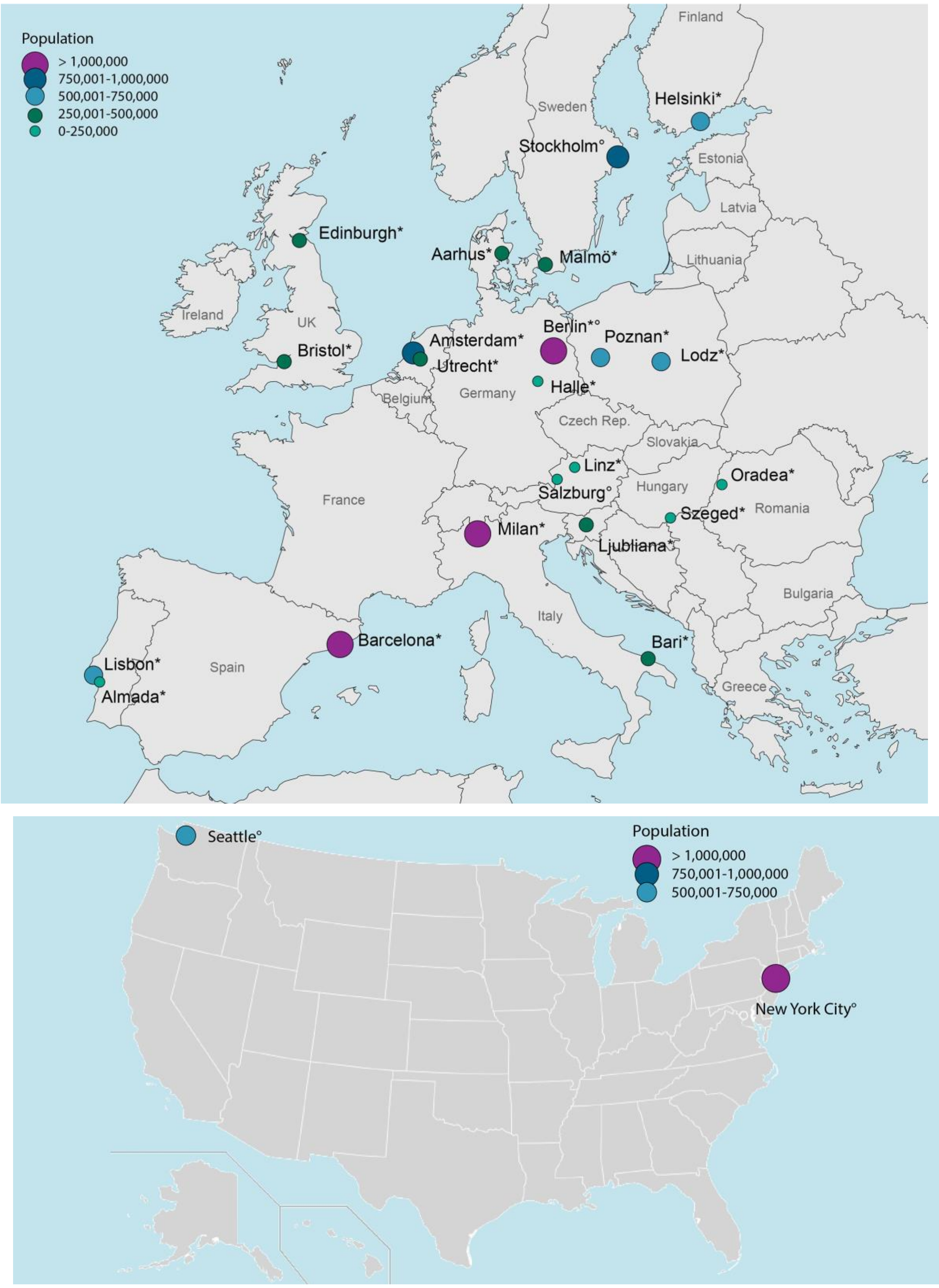

Fig. 10: The location of the 22 European case study cities (top; based on Open Street Map, Urban Audit data from http://ec.europa.eu/eurostat/web/cities) and the two US case studies (bottom; based on Wikimedia Commons, US Census data from https://www.census.gov/data/tables/2016/demo/-popest/total-cities-and-towns.html; different scales). The size and colour of the dot represent the population number within the municipal area, the degree character (°) indicates cases from study 1, the asterisk (*) cases from study 2.

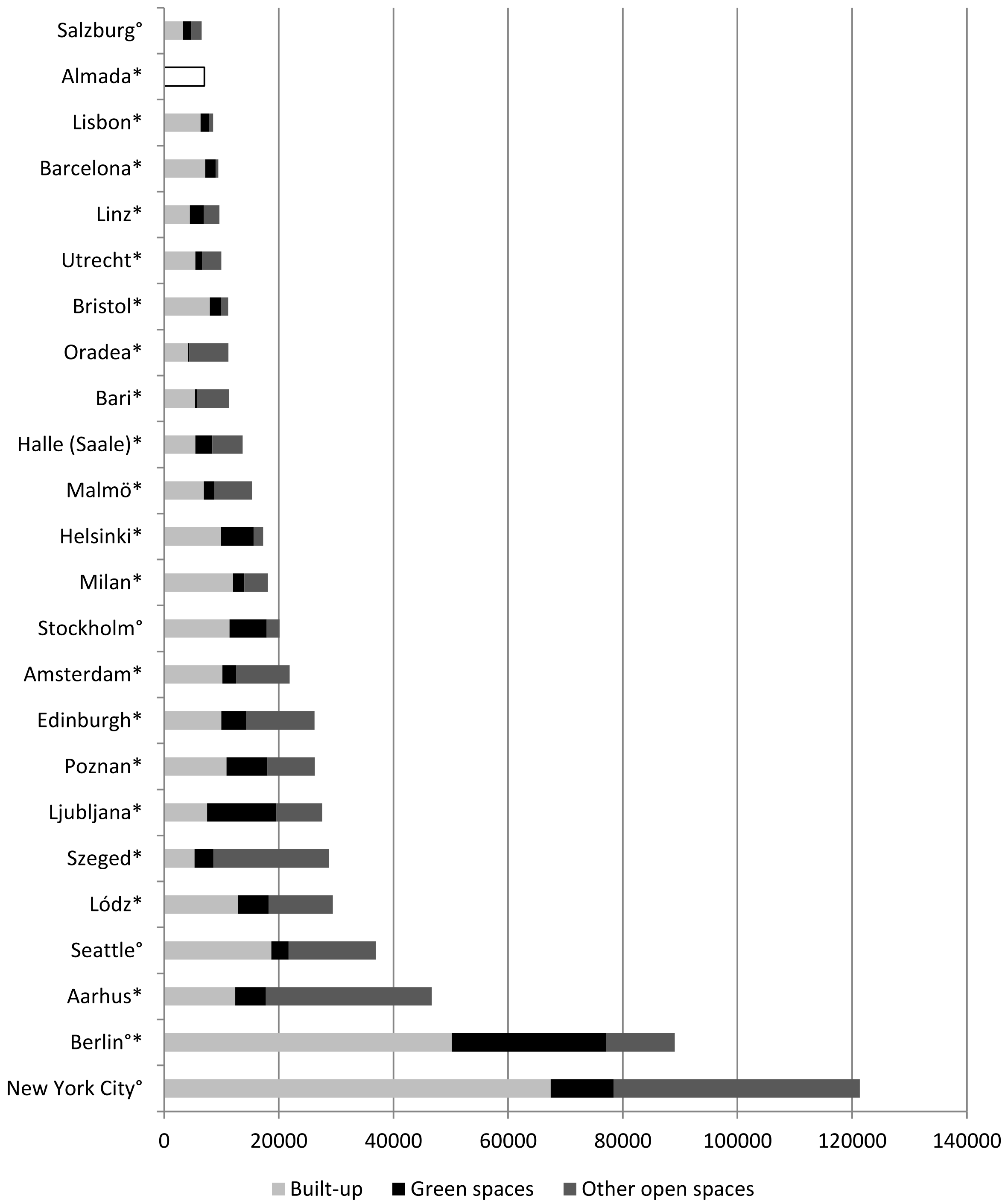

Fig. 11: The 24 case study cities sorted by size with their open and built-up land uses. Land use for the European cities has been calculated based on Urban Atlas data (2006). Category “green spaces” includes Urban Atlas classes most relevant for recreation: green area, sport and leisure, and forest area; category “other open spaces” includes classes: agriculture, water area, and land without current use. Category “built-up” includes all other Urban Atlas classes dominated by sealed and overbuilt surfaces. For Almada, land use information had not been available. For Seattle and New York City, values have been calculated based on statistical data (City of Seattle, 2013; New York City Department of City Planning, 2013). For both US cities, category “other open spaces” represents water area surrounding land mass. The degree character (°) indicates cases from study 1, the asterisk (*) cases from study 2.

3.5.1. Cases within Study 1

For the case study selection of study 1, the focus was on European and US cities. Both continents entered the discourse on ecosystem services in different time periods. In the US, the concept has been applied by the federal governmental bodies such as the USDA Forest Service and the US Environmental Protection Agency for about a decade (e.g. Molnar and Kubiszewski, 2012). European policy, on the other hand, promoted ecosystem services only recently (European Commission, 2011; European Commission, 2013). Based on local expertise among the study contributors and the role as case study cities in the URBES project (except Seattle), to secure place-based knowledge the following five case studies were selected:

- Berlin in Germany,
- Salzburg in Austria,
- Stockholm in Sweden,
- New York City, and
- Seattle in the US.

These cities represent a variety different planning traditions and contexts. In terms of spatial planning, New York City's so called PlaNYC gained international attention as a landmark vision for sustainable and integrated development (Newman and Thornley, 2013). The city of Seattle was chosen as a second case study from the US due to its prominence as a frontrunner city in terms of its collaborative green space planning approaches within the US (Karvonen, 2010; Rouse and Bunster-Ossa, 2013). In Europe, Stockholm represents a forerunner in terms of sustainable development and early uptake of the concept of ecosystem services (Colding, 2013; Metzger, 2013; Granath et al., 2012; Lewan, 2000). Berlin represents a hierarchical planning system based on formal land use planning. However, formal planning is increasingly supplemented by informal strategic planning approaches (Kabisch, 2015). Salzburg is the smallest city in this study, and uses a conservative approach to green space planning. Since the 1980s more than half of the city area is protected by a Green Space Declaration (Amt für Stadtplanung und Verkehr, 2009).

3.5.2. Cases within Study 2

The cities for study 2 were chosen within the GREEN SURGE project (Hansen and Rall, 2014). They were selected in a systematic manner to represent growing, stagnating, and shrinking cities from different geographic regions. Furthermore, the cities vary in population sizes and have different (spatial) planning cultures. This ensures, to a certain degree, representativeness across Europe. Hence, the selection criteria were defined as follows:

(1) Planning family and territorial government typology: Based on a review of classification frameworks for European planning systems the EU countries (Nadin and Stead, 2008; ESPON, 2000; European Commission, 1997) five main categories of European planning systems were developed:
    - Nordic/Comprehensive integrated,
    - British/Land use management,
    - Central/Regional economic planning,
    - Mediterranean/Urbanism, and
    - New Member States/Post-socialist.

Additionally, a territorial government system typology, based on formal governance structures, legal and administrative systems, was used as a sub-criterion (Tosics, 2013; for details see Hansen and Rall, 2014).

(2) Physical/socio-economic criteria: To include EU-wide comparable data on land use, socio-demographics and economic development the EEA's Urban Atlas and the Eurostat's Urban Audit datasets for more than 300 cities were used to identify three physical and socio-demographic criteria:
    - Population size (as an indicator for administrative capacity for green space planning)
    - Population change (as an indicator for economic prosperity)
    - Green space per capita (as an indicator for urban green area density)

    The data was classified into four groups according to their average values (in order to reduce the effect of outliers).

(3) Pragmatic criteria: Knowledge of the particular language and planning context influenced the selection of potential cities. Therefore the case city selection was also influenced by the availability of involved researchers with good language skills and/or experience from prior research in the given countries and cities. Additionally, a number of cities had already been selected as GREEN SURGE case studies[7] and a few other cities had indicated their interest in participating in the study. Those were considered if they fitted into the selection scheme.

In an iterative process a shortlist was developed by the author of this thesis with contributions from the research consortium (Hansen and Rall, 2014) starting with the pool of cities included in the Urban Atlas and the Eurostat's Urban Audit. Based on the pragmatic criteria as well as aiming at a broad variance of physical/socio-economic criteria, two to five cases were chosen for each planning family, depending upon the number of countries belonging to each planning family. The selected case studies also cover more than half of the eleven European biogeographic regions (see Davies et al., 2015):

- Nordic: Aarhus (Denmark), Helsinki (Finland), Malmö (Sweden)
- British: Bristol and Edinburgh (UK),
- Central: Amsterdam and Utrecht (The Netherlands), Berlin and Halle an der Saale (Germany), Linz (Austria),
- Mediterranean: Almada and Lisbon (Portugal), Barcelona (Spain), Bari and Milan (Italy), and
- New Member States: Lódz and Poznan (Poland), Ljubljana (Slovenia), Oradea (Romania), Szeged (Hungary).

3.5.3. Cases within Study 3

The survey of 20 European cities mentioned above represented the pool of potential cases for the good practice study. After completion of study 2, all participating researchers reviewed their cases for innovative approaches which can be considered as urban green infrastructure planning. From the findings, a shortlist was created and discussed in a workshop (Utrecht, February 24 2015), with the researchers. Planning approaches of the following cities stood out as potential good practice cases for application of multifunctionality:

[7] Five so called urban learning labs, cities in which collaborative processes for learning and knowledge exchange between researchers and practitioners were initiated (van der Jagt et al., 2016).

- Aarhus (Denmark),
- Berlin (Germany), and
- Edinburgh (UK).

The cases differ in terms of plan or strategy type and spatial scale, nevertheless they are all three facing urban growth and thus need to balance urban growth with conserving and enhancing the city's green infrastructure. They are briefly introduced below (see also Fig. 12).

Edinburgh, UK

The case study in Edinburgh deals with the city's Open Space Strategy (OSS) (city-, neighbour-hood-, and site-scale) and is focussed on considering multifunctionality in a green space assessment (called audit). Edinburgh's expected continuous population growth leads to urban development, including regeneration and redevelopment of vacant and derelict land (CEC, 2014). The main objectives of urban green space policies are to improve existing green spaces (i.e., quality and accessibility), minimise their loss to urban development and provide an adequate share of green spaces in new developments. The OSS includes three components: the audit, the standards, and action plans (ibid., 2009, 2010). The audit classifies Council-owned open spaces of about 500 square meters and provides basic information about the quantity and quality of different green space types. The standards were introduced, to ensure adequate access to high quality green and open spaces for all citizens. The neighbourhood action plans indicate measures for improving individual green spaces which are not in line with the standards.

Berlin, Germany

The Berlin case concerns the city's Landscape Programme (LaPro) and is focussed on multifunctionality as a strategic planning principle. Berlin, the second largest city in the EU, faces population growth from 3.5 to 3.8 million inhabitants by 2030 (SenStadtUM, 2016a: 23). The compact city model is guiding urban development (ibid. 2015a,b) which increases development pressure on green and open spaces. The city model, moreover, aims for an adequate share of green space (ibid. 2015b). The LaPro is an important strategic instrument for conserving the cities green spaces and their functions and for developing a multifunctional, connected city-wide green infrastructure (ibid., 2016b).

Aarhus, Denmark

The Aarhus case is a green space restoration project (district- and site-scale) and multifunctionality is mainly considered as a principle for site design and management. Aarhus, the second largest city in Denmark with about 330,000 inhabitants (Statistic Denmark, 2016), is currently confronted by growth of approximately 4,000 inhabitants per year (Aarhus City, 2016: 2). Urban planning policy is aiming at a compact city that is supposed to host a population of 450,000 by 2050 without urban sprawl (Plan Strategy, 2015: 5). Thus, densification and urban renewal are priority measures to create room for the growing population. The urban renewal and green space restoration takes place in Gellerup-Toveshøj, Denmark's largest social housing area for approximately 7,000 people. The area is in deprived conditions and thus, a key urban development project for Aarhus (Aarhus Municipality, 2011). The project's aim of increasing the districts multifunctionality is closely connected to restoring green space functions and quality (SLA, 2014).

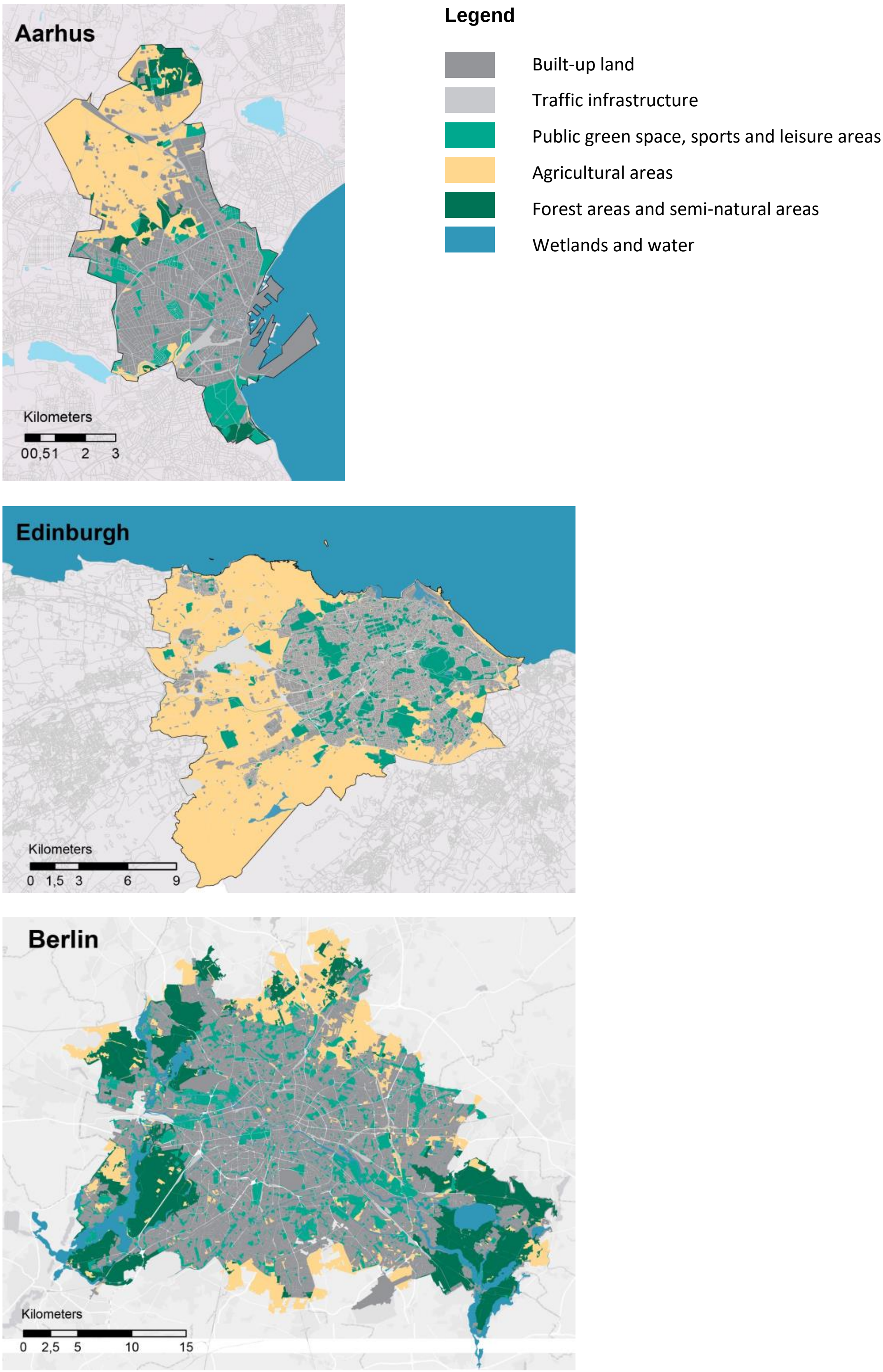

Fig.12: The municipal areas of the three good practice cities Aarhus, Edinburgh and Berlin (different scales; based on data from Urban Atlas 2012, Open Street Map, Esri, HERE, DeLorme, Mapmyindia, and the GIS user community; basic data compiled by Sabrina Erlwein).

4. Synthesis of Results

The following chapter summarises the main results of the conceptual and empirical research papers I-III. The first part presents the developed framework for linking green infrastructure and ecosystem services (research question 1). The second part focuses on the current consideration of multifunctionality and ecosystem services in planning practice based on case studies, including three good practice studies (research question 2). The chapter concludes with an overview of the key findings and builds the foundation for the discussion and the development of recommendations for planning practice (research question 3) in Chapter 5.

4.1. Conceptual Framework (Paper I)

Paper I combines the current knowledge from scientific literature on green infrastructure with the one on ecosystem services into a common framework for multifunctionality in urban planning. The starting point was a perspective that regards cities as complex and multi-scale social-ecological systems (Ernstson, 2013; Pickett et al., 2011; Alberti et al., 2003, see also Chap. 2.1.2).

The developed framework involves three pillars: a **system analysis**, leading to different **valuation** aspects and the formulation of a **strategic plan** (see Chap. 2.1.1). The 'system analysis' pillar includes two dimensions: the ecological dimension and the societal dimension, while the other two pillars each represent one dimension (see Fig. 13).

The first dimension (D1) is targeted by analysing the status quo concerning the existing green spaces and their features in order to identify their capacity to provide multiple functions or services. A holistic consideration of the ecological dimension involves:

a) the different types of green and blue spaces (**green infrastructure elements**) and their (ecological) **conditions,**
b) the spatial relations between the green infrastructure elements that together constitute the city's green network (**distribution** and **connectivity** of elements),
c) the **supply of ecosystem services** which includes identification of the relevant ecosystem services and the capacity of the different green infrastructure elements to provide and distribute these services.

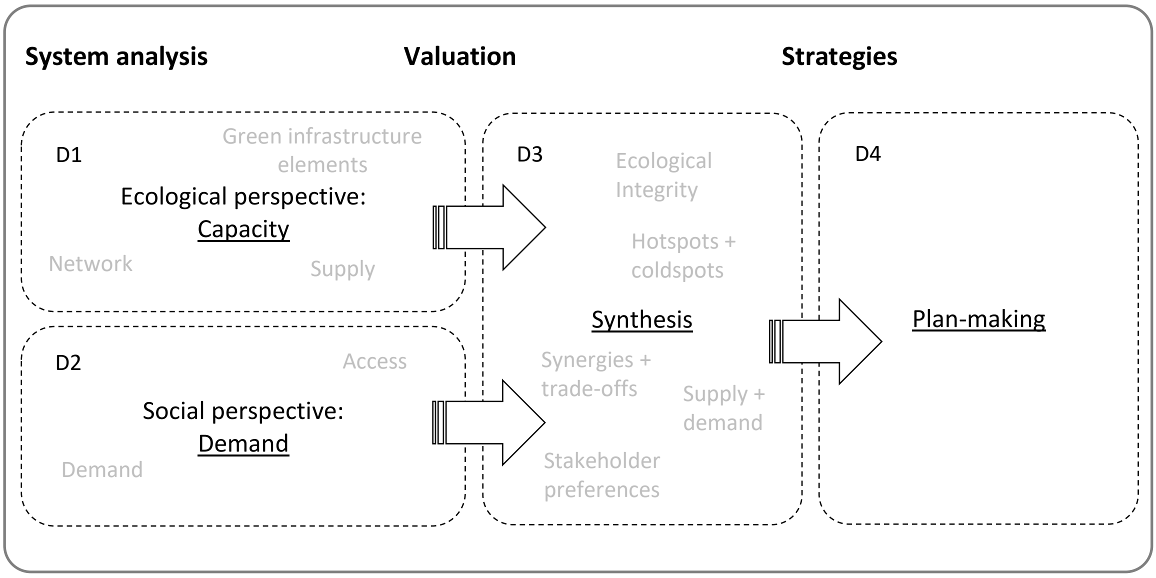

Fig. 13: Conceptual framework for assessing multifunctionality within urban green infrastructure planning. Grey text in indicates sub-categories (D = Dimension).

The second dimension (D2) concerns the status quo of the social system:

d) the **demand** for ecosystem services of the local population, including their concerns and negative perceptions, and
e) just **access** to these services, including awareness about who would benefits from investments in green infrastructure and who might be excluded.

The **valuation** dimension (D3) combines the different social and ecological aspects in order to assess multifunctionality:

f) the green infrastructure's overall **ecological integrity**[8] can be assessed by combining data for points a) and b),
g) points a) and c) can be combined to identify **hotspots of multifunctionality**, respectively areas that provide a high number of services or are important for the provision of certain services; likewise, **cold spots** with low provision can be identified,
h) data for point a) and c) are of further relevance to analyse **synergies and trade-offs** between different ecosystem services,
i) data on point c) and d) can be combined with the aim to identify areas or services where the **balance between supply and demand** needs to be improved,
j) **stakeholder preferences** and needs should be assessed with data for points d) and e) in combination with the ecological analysis to ensure just access to the provided benefits.

[8] Ecosystem integrity can be considered through indicators for biotic and abiotic ecosystem functions, structures and balances (Müller, 2005).

For valuation of these different aspects, a variety of frameworks, assessment methods and tools for stakeholder involvement is available which can support a consideration of multifunctionality (see Tab. 3, partly, an adaptation to urban contexts would be necessary). A holistic approach will require the combination of different methods and synthesis of different kinds of data, as described above.

After a comprehensive valuation, priorities and strategies for action would need to be identified in the **plan-making** phase (Dimension 4). These include:

- priorities for improving the city's green network (e.g. increasing connectivity, addition of new elements or restoration of the existing ones, see Fig. 4 in paper I), or
- measures to promote the synergies and reduce trade-offs.

Tab. 3: Examples of conceptual frameworks and assessment components that can aid a comprehensive consideration of multifunctionality.

	Conceptual frameworks	**Assessment components**
Analysis of the ecological system		
Typologies of green infrastructure elements	see Chapter 2.3.1	Typologies of green space types (e.g. Cvejić et al., 2015)
Identification of green infrastructure networks	see Chapter 2.3	Spatial analysis of green infrastructure networks including connectivity (e.g. Davies et al., 2006)
Conditions of green infrastructure elements	Ecosystem/landscape properties and potentials (Bastian et al., 2012; van Oudenhoven et al., 2012) Ecological integrity (Burkhard et al., 2012 based on Müller, 2005); Ecosystem health (Tzoulas et al., 2007)	Indicators (e.g. Burkhard et al., 2012)
Classifications of urban ecosystem services	see Chapter 2.4.1 (e.g. Gómez-Baggethun and Barton, 2012; Niemelä et al., 2010)	Indicators (e.g. Maes et al., 2016; Gómez-Baggethun and Barton, 2012)
Ecosystem service supply	Frameworks for provision and flow of ecosystem services (Syrbe and Walz, 2012; Fisher et al., 2009) Service providing units in urban areas (Wurster and Artmann, 2014)	Indicators for assessing ecosystem service supply: -Criteria to select indicators (van Oudenhoven et al., 2012) -Indicators (e.g. Gómez-Baggethun et al., 2013; de Groot et al., 2010) Assessment approaches based on expert or stakeholder judgement (e.g. Burkhard et al., 2012) Monetary and non-monetary valuation approaches (e.g. Gómez-Baggethun and Barton, 2012) Study examples (e.g. Maes et al., 2016; Burkhard et al., 2012; Haase et al., 2012)

Analysis of the social system		
Consideration of demand	Demand (Fisher, 2009) Disservices (Lyytimaki and Sipila, 2009)	Expert judgements, statistical data or politically agreed standards (e.g. Burkhard et al., 2012; Kroll et al., 2012) Stakeholder participation (e.g. Diaz et al., 2011)
Consideration of access	Just access (Robards et al., 2011) Ecosystem services and private-public good aspects (Fisher et al., 2009)	Indicators: e.g. access standards (e.g. Accessible Natural Greenspace Standard, Natural England, 2010; Maes et al., 2016)
Valuation of multifunctionality		
Integrity of the green infrastructure network	see Chapter 2.3	Decision support matrix (see Fig. 4 in paper I based on Davies et al., 2006)
Hot and cold spots		Examples: Lovell and Taylor, 2013; The Mersey Forest, 2011
Synergies and trade-offs	Frameworks and definitions (Haase et al., 2012; Rodríguez et al., 2006)	Assessment (e.g. Haase et al., 2012)
Supply and demand balance		Assessment (e.g. Burkhard et al., 2012)
Stakeholder preferences		Weighting of stakeholder preferences (e.g. Diaz et al., 2011) Multi-Criteria Decision Analysis (e.g. Langemeyer et al., 2016) Scenarios (e.g. Sanon et al., 2012) 3D Visualizations (e.g. Grêt-Regamey et al., 2013)

4.2. Consideration in Planning

The current consideration of ecosystem services and multifunctionality as planning principle has been examined in study 1 and 2 whereof core results are presented below.

4.2.1. Ecosystem Services in Planning Documents (Paper II, Study 1)

In study 1 on the **conceptual level**, 10 of 33 planning documents explicitly mentioned ecosystem services as a concept, while the US documents also largely referred to benefits from nature and 13 documents from both the US and Europe considered landscape/ ecological functions. 11 plans regarded none of the three terms (see Fig. 2 in paper II).

The **perspective on human-nature relations** conveyed by ecosystem services, representing an anthropocentric, benefit oriented view, was mirrored in several planning documents from the US and Europe. The planning documents from Seattle in particular pointed to the interdependence between humans and nature. Additional perspectives on nature included the awareness of the negative impacts that human activities have on natural systems, the responsibility to protect nature and the need to protect humans from hazards and environmental risks. However, environmental issues such as flooding, air quality or noise have also been raised without referring to potentials of ecosystem services to mitigate those (see Tab. 4 in paper II).

Regarding the **content** of the plans dealing with representation of different ecosystem services, habitat services have been included. Together with recreational/health services, they belong to the two services that not only have been mentioned most often but have also been elaborated on most often, i.e., underpinned with measures or targets. In addition, the analysis of planning documents revealed that more than half of the ecosystem services types (14 of 21 services) have been considered in the majority of the planning documents, with an average of eleven services per document (see Fig. 3 in paper II).

Types of plans that indicated awareness for multiple services were strategic plans providing visions on urban development (such as the PlaNYC for New York) or on green space development (such as Berlin's Urban Landscape Strategy) which referred to a comparably high number of ecosystem services. Furthermore, regional plans such as New York's Open Space Conservation Plan or Salzburg's Regional Plan stood out in number of acknowledged services. A low number of services were mentioned in sectorial plans such as Seattle's Stormwater Management Plan or Salzburg's Concept for Traffic (see Fig. 4 in paper II).

4.2.2. Multifunctionality in Planning Practice (Paper III, Study 2)

The analysis of planning practice in 20 European cities in study 2 on the **conceptual level** revealed a broad awareness for the ability of urban green space to provide multiple benefits. This was the case in the interviews as well as in the document analysis (see Fig. 3 and 4 in paper II).

While most planning documents from the 20 cities referred to multiple functions of urban green spaces, less than half mentioned enhancing multifunctionality as planning objective or principle. An explanation of what is meant by multifunctionality or how it should be **operationalised** was missing in most cases. When comparing cities that consider multifunctionality as a planning objective with contextual factors, it became evident that in particular cities with strong population growth considered enhancing multifunctionality.

The qualitative analysis of the **content** of the plans revealed that the plans referred to several regulating (mainly stormwater regulation and flood protection, microclimate regulation and air circulation) and cultural (such as recreation, aesthetics) functions and services as well as to biodiversity protection as a planning aim. Additionally, functions have been mentioned that usually do not fall under the concept of ecosystem services such as providing mobility (through a route network for walking and cycling) or structuring of the urban form (e.g. by constituting a physical buffer that prevents urban sprawling into the countryside).

4.3. Good Practice Approaches (Paper III, Study 3)

To explore the application of multifunctionality in urban green space planning practice, three good practice examples have been studied: the Open Space Strategy (OSS) from Edinburgh, Berlin's Landscape Programme (LaPro), and the Gellerup green space restoration project in Aarhus. The cases have been used to explore how multifunctionality has been assessed and, considered as planning strategy, and as design and management principle. Since none of the cases applied the concept of ecosystem services, "function" is used as an umbrella term.

4.3.1. Spatial Assessment

The three cases applied different approaches to ensure that different green space functions are considered in a systematic manner, most prominently the OSS from Edinburgh. The OSS is based on a systematic quality audit of each public green space (see Tab. 2 in paper III). Experts filled out a checklist at a site visit. The audit included several criteria on green space quality from a human user perspective (access and appearance) as well as on biodiversity (diversity of habitats and connectivity). Furthermore, it assessed the suitability of the site for different green space uses such as ball games, cycling and picnicking and potential conflicts caused by inadequate uses. This approach resulted in a ranking of each green space against the city's standard (see Fig. 5 in paper III).

The LaPro from Berlin largely synthesised existing surveys and updated environmental information from the prior LaPro version, including GIS-data. The plan's objectives and measures have been displayed in thematic maps for the whole city. Priority areas for actions for the plan's different themes are combined within the one plan based on the city's green structure, the so called "General Urban Mitigation Plan" (Gesamtstädtische Ausgleichskonzeption) or GAK (see Tab. 4 in paper III).

In Aarhus, the park restoration was assessed by the involved landscape architects, regarding three dimensions: (1) social and health issues, (2) economic sustainability, and (3) ecological, climate and environmental sustainability. This qualitative assessment was applied for all plan features to illustrate how they contribute to a multifunctional park and the neighbourhood's sustainability (see Tab. 3 in paper III).

4.3.2. Multifunctionality as Planning Principle

The emphasis on multifunctionality as planning principle was most evident in Berlin. Together with increasing accessibility and connectivity, multifunctionality and high quality of urban green spaces were core strategies to ensure green space provision in densely built-up areas. Therefore, multifunctionality was explicitly mentioned as a planning aim and linked to the GAK as city-wide framework. The GAK was supposed to ensure that core elements of the green space networks are developed or restored under consideration of several priority functions in concert (see Fig. 6 in paper III).

In contrast to the comprehensive perspective on green space functions in Berlin, the OSS had a strong focus on social functions with a few criteria for biodiversity. In Edinburgh, other plans ensure, for instance, the consideration of regulating functions. In Aarhus, multifunctionality was a guideline for the urban renewal project encompassing the park restoration as well as the adjacent district. For the park project the social perspective was strong, too. However, the involved professional planners ensured that economic and ecological aspects have been included in the park concept.

4.3.3. Multifunctionality for Site-Level Design and Management

As a design and management principle, the Aarhus case was most informative due to its scale. Many of the designed park features promoted multiple functions such as areas that temporarily serve for water retention during heavy rainstorms while otherwise being used as a football pitch or a cherry grove. A wetland area was also supposed to create synergies between water retention, biodiversity conservation, and nature experiences (see Fig. 7 in paper III).

Similarly, in Berlin the implementation of the GAK led to the development of multifunctional green spaces. One example from the prior version of the GAK is the 'Park auf dem Nordbahnhof', which provides several social and cultural functions (such as recreation, cultural heritage, nature experience, mobility) while promoting biodiversity. By zoning, areas with a priority for biodiversity or for recreation have been created (see Fig. 8 in paper III).

In Edinburgh, the focus is on improving green spaces that do not comply with the quality standard. These spaces are considered in neighbourhood action plans.

4.4. Key Findings

The key findings from the three papers concern the conceptual basis of multifunctionality, the current consideration in planning practice and examples how multifunctionality has been operationalised in different cities. They are summarised in the following Table.

Tab. 4: Overview of the key findings

Key Findings
Conceptual Level ▪ Multifunctionality can link green infrastructure and ecosystem services and provide a framework for holistic planning of urban green spaces as part of complex social-ecological systems. ▪ A comprehensive approach to multifunctionality includes consideration of supply and demand, synergies and trade-offs, as well as the provision capacity of green infrastructure elements. ▪ A broad variety of concepts and assessment approaches from research on ecosystem services is available and should be employed in green infrastructure planning.
Consideration in Planning ▪ Several concepts as well as perspectives on human-nature relations are embedded in planning documents of the analysed cities that provide potential linkages to the ecosystem services concept. ▪ Ecosystem services most often considered in the analysed planning documents include habitat services and cultural services. Overall, the majority of the planning documents referred to more than half of the 21 ecosystem services. ▪ Strategic plans providing visions for urban development, including strategic plans for urban green spaces, often included a large number of services. High numbers were also found in regional plans, while sectorial plans dealing with certain environmental aspects (such as water or climate) or technical infrastructure likely include low numbers. ▪ Regarding multifunctionality, the capacity of urban green spaces to provide multiple benefits is widely acknowledged. This became apparent in planning document analysis and interviews with planners. ▪ Enhancing multifunctionality as a planning objective is less common across European cities but is considered in particular by cities facing population growth.
Approaches for Operationalising Multifunctionality ▪ In the three analysed good practice cases, multifunctionality is related to varying degrees to green space assessments, planning strategies, as well as design and management principles: - Multifunctionality assessments involved the integration of surveys for specific functions at the city-scale (layering of GIS data for different functions), systematic audits of all (public) urban green spaces according to a measurable standard, and qualitative assessments of green space features (e.g. provision of ecological, social, and economic functions). While these assessments have been undertaken by experts, they have partly been informed by public participation. - Multifunctionality as a principle for strategic planning has been related to different aims such as using space efficiently in dense urban areas, to identify priorities for actions or to increase attractiveness of certain spaces. - For the site level, multifunctionality has been enhanced through different strategies such as fostering synergies between complementary functions within one area, accommodating priority functions at certain times (such as flood events) or spatially separating competing functions (e.g. by zoning).

5. Discussion

The discussion of the main findings begins with an elaboration of the developed conceptual foundation by exploring the different dimensions of multifunctionality in the context of green infrastructure planning. This includes a discussion of how the concept of ecosystem services can help to systematically consider multiple functions and their interrelations. Findings are linked to the empirical results in order to identify gaps and potential linkages between theory and practical application. In a second step, the findings are synthesised into recommendations for planning, including a brief presentation of how they have been integrated in a guide for urban green infrastructure planning, which was produced as part of the GREEN SURGE project. The chapter concludes with methodological reflections and implications for future research.

5.1. Multifunctionality as a Conceptual Linkage between Green Infrastructure and Ecosystem Services – Potentials and Challenges

Paper I has explored how multifunctionality can connect the green infrastructure approach with the ecosystem services concept. While the discourses on green infrastructure and ecosystems services have largely evolved independently from each other, both consider 'functions' of ecosystems (or in general vegetated areas) to different degrees, and references to 'multifunctionality' can be found in the literature as well as planning documents. However, in the context of green infrastructure, multifunctionality is often mentioned as a (normative) principle for developing networks of green spaces that provide multiple social, ecological and economic benefits in a synergistic manner; in the context of ecosystem services, usually ecological functions are discussed as a precondition for the provision of ecosystem services (see Chap. 2.3 and 2.4). Linking both can on the one hand strengthen the theoretical underpinning of green infrastructure, in particular with regard to a systematic capture and assessment of different functions respectively services. On the other hand a linkage of both can also indicate ways forward for ecosystem service approaches towards better correspondence with urban planning needs.

5.1.1. Multifunctionality as a Holistic Concept

As shown in Chapter 2.2, multifunctionality in itself is a "fuzzy concept". Understood in its simplest and literal meaning, multifunctionality refers to the provision of multiple functions or services that can be measured, for instance, by assessing the provision of different ecosystem services or analysing landscape functions. As a planning principle, multifunctionality involves a normative dimension aimed, for example, at contributing to sustainable land use (Brandt et al., 2004), promoting density and mixed-used in order to use space efficiently, within an emphasis on promoting synergies between different functions (Rodenburg and Nijkamp, 2004; Westerink et al., 2013).

However, the current understanding of multifunctionality in planning practice remains elusive. The results of the semi-quantitative study of green space planning in 20 European cities clearly indicate that planners have a general idea about multifunctionality (paper III), similar to the large body of literature that points to the multiple benefits provided by green spaces (see Chap. 2.2.3). On the other hand it seems to be taken for granted that green spaces in any case provide multiple functions in concert since attempts to define or operationalise multifunctionality in strategic plans have been rare.

Scholars have raised concerns that a lack of proactive planning for multifunctionality might be problematic (see Chap. 2.3.3). In the literature, several examples can be found for sub-optimal use of green and open spaces or conflicts between functions, when these interrelations are not considered. Examples include spaces that are designed for one dominant function such as streets including their margins and parking lots or technical water management infrastructure (e.g. Rouse and Bunster-Ossa, 2013). Typical conflicts occur in green spaces that are used for recreation and concurrently host rare and sensitive species (e.g. Pauleit et al., 2011).

To support a holistic perspective on green infrastructure and its benefits, the multifunctionality concept needs a multidimensional underpinning (see also Naveh, 2001). Based on the results from paper I-III, such a comprehensive understanding should be based on a social-ecological perspective that captures the dynamisms and complexity of cities and their green spaces, for example by combining social and ecological valuation of green infrastructure. Such a comprehensive approach involves:

(1) a consideration of green infrastructure elements and their (spatial and functional) connections within a city at different spatial scales, including the different capacity of those elements to provide certain functions or services (ecological dimension),
(2) demand for green space benefits by different social groups, including access to them (social dimension),
(3) an integrated assessment of the ecological and social dimension, including synergies and conflicts between different functions or services as well as between supply and demand, and
(4) spatial and temporal arrangement of functions and services within the same area in ways that leverage synergies.

5.1.2. Ecosystem Services as a Concept for Operationalising Multifunctionality

Many examples from research focus on the assessment of different ecosystem services without attention to interrelations between them (Pulighe et al., 2016). Nevertheless, the discourse on ecosystem services is rich in conceptual frameworks as well as assessment approaches that can help to operationalise different aspects of multifunctionality. Additionally, all three good practice cases aimed at a systematic consideration of green space functions and provided some instructive aspects yet also lack comprehensive approaches (paper III).

Instructive approaches but also challenges from both theory and practice include:

Classifying functions and services

Ecosystem service classifications can provide a framework for evaluating if a broad range of services is considered. Paper II revealed that none of the four groups of provisioning, regulating, habitat/supporting, or cultural services were significantly underrepresented in planning practice. However, the analysis of planning documents from US and European cities also has shown that planners' priorities differ from the consideration of urban ecosystem services in research. In planning documents, benefits related to biodiversity and social-cultural values are of high importance. This focus can be explained by the relatively long tradition of nature conservation and recreational planning in many cities around the world (Randolph, 2012; Elmqvist et al., 2004; Ahern, 1995; Turner, 1992). Furthermore, provisioning services have often been considered (with the exception of medicinal resources), while regulating services such as carbon sequestration, noise reduction, waste water treatment, and pollination were comparably rarely addressed in planning practice, but are widely suggested in the academic literature as core urban ecosystem services (see Chap. 2.4.1). The presence of provisioning services may be caused by the inclusion of regional planning documents that also cover rural areas or by city boundaries that include large areas of agricultural and forested land. The relatively low priority on regulating services in certain documents might be related to presence of stand-alone sectorial plans that deal with issues such as noise, stormwater or sewage. However, cross-cutting issues such as climate change are supposed to raise the need for more integrated planning approaches (Gill et al., 2007). Comparing these results with similar studies (Wilkinson et al., 2013; Piwowarczyk et al., 2013), it becomes evident that it might be difficult to generalise major urban ecosystem services since their relevance is context dependent.

In urban areas the concept of ecosystem services faces further limitations due to the fact that ecosystem services concern benefits provided by vegetated elements while urban green spaces usually consist of natural and technical elements that both can be very important for its value from a human perspective. Examples for technical elements include a (paved) path network or facilities such as benches and playground equipment. In line with this, the study of planning documents from 20 European cities (paper III) revealed a number of green space functions that would not fall under the concept of ecosystem services such as promoting biodiversity, supporting mobility (through a route network for walking and cycling), or structuring of the urban form (e.g. by constituting a physical buffer that prevents urban sprawling into the countryside). Therefore, in urban areas the concept of ecosystem services should be supplemented with a wider framework that captures the additional functions of urban green spaces (for a multifunctionality concept in agricultural landscapes involving ecosystem services see Huang et al., 2015).

Assessing functions and services

The current state of the art of mapping and assessing ecosystem services for urban areas in Europe, published by the European Union in the report "Mapping and Assessment of Ecosystems and their Services – Urban ecosystems" (Maes et al., 2016), is based on Urban Atlas data, ideally supplemented with more fine-grained local data such as tree inventories or aerial photos. For assessing urban ecosystem services an indicator framework based on the CICES ecosystem service classification[9] is recommended. However, the suggested indicators lead to relatively coarse results on the city-regional level, lack a consideration of biodiversity, and reduce cultural ecosystem services to presence of specific green space types and access parameters. Moreover, many urban ecosystem service assessments in research are still limited to studies of a few or even single services (Pulighe et al., 2016).

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[9] CICES stands for "Common International Classification of Ecosystem Services", a classification system proposed by the European Environment Agency, available from https://cices.eu.

The studied good practice approaches have been operating on a much finer resolution of data than the indicator-based approaches discussed in research. The case from Berlin is most similar to indicator-based GIS analysis commonly used in the context of ecosystem service assessments since it aims at "layering" data for the whole city, yet the approach covered a broad range of ecological and social functions. The case from Edinburgh exemplified how a simple checklist approach can be used to gather information for each green space individually in a systematic and pragmatic manner. Generating data via field work is, of course, much more resource intensive than analyses of (existing) data sets covering large scales, which explains their popularity in research.

However, to support local planning with sound ecosystem services assessments, both high quantity (data on different services) and high quality of data (complex metrics and indicators) of ecosystem features is required (BenDor et al., 2017). This is especially true for assessing multifunctionality. Moreover, spatial assessments need to more strongly incorporate social-cultural and biodiversity aspects (Kremer 2016a et al., 2016).

The different kinds of data require integrated assessments that combine ecological and social (and economic) valuation methods (Kronenberg and Andersson, 2016; Castro et al., 2014; Schetke et al., 2010). Recent advancements in ecosystem service research offer first approaches for integrating these dimensions (cf. Kenter, 2016; Saarikoski et al., 2016).

Demand

The consideration of multifunctionality also requires the integration of multiple viewpoints, or in other words, divergent demands by multiple stakeholders. In the good practice cases demand has been identified by experts (such as green space provision standards in Berlin), but also by extensive consultation of citizens, for instance to develop a green space standard in Edinburgh or to create a park that meets the demands of the diverse neighbourhood in Aarhus. In regard of inclusive planning, many cities already have experiences and tools which can be instructive for research, including tailored approaches for different social groups (Hansen et al., 2016a; Wilker et al., 2016). Working with scenarios has also been suggested as a way for fostering discussion among stakeholders (O'Farrell et al., 2010). Visualisations can be used to discuss alternatives and make them tangible (Grêt-Regamey et al., 2013; see Tab. 3 in Chap. 4.1). Such methods can be applied to map out different demands.

Synergies and conflicts

In terms of identifying synergies and conflicts, in the case of Aarhus synergies have been considered to some degree, while the OSS in Edinburgh included conflicts in the green space checklist. A comprehensive consideration of synergies and trade-offs was missing in all cases. Assessments for analysing synergies and trade-offs between ecosystem services have been developed (e.g. Howe et al., 2014; Mouchet et al., 2014; Queiroz et al., 2015), yet for urban green space planning these approaches would need to be developed further to include more fine-grained information.

5.2. Recommendations for Urban Planning

The results from all three papers can be synthesised into a planning strategy for multifunctionality. A planning strategy can be understood as an approach to achieve long-term goals for planning and implementation with a thematic focus such as multifunctionality. Components of such a strategy include the definition of the main theme or concept and related objectives as well as measures for setting the strategy in place. Approaches and tools are needed to assess the current state of the city's green spaces, for instance, to identify potential improvements. Other factors that contribute to a strategy and its implementation are actors and resources; this means stakeholders that are able to contribute to the achievement of certain objectives as well as required financial and technical means. For continuous implementation, measuring of success, or adaptation of the approach, monitoring is needed (see Chap. 2.1.1). For planning in any given city the following recommendations should, however, not be taken up uncritically and always be tested against local conditions and needs. But before touching upon the operational questions, first the conceptual level will be discussed.

5.2.1. The Capacity of Urban Planning to Embed New Concepts

Paper II revealed that planning organisations are on the one hand able to pick up new terms such as ecosystem services relatively quickly. On the other hand, the study has shown that there is often no straightforward or literal representation of these new concepts. The following factors appear to support mainstreaming.

The concept of "issue-attention cycles" (Downs, 1972) explains how global or local issues and related policies might facilitate the uptake of new concepts. Downs described a pattern in which the public attention of a certain issue rises to a peak followed by a decline. This pattern can leave an issue unresolved, but might also lead to mainstreaming it in policy-making and institutional changes as well as increasing public awareness for it (ibid.). "Trigger events" such as the Rio summit for the concept of sustainable development or Kyoto for climate change can propel the rise of attention (Holt and Barkemeyer, 2012).

For multifunctional forestry the impact of high-level policies and legal obligations has also been noted as a driver for different countries (Pröbstl et al., 2008). In line with this, the influence of legal frameworks on consideration of specific ecosystem services was evident in certain cities studied within paper II; for example, the Clean Water Act in the US that obligates US cities to improve their stormwater management and promotes the uptake of Water Sensitive Urban Design and other approaches which involve the promotion of water-related regulating services (Fletcher et al., 2014). Similarly, the presence of air quality as an environmental issue can be related to US and EU legislation (Clean Air Act in the US; Air Quality Directive in the EU). While legislative acts often force cities to act and may be the results of a previous issue-attention cycle, other supporting factors included **national discourses** or **pilot projects** on ecosystem services which increased attention and interest among urban planners.

Another strong driver for mainstreaming concepts can be to increase local awareness on **global challenges** if linked to local issues such as vulnerabilities to hazardous events like floods, droughts, or heat waves (Mazur, 1998). Some of the planning documents, analysed within paper II, pointed to local threats posed by extreme natural events. For instance, single extreme events such as Hurricane Sandy have been driving the development of new plans and policies in New York City.

Linking ecosystem services with the topic of resilience can help to emphasise the potentials of regulating services in avoiding or mitigating extreme events. The need to more strongly consider multifunctionality was also found in cities facing urban growth (paper III). Under conditions of global urbanization, multifunctionality can be an important strategy to use urban green space not only more efficiently, but also more sustainably and to increase urban resilience (cf. Haaland and van den Bosch Konijnendijk, 2015; Ahern, 2011). For green infrastructure planning, it could be a supporting factor to take up issues with high attention and develop strategic plans that tackle those (Hansen et al., 2016).

5.2.2. Conceptual Understanding

The suggested framework for multifunctionality can provide a starting point for developing a strategy for multifunctionality and informs practitioners about the theoretical knowledge on the nexus of ecosystem services and green infrastructure (paper I). Generally, theoretical frameworks can help to 'simplify thinking', 'structure work', 'clarify issues', or 'provide a common reference point' (Potschin-Young et al., 2017). The outlined framework can help to clarify issues by disclosing the multifunctionality concept and its dimensions, be used to formulate objectives, and to develop shared reference points.

If the concept will be adapted to urban areas, the integration of ecosystem services can support plan- and policy-making processes by systematically considering which of the broad range of services are relevant in the local context (see Chap. 5.1.2). Additionally, by pointing at interdependencies between human and nature the normative dimension of the ecosystem service concept can also strengthen the consideration of human-nature relations in urban planning. The anthropocentric perspective of the ecosystem services concept, emphasising the benefits for humans, links particularly well with (comprehensive) urban planning which strongly involves economic and social considerations. In green space plans, nature can be emphasised as a foundation for human well-being, indicating that protection and carefully management is needed to maintain the provision of these benefits (paper II). This understanding is also in line with the concept of green infrastructure which promotes green space networks that provide crucial benefits to humans, much like social or technical infrastructure (Benedict and McMahon, 2002).

Opposed perspectives on human-nature relations found in planning documents included an emphasis on the negative impacts that human activities have on natural systems or the need to protect humans from natural hazards and environmental risks. The concept of ecosystem services could be linked to both, the latter to ecosystem service that can prevent harm caused, for instance, by flooding or erosion and the prior to the need to protect nature in order to ensure the provision of benefits.

5.2.3. Embedding Multifunctionality as a Planning Principle

To ensure consideration of multifunctionality in green space planning for the entire city, the concept must be embedded at city-wide strategic planning and be underpinned with objectives. These high-level planning objectives should be linked to implementation mechanisms such as in the case of Berlin or Edinburgh (paper III). Outside of strategic planning, commonly agreed standards or guidelines can ensure that multifunctionality is implemented during investments in green infrastructure.

Reasons for pursuing multifunctionality include the efficient use of green spaces by promoting multiple functions as well as efficient use of resources to invest in urban green spaces by identifying priority actions. An additional reason is to ensure that green space meet demands and are of a certain quality. In particular under conditions of urban growth and densification, it appears to be an advantage if green space planners can argue for the conservation and development of urban green spaces on the basis of systematic assessments and comprehensive plans for the city green infrastructure (paper III).

Multifunctionality is rather targeted at enhancing and optimising green spaces or developing new spaces with multiple functions than at securing existing green spaces in their current state (paper III). However, a protective and defensive approach can also be used for those spaces that already reveal a high multifunctionality and could form a part of the planning strategy (Ahern, 2007 in Chap. 2.3.2). Furthermore, multifunctionality should be considered as just one principle within a comprehensive green infrastructure strategy, and should be combined with other principles such as increasing connectivity (see Chap. 2.3.2, paper III and Haaland and van den Bosch Konijnendijk, 2015).

Concerning plan types, comprehensive as well as green space plans appear suitable to include the multifunctionality principle (paper III). Furthermore, the plans belonging to comprehensive planning (group 1) and green space/landscape/biodiversity planning (group 2) were also the ones integrating a broad range of ecosystem services, while environmental or grey infrastructure plans (group 3) often had a limited scope on specific topics such as transport, food, or fresh water supply. Nevertheless, plans on urban climate or stormwater management were capable of attaining a broad perspective, and might likewise be suitable to contribute to multifunctionality. At the same time, some plans from group 2 narrowly focused, for instance, on habitat or cultural services (paper II). When such plans will undergo an update, the range of functions should be reassessed.

Ideally, the multifunctionality concept is taken up in several plans relevant for the conservation or development of green infrastructure, and which together form a comprehensive strategy. Cross-references and coordination should be ensured, so that the different planning instruments of a city work in concert, and contribute to multifunctionality from different angles (paper III).

5.2.4. Multifunctionality Assessments

The developed framework for assessing multifunctionality emphasises the multi-dimensionality of the concept. The variety of concepts and assessment approaches from research on ecosystem services that aid green infrastructure planning as well as the challenges for their application, have been outlined above and shall not be repeated here. However, some core recommendations for planning include: Systematic multifunctionality assessments can aim, for instance, at identification of areas where action is needed for increasing multifunctionality and/or for promoting priority functions. Further, such assessments can be used to identify potentials to increase synergies or mitigate conflicts (paper III).

A comprehensive assessment of multifunctionality should be able to differentiate between green space types. Such an approach may benefit from a defined range of different multifunctionality solutions, like number and constellation of functions and their spatial and temporal arrangement. Furthermore, target values can be needed for different green space types which recognise the capacity and limits of different spaces to provide these functions. For instance, functions of high value or importance, such as often given in flood retention areas, habitats of protected species, or cultural heritage sites, might need to be prioritised over other functions which potentially limits the choice of enhancing multifunctionality (see Fig. 14).

In particular, in dense cities, the limited green space resources need to be carefully assessed so that trade-offs or continuous decline of certain functions can be avoided, for example if recreational demand exceeds the capacity of a green space. In the end, it must also be recognised that a green space might be too small to host a high variety of functions in the desired degree.

Comprehensive assessments need to be informed by different data sets covering social and ecological (and potentially also economic) aspects and be able to integrate such data. Next to expertise from different fields, stakeholder involvement and citizen participation can contribute to gain knowledge on functions and services or for their demand (BenDor et al., 2017; Tudor et al., 2015; Kopperoinen et al., 2014; Colding et al., 2006). Assessment and planning for multifunctionality is thus ideally inter- and transdisciplinary (O'Farrell, 2010).

Joining expertise from different sectors and organizational levels can be challenging for planning authorities (Primmer and Furman, 2012). Barriers can be overcome when green infrastructure plans are built on goals and issues shared by different sectors (e.g. related to climate change adaptation, river restoration or car-free mobility).

The good practice cases show how multiple green space functions can be considered in a systematic manner at the city-wide level, for individual green spaces as well as for features within green spaces. However, approaches from practice and science would both benefit from a more upfront consideration of synergies and trade-offs. In city-wide strategic planning, even if not assessed, potential synergies and trade-offs between different functions or priority actions should at least be raised (Kremer et al., 2016b; Sussams et al., 2015; Demuzere et al., 2014). Simple matrices such as developed by Gamfeldt et al. (2013) can vividly illustrate common interrelations (see Fig. 15).

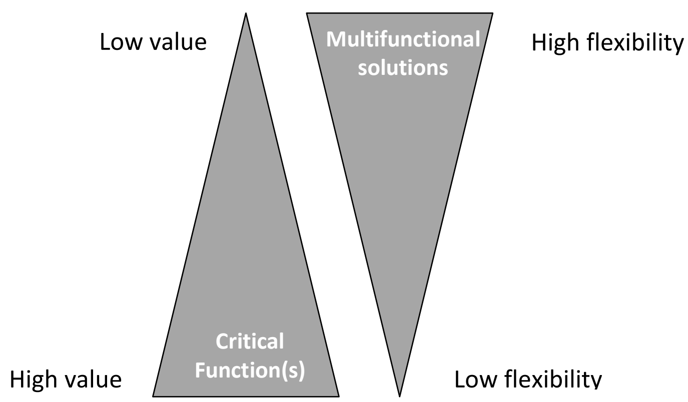

Fig. 14: The scope of action for enhancing multifunctionality in correspondance with critical functions in a given area (based on Erz, 1980 and von Haaren 2002).

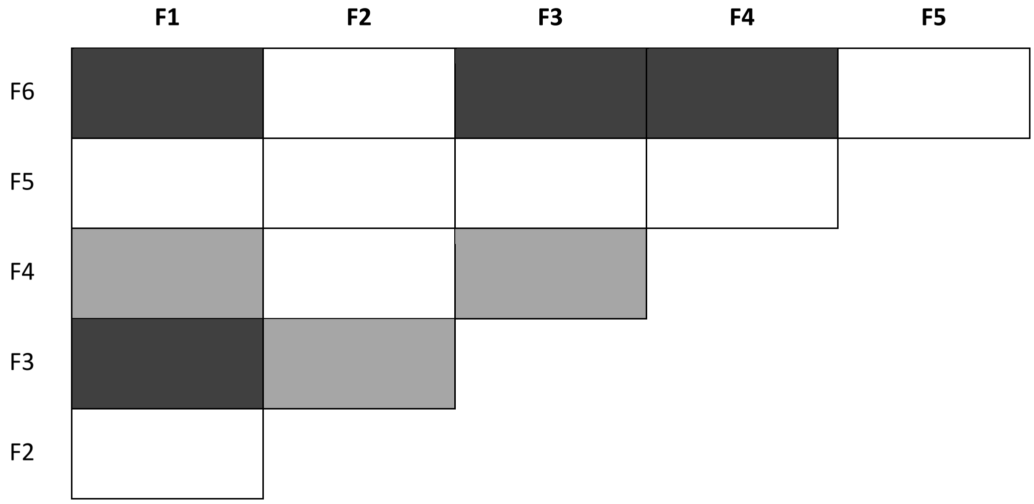

Fig. 15: Abstract representation of pairwise relationships between six different green space functions (F) or ecosystem services. Dark grey are negative relationships, medium grey are positive relationships. White represents constellations without interrelations (based on Gamfeldt et al., 2013).

5.2.5. Multifunctionality for Site Design and Management

The site level is important for developing multifunctional spaces that promote synergies between compatible functions. In the good practice cases, several examples have been found for such spatial arrangements. The combination of functions include, for instance, promoting biodiversity in concert with contemplation and nature experience in green spaces developed in Berlin and Aarhus. An example for giving priority to one function at certain times (such as flood events) has also been found as well as for the spatial separation of competing functions (by establishing attractive zones for recreation and others with habitat functions). Developing space to accommodate several functions in a temporal sequence can allow that areas have one dominant function for a limited period while promoting a variety of functions at other points in time. Next to stormwater and flood management, examples include the protection of habitats during breeding periods or other sensitive phases. These findings confirm approaches for multifunctionality considering both the spatial and temporal dimension that also have been suggested in research (see Chap. 2.2.3).

Comparing the approaches to the concept developed in the Kronsberg project, mainly “partial” and “tessellated” multifunctionality has been found. As already pointed out in Chapter 2.2.2 “total” multifunctionality might be challenging. Avoiding conflicts by spatial separation within one area can happen, for instance, through zoning or visitor management. Approaches for total multifunctionality such as the Allmende in Hannover should be further tested and improved.

Site-specific solutions could be supported by models of multifunctionality for different green space types. Such model could be used to illustrate levels of multifunctionality for different kinds of green spaces (e.g. high, medium or low levels of multifunctionality, cf. Wilson, 2007). Furthermore, models could help to clarify which green spaces provide a few priority functions compared to “generalist” green spaces types that are capable to provide a broad range of functions (see Fig. 16 and also Chap. 5.2.4). Such models could be used to develop local standards that are supposed to be considered in site-specific decisions.

Fig. 16: Two park types on former wastelands in Berlin with different priority functions: The “Park auf dem Gleisdreick” (top) was developed as a park for active recreation with plenty of opportunities for sports, play, and meeting up with people, including a small portion of sites for spontaneous nature development to support biodiversity and for nature experiences. The “Schöneberger Südgelände” (bottom) promotes contemplation and nature experience. The park is at the same time a nature reserve, and thus habitat and species protection is the priority function to which other functions must be subordinated. For example, access to the whole area is restricted to daytime, and species-rich locations may not be entered (own photos from 2011 and 2015).

5.2.6. Translating the Findings into Guidance for Planners

The results gathered within this thesis project have been condensed further as recommendations for an urban green infrastructure planning guide for practitioners and also used to develop a checklist for planners as part of the GREEN SURGE project (see Chap. 3.4, both published by Hansen et al. 2017). This guide has been published in September 2017 as a digital and printed resource to aid green space planners and decision-makers across Europe interested in the concept of urban green infrastructure.

The chapter on multifunctionality in the planning guide includes:

- A concise definition including examples and key objectives (see Tab. 5),
- An explanation of the concept of ecosystem services in comparison to green space functions and an illustration of the wide range of potentially relevant functions and services, including a recommendation of how to select functions,
- A case example from Malmö illustrating how selected functions and services are related to different kinds of urban green spaces,
- Recommendations for strategic planning for, assessment of multifunctionality and for developing multifunctional green spaces,
- A summary of key recommendations (see Tab. 5).

The guide aimed at presenting the information in an illustrative and application oriented-manner. The included checklist shall help planners to self-evaluate their green space planning approaches by taking the concept of green infrastructure planning into account. The checklist is targeted at strategic planning and can be used for plans under review or under development. The checklist section on multifunctionality is supposed to evoke reflection if different aspects of multifunctionality already have been regarded in planning and if there is a need to do so more strongly in the future (see Fig. 17).

Tab. 5: Definition, key objectives, and key messages for using multifunctionality as a planning principle (Hansen et al., 2017; UGI stands for Urban Green Infrastructure. Cross-references to other guide chapters have been deleted for this table).

Definition

- UGI planning aims at intertwining or combining different functions to enhance the capacity of urban green space to deliver multiple benefits. Planning for multifunctionality seeks to create synergies between functions, while reducing conflicts and trade-offs.

Key objectives

Multifunctionality…

- …aims to secure and increase the multiple ecological, socio-cultural and economic benefits of UGI.
- …considers interrelations between different functions and services and the capacity of different urban green spaces to provide them, while avoiding trade-offs.
- …targets the social questions of demand for and access to UGI and its benefits.

Key messages

- **Support multifunctionality at different planning levels**
  Increasing multifunctionality should be included as an objective in strategic green space plans, supported by the assessment of different functions and services, including demand for them and their spatial distribution. Clever design and visitor management can help to maximise synergies at the site-level.
- **Use tools to identify functions and benefits**
  Tools such as multifunctionality inventories or ecosystem services assessments are useful to identify multiple green space functions and benefits. However, they should be supported by a sound understanding of the kind of interrelations, synergies and trade-offs that exist between these.
- **Support participation to raise awareness of demands and needs**
  Actively involving a diverse group of local residents in UGI planning makes it more likely that outcomes will increase UGI benefits and their accessibility for a wide range of people.
- **Foster inter- and transdisciplinary collaboration**
  Multifunctional thinking and planning requires cross-sectoral and cross-departmental cooperation to integrate expertise from different professions. Thus, silo-thinking must be overcome to successfully plan for multifunctionality, e.g. by sharing tools and outputs between departments and communicating the benefits of working together.

B3	Multifunctionality: Specific activities and measures may include:		
B3.1	**Assessing** the various **ecological, social** and **economic** benefits of urban green spaces and **communicating** these to policy-makers and the public.	☐	☐
B3.2	Assessing the **demand** for green spaces across the city and their **capacity** to provide services, now and in the long term.	☐	☐
B3.3	Developing strategic plans that highlight UGI's diversity of functions and services city-wide, including **socio-cultural** (e.g., nature contemplation, social interaction, sports and play), **biodiversity** (e.g., habitats for rare species, wilderness), **regulating** (e.g., temperature regulation, flood control) or **provisioning** (e.g., agricultural products, fresh water, wood).	☐	☐
B3.4	At the site level, developing green spaces in ways that **create synergies** between different functions and services and **reduce conflicts** (e.g., through visitor management and guidance or spatial separation of conflicting uses).	☐	☐
↗	*C3 Engaging stakeholders, C2 Assessing UGI networks*		

Fig. 17: Excerpt from the checklist on urban green infrastructure planning regarding multifunctionality. Planners are supposed to self-evaluate their planning practice. The arrow points to related checklist topics. The left box is to be ticked if an item has already been considered in the plan under evaluation, the right one is for the case that further action is needed (Hansen et al., 2017).

5.3. Implications for Research

This thesis revealed gaps as well as linkages between planning practice and research discourses regarding multifunctionality, green infrastructure and ecosystem services. Beyond discussion of these core concepts, this study points to a number of implications for future research also relevant for other concepts that aim an influencing environmental planning and management.

5.3.1. Methodological reflections

This thesis contributes to urban planning research and sheds lights on gaps and linkages between theory and practice based on the academic literature as well as empirical data. Planning in itself is not always based on 'scientifically-robust' knowledge (Schön, 1983 in Silva et al., 2016: xxvi) but involves tacit and practical knowledge, often connected to local experiences and knowledge, and linked to complex processes of decision-making and implementation, which are difficult to analyse (see Chap. 3.1). Within this study, planning documents have been a key source. They are relatively easy to access and their content can be analysed in a systematic manner in a relatively short time frame. However, due to the complex nature of planning, a plan is not an end in itself and its content cannot be equalled with the explicit and implicit effects of planning processes (Faludi, 2000). To gain a more thorough understanding, mixed-method research is necessary. Thus, the analysis of local practices in different cities within this thesis also involved data gathered through direct interaction with stakeholders (e.g. interviews or workshops) as well as secondary data (contextual desk studies).

However, the empirical studies have been confined by pragmatic considerations. For instance, for study 1 the capacity for additional study-specific interviews was not given in all cities (for New York and Berlin see Rall et al., 2015). The 20 interviews with local experts in study 2 were part of a larger survey on the current status of green space planning in Europe (see Davies et al., 2015) and thus could not go into depths considering multifunctionality. Additionally, the content analysis of planning documents in study 2 involved a large variety of factors and thus could not assess the functions/services at the same level of detail as in study 1.

Regarding the analytical depth, study 1 and 2 established an empirical basis of the current application of multifunctionality in practice and thus focussed at number and variance between cases instead of a deep understanding of each case. Consequently, for the two comparative studies, data are presented next to each other and converged only in the discussion. In contrast, a high level of triangulation and cross-case comparison was applied in the three in-depth case studies (study 3) (cf. Yin, 2010). In future research, semi-quantitative studies with large numbers of cases should be supplemented by few in-depths case studies to understand contextual factors and interrelations like in paper III. Overall, mixing qualitative and quantitative methods requires careful consideration in order to avoid a situation of mixing different but not sound study components. The limitations of and requirements for such studies are still under debate (Flick, 2012).

Within this thesis, context analyses and narratives ensured that data from all three studies can be interpreted in light of the specific local conditions and other factors such as national spatial planning systems. This approach required the involvement of researchers in the URBES and GREEN SURGE projects that either had or gained knowledge on the local planning practice and framing conditions. Knowledge exchange during discussions and workshops helped to train researchers from different professional backgrounds, who are partly unexperienced with green space planning. Furthermore, detailed instructions, including explanations of terms and concepts, as well as templates with examples of narratives and case tables were shared. Together with the reviews of each case study's coding protocols and case narratives, a basic level of common understanding was developed. But, of course, with a large number of cases such time consuming processes cannot be facilitated to a degree that would rule out uncertainties or misinterpretations. Many studies on planning practice in different countries might not have capacity to undertake comprehensive case studies by local researchers. For such studies the potential of secondary data such as the "International Manual of Planning Practice" (ISOCARP, 2015) should be explored as a source for gaining contextual data.

5.3.2. Transdisciplinary research

Transdisciplinarity is often considered as required for capturing multifunctionality in a comprehensive manner. For instance, Naveh (2001: 269) demands that researchers *"abandon the reductionistic and positivistic assumptions, which are still widely accepted in the natural sciences"* in exchange for a holistic view (see also O'Farrell, 2010; Wiggering et al., 2003). However, this is not supposed to mean that disciplinary knowledge is arbitrary but it needs to be shared and synthesised between, for instance, disciplines from the natural sciences, engineering sciences, social sciences and humanities, as well as practitioners of different professions and decision-makers (Naveh, 2001). Major challenges to inter-, and even more to transdisciplinarity, involve barriers posed by academic traditions, logics of systems in academia versus practice, and a lack of theory as a common basis for discussion (Fry, 2001).

This thesis contributes to the theory of multifunctionality and aims to support the understanding of needs and approaches in planning practice. It also aims at supporting planners by contributing recommendations for an application oriented guide. The latter has been developed in transdisciplinary cooperation. However, such processes are time-demanding for all involved since they require time to develop personal relationships and trust as well as a common ground regarding core concepts, objectives, tasks and ways of cooperation. Such processes require

- researchers to develop clear and application-oriented concepts that are not only accepted by planners but also perceived as useful in practice,
- preparation and facilitation of interactive formats such as workshops as well as team building processes, and not least
- continuous or at least repeated knowledge exchange that creates benefits for all actors and not only meets information needs of researchers (Fry, 2001; Healey, 2016).

The time and effort necessary for cooperative processes as well as essential skills for leading such processes, which might require training of researchers or professional facilitators, need to be taken into account in future transdisciplinary research.

6. Conclusion

In conclusion, this dissertation thesis on multifunctionality as a core principle for urban green infrastructure planning is based on three aims:

(1) exploring linkages between ecosystem services and green infrastructure on a conceptual level, focussing on multifunctionality as a potential connection,
(2) analysing current approaches to ecosystem services and multifunctionality in planning practice, including case studies of good practices, and
(3) synthesising the theoretical and empirical findings into recommendations for planning practice.

The thesis contributes to the conceptual and operational understanding of multifunctionality in the context of green infrastructure and ecosystem services. The academic discourse was compared to empirical findings on current application based on semi-quantitative studies and qualitative studies. The semi-quantitative studies were undertaken in five cities from Europe and the US focussed on planning document, as well as in 20 European cities equally involving planning document analysis and interviews of local experts. The three in-depth qualitative case studies shed light on how multifunctionality is currently operationalised in green space planning. On the one hand, differences between the theoretical discourse on ecosystem services and multifunctionality and the current planning practice became evident; on the other hand this thesis reveals potential ways for combining approaches established both by researchers and planning professionals into a comprehensive approach to multifunctionality.

Multifunctionality has been long discussed as being complex. The conceptual framework developed within this thesis confirms that also in the context of urban green infrastructure multifunctionality should be regarded as multifaceted as it needs to be able to correspond to the dynamism and complexity of cities as social-ecological systems.

Researchers and planners both appear to be well aware of the fact the urban green spaces provide multiple functions. However, the lack of operational approaches for considering multifunctionality in a comprehensive manner points to the fact that a more multidimensional understanding in research and planning is required.

The three good practice cases show how different aspects of multifunctionality can be integrated in planning practice. This thesis recommends strategically embedding multifunctionality in planning in three different ways: (1) city-wide strategic planning, (2) assessment of urban green spaces, and (3) site-level design and management, aiming at synergies and high number of functions by arranging them across space and time. These recommendations can be used in planning to develop comprehensive approaches to green infrastructure planning based on multifunctionality as a core principle. However, gaps occur particularly when assessments are concerned.

For a comprehensive assessment of multifunctionality, a number of aspects need to be considered: first, a broad variety of green space functions is potentially relevant, and second, their interrelations are complex and non-linear. Current approaches for ecosystem services from research can help to systematically consider a certain range of functions, but are only partially congruent with the social, ecological, and also economic green space functions considered by planners. Ecosystem service approaches can also help to take services into account that are often not yet in focus in strategic planning, such as regulating services, and provide novel indicators for assessing the provision in a given city. However, limitations occur regarding functions and services that are difficult to capture with land cover-based indicators. Integrated and fine-grained assessments are needed that in particular capture social-cultural and biodiversity values. This includes consideration of demand, for instance, based on stakeholder and citizen involvement. Consequently, the broad variety of concepts and assessment approaches from research on ecosystem services can aid green infrastructure planning, but requires adaptation to local contexts and/or further development for practical applications.

Moreover, planners need assessment approaches that take interrelations – in particular intended and unintended ones such as synergies and conflicts – into account. Researchers must develop approaches for a systematic consideration of these interrelations since existing approaches from planning and research have shown limitations in this regard.

Overall, planners need tools that support planning practice in comprehensive and integrated multifunctionality assessments, adaptable to local issues. The suggested conceptual framework can provide a starting point for developing such approaches in cooperation between planners and researchers. Additionally, the framework can foster a more intense discourse between the research communities concerning ecosystem services and green infrastructure.

While this examination points to the disconnectedness of research communities, it can be concluded that researchers working on topics relevant for urban green space planning such as ecosystem services often lack a close connection to planning practice. The resulting science-driven approaches fail to contribute to better informed decision-making, planning, and management in cities if they are not translated into practice-oriented tools and/or communicated to practitioners. In fact, mainstreaming of concepts such as ecosystem services appears to be driven by high-level policies, but also by local needs. Researchers are thus well advised to be aware of the planning issues and tasks that are framed by overarching political objectives, requirements of spatial planning systems and local contexts in different cities.

Overall, this study establishes multifunctionality as an important component of urban green infrastructure planning. Multifunctionality can not only support the theoretical underpinning of the green infrastructure concept, but also point to consistent and strategic green infrastructure development based on sound assessments and clear planning priorities. Such strategic approaches are particularly important in cities that face pressure from population growth and densification.

This thesis aimed at developing hands-on recommendations for planning practice which have been informed by consultation and cooperation with experts and planning practitioners from different cities as well as analysis of concrete cases in different cities. In future inter- and transdisciplinary cooperation, the theoretical foundation established within this thesis should be refined, operationalised, adapted and tested for application in different cities. For doing so, future research on green infrastructure and ecosystem services should aim at even more upfront inter- and transciplinary approaches.

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Acknowledgements

Facing an important academic milestone, I like to note that many people already early in my life helped me to take this direction, starting with encouraging school teachers such as Rainer Erdmann and Joachim Klinke. I also owe thanks to different lecturers and supervisors at the Leibniz Universität Hannover who inspired me to enter a career path as a researcher; in particular Carsten Schneider, Anka Förster, and Simone Schipper who trained me as a young research assistant, provided me with first “real” research tasks, and placed trust in me. I like to give further cordial thanks to Bettina Oppermann for promoting my first publications and being a supportive and critical mentor.

However, not only supervisors in academic spheres have facilitated and inspired my dissertation. Two years of Technical Clerkship in Landscape Planning for the State of North Rhine-Westphalia helped me to gain insights in environmental and urban planning practice, and I owe gratitude to many planners and administrative officers for sharing their experiences. Without these insights into planning practice, I would not have been able to choose the topic of my thesis.

For several years, I am now working at the Technical University of Munich, and I express my greatest gratitude to my supervisor Stephan Pauleit, who always supported me during the developing this dissertation and beyond. He was not only willing to discuss questions and concerns whenever needed, but also freely shared his experiences and extensive knowledge on urban green infrastructure. Moreover, he provided me with many opportunities to establish a wide scientific network, collaborate with many excellent researchers, and discuss my topic with international audiences. Additionally, I like to express my special thanks to my examiners Regine Keller and Christian Albert for their openness to my thesis project and generous willingness to support it.

I want to thank my colleagues Isabel Augenstein, Werner Rolf, Martina van Lierop, Sandra Fohlmeister, Wolfgang Zehlius-Eckert, and Susanne Bose in representation of all colleagues at the Chair for Strategic Landscape Planning and Management, who have been extremely supportive in all kinds of technical, scientific or bureaucratic concerns, gave advice whenever needed, and created a motivating working atmosphere. Warm thanks also go to my fellow PhD students at our Chair, who shared their experiences, achievements, and struggles in our monthly jour fixe; particularly Emily Rall, who was largely involved in my research, shared the same office, helped me with numerous constructive discussions, and – not least – writing advice. I also thank my student assistants, who were a great support in the research projects, in particular Eleanor Chapman and Sabrina Erlwein. Many of you became from colleagues to friends.

I am further grateful for the opportunity to participate in international research projects and work with so many brilliant (green space) experts. Without the cooperation and dedication of wonderful colleagues and co-authors such as Anton Stahl Olafsson, Ana Catarina Luz, Alexander van der Jagt, Martina Artmann, Nadja Kabisch, Timon McPhearson, and many more this PhD project involving data from numerous cities would not have been possible. The case studies also involved practitioners that supported us generously with insight, critical discussions, and who inspired the development of planning recommendations, including Holle Thierfelder from Berlin as well as Tim Delshammar and Camilla Andersson from Malmö. Additionally, Nancy Rottle made a research stay in Seattle possible and shared many insights on green infrastructure planning in the US.

I owe countless thanks to my large patchwork family, friends from near and far, and current or former flatmates for supporting me and their enduring understanding when I was physically or mentally absent; in particular I like to thank Anna Bock and Lars Hopstock for sharing experiences and worries as well as for comments and edits to my work. My greatest thank goes to my Lieblingsmensch Bea. Thank you for always being there for me and for putting things into perspective.

My work during this dissertation was partly made possible through funding from the EU ERA-Net BiodivERsA project URBES (Urban Biodiversity and Ecosystem Services, 2012-2014) through the German Federal Ministry of Education and Research and the GREEN SURGE project (Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy, 2013-2017, FP7-ENV.2013.6.2-5-603567) through the European Union's Research and Innovation funding programme FP 7.

Annex: Research Papers

Paper I

Hansen, R. and Pauleit, S., 2014. From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. *AMBIO: A Journal of the Human Environment* 43 (4): 516–529.
DOI: 10.1007/s13280-014-0510-2

AMBIO 2014, 43:516–529
DOI 10.1007/s13280-014-0510-2

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From Multifunctionality to Multiple Ecosystem Services? A Conceptual Framework for Multifunctionality in Green Infrastructure Planning for Urban Areas

Rieke Hansen, Stephan Pauleit

Abstract Green infrastructure (GI) and ecosystem services (ES) are promoted as concepts that have potential to improve environmental planning in urban areas based on a more holistic understanding of the complex interrelations and dynamics of social–ecological systems. However, the scientific discourses around both concepts still lack application-oriented frameworks that consider such a holistic perspective and are suitable to mainstream GI and ES in planning practice. This literature review explores how multifunctionality as one important principle of GI planning can be operationalized by approaches developed and tested in ES research. Specifically, approaches developed in ES research can help to assess the integrity of GI networks, balance ES supply and demand, and consider trade-offs. A conceptual framework for the assessment of multifunctionality from a social–ecological perspective is proposed that can inform the design of planning processes and support stronger exchange between GI and ES research.

Keywords Social–ecological systems · Ecosystem services · Green Infrastructure · Urban planning · Environmental planning

INTRODUCTION

Within the last few years green infrastructure (GI) has become a popular concept to guide planning toward sustainable land use (Ahern 2007; Mazza et al. 2011). Within Europe, for instance, the European Union's environmental policy promotes GI as a planning approach applicable at different spatial levels (ibid.). Recently, the European Commission launched a strategy titled "Green Infrastructure—Enhancing Europe's Natural Capital," which aims at mainstreaming GI in spatial planning and territorial development in order to consciously consider the manifold benefits humans obtain from nature. GI is defined as a "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services" (European Commission 2013). In contrast to monofunctionally planned "gray" infrastructure, GI enhances and synergizes benefits provided by nature.

Despite its increasing popularity, GI remains a broad and elusive concept. One reason for this is its broadness of scale: The term can be used for regional or national ecological networks (e.g., Weber and Allen 2010), green space networks for urban areas (e.g., Kambites and Owen 2006), as well as local storm water management projects (e.g., Ahern 2010). In the scientific literature, GI planning is discussed as based on various principles or guidelines such as multifunctionality, connectivity, or collaborative planning (Table 1). However, the specific sets of principles which characterize GI planning vary (e.g., Benedict and McMahon 2006; Kambites and Owen 2006; Pauleit et al. 2011). Overlaps with other concepts that share principles such as connectivity or strategic and adaptive planning (e.g., Ahern 1995) further complicate the discussion on GI as a distinctive approach. Accordingly, GI planning represents more of a synthesis of different planning approaches than a completely new approach (Mell 2009). Rather, the defining characteristic of GI planning is that it is a melting pot for innovative planning approaches in the field of nature conservation and green space planning.

Electronic supplementary material The online version of this article (doi:10.1007/s13280-014-0510-2) contains supplementary material, which is available to authorized users.

Table 1 Green infrastructure planning principles

Green infrastructure planning principles (based on Benedict and McMahon 2006; Kambites and Owen 2006; Pauleit et al. 2011)
Approaches addressing the green structure
Integration: Green infrastructure planning considers urban green as a kind of infrastructure and seeks the integration and coordination of urban green with other urban infrastructures in terms of physical and functional relations (e.g., built-up structure, transport infrastructure, and water management system)
Multifunctionality: Green infrastructure planning considers and seeks to combine ecological, social and economic/abiotic, biotic and cultural functions of green spaces
Connectivity: Green infrastructure planning includes physical and functional connections between green spaces at different scales and from different perspectives
Multi-scale approach: Green infrastructure planning can be used for initiatives at different scales, from individual parcels to community, regional, and state. Green infrastructure should function at multiple scales in concert
Multi-object approach: Green infrastructure planning includes all kinds of (urban) green and blue space; e.g., natural and semi-natural areas, water bodies, public and private green space like parks and gardens
Approaches addressing governance process
Strategic approach: Green infrastructure planning aims for long-term benefits but remains flexible for changes over time
Social inclusion: Green infrastructure planning stands for communicative and socially inclusive planning and management
Transdisciplinarity: Green infrastructure planning is based on knowledge from different disciplines such as landscape ecology, urban and regional planning, and landscape architecture; and developed in partnership with different local authorities and stakeholders

Furthermore, the potential of GI planning to combine ecological and social perspectives is broadly acknowledged (Mell 2009). Due to its holistic approach, GI planning is considered to be more effective and able to handle more complexity than traditional planning for nature conservation or open space (Kambites and Owen 2006). In this light, GI planning appears to be especially suited for urban areas because these areas are characterized by the strong, dynamic interplay of ecological and social systems (e.g., Alberti et al. 2003; Pickett et al. 2011).

Examples of GI planning can be found especially in the US and in the UK, where GI was taken up and promoted by policy (Benedict and McMahon 2002; Kambites and Owen 2006). For other regions, such as Asia or Africa, scattered publications refer to the GI concept (e.g., Chang et al. 2012; Schäffler and Swilling 2013). Yet, often it remains to be clarified if planning practice actively adopted the concept or if it was only introduced by the authors on a theoretical level. In Europe, numerous initiatives to establish ecological networks exhibit overlaps with GI planning but rarely consciously relate to the concept (Mazza et al. 2011). Boosted by the EU-GI-strategy awareness of the concept will most likely further rise and questions on how to apply GI as a planning approach will become more important.

Apart from a few analytical studies of GI planning in practice (Sandström 2002; Lafortezza et al. 2013) and the presentation of some best practice examples (e.g., Mazza et al. 2011; Pauleit et al. 2011), research on how GI as a social–ecological approach can be applied is scant. In contrast to the frequent references to the concept, which recently can be found in scientific publications, little development of its theoretical foundation can be observed since its seminal description by Benedict and McMahon (2002, 2006) and the proposal of a conceptual framework to link ecological and social aspects by Tzoulas et al. (2007).

Consequently, GI research appears fragmented and lacks a distinctive theoretical foundation (Mell 2009). The lack of a specific theory of its own may be explained by the fact that GI principles such as ecological connectivity were adopted from landscape ecology (e.g., Ahern 2007; Chang et al. 2012). The concept of ES is also frequently adopted in GI literature to replace GI functions (e.g., Mazza et al. 2011; Lovell and Taylor 2013) but approaches for the operationalization of multifunctionality as a planning principle are still missing.

Developing a conceptual framework for multifunctionality could build an important foundation of GI theory and inform practitioners on crucial aspects in the design of planning processes from a social–ecological perspective. It would thus support mainstreaming GI in planning practice as pursued by European environmental policy. The synthesis of GI and ES theory into one framework seems promising, as ES research discusses several relevant aspects for multifunctional planning such as how to enhance ES in a beneficial way while avoiding trade-offs (e.g., Chan et al. 2012; Haase et al. 2012). Moreover, ES research helps to shed light on the interrelations between social and ecological systems and the integration of stakeholder perspectives in assessments (e.g., Diaz et al. 2011; Ernstson 2013).

Therefore, this paper aims at exploring possible linkages between GI and ES research with regard to multifunctionality. The review of GI and ES theory is an initial step to relate both fields of research and in so doing provide the ground for identifying opportunities for joint research with a view to support GI planning and implementation. The following is based on a review of GI and ES literature. The focus lies on studies for urban areas, but promising approaches or axiomatic theories from non-urban literature were not generally excluded. Using the Web of Knowledge, the search term "green infrastructure" was linked to "planning"; "framework"; or "strategy." Furthermore, chapters of landmark environmental planning and urban ecology textbooks as well as policy guidance reports dealing with GI were included. Due to the extensive body of ES literature (Seppelt et al. 2011; Haase et al. 2014) the focus lies on publications that discuss the theoretical foundation of ES (e.g., relations between services and functions); that suggest the application of ES in planning processes; or that explore a social–ecological approach (e.g., frameworks for inclusion of stakeholder perspectives in ES assessments). Using a snowball approach, literature referenced in the reviewed papers was added. Overall, about 200 papers were reviewed (Electronic Supplementary Material, Appendix S1).

The GI and ES literature was reviewed for theoretical components that can be related to the concept of multifunctionality. Using GI theory as point of departure, ES theory was surveyed for complementary or additional aspects. Inspired by frameworks from ES and GI literature, components were then linked in an iterative process to form a conceptual framework for the assessment of multifunctionality.

FOUNDATIONS FOR CONSIDERING MULTIFUNCTIONALITY

Before presenting the conceptual framework, this section defines basic terms used in the proposed framework such as functions and services because they are used differently in GI and in ES literature. Furthermore, we review the spatial levels on which GI can be considered and general frameworks for GI to illustrate the foundation for a framework of multifunctionality.

From Functions to Services

Definition of Multifunctionality

Multifunctionality represents the holistic thrust of GI and can be—together with connectivity—considered as a core element of GI planning (Kambites and Owen 2006; Pauleit et al. 2011). The concept of multifunctionality in GI planning means that multiple ecological, social, and also economic functions shall be explicitly considered instead of being a product of chance (ibid.). Multifunctionality aims at intertwining or combining different functions and thus using limited space more effectively (Ahern 2011). The multiple functions should offer benefits for humans, for instance, in relation to human health or social cohesion, and likewise secure intact ecological systems (Tzoulas et al. 2007; Lafortezza et al. 2013).

Functions of GI

In literature on GI, its functions are usually listed without their further definition. They are, for example, grouped as ecological, social, and economic functions (Pauleit et al. 2011) or, following an alternative classification, as abiotic, biotic, and cultural functions of green spaces (Ahern 2007). These approaches usually capture a broad understanding of functions—ranging from soil development processes, support of species movement to physical recreation (e.g., Ahern 2007; Llausas and Roe 2012). Occasionally, ES classifications are transferred to GI approaches to replace functions (e.g., Mazza et al. 2011; Lovell and Taylor 2013). The latter causes a conceptual problem because in ES research functions and services are not considered as interchangeable.

Functions, Services, and Benefits in Research on ES

The distinction between functions and services in ES research may help to achieve a more profound and differentiated understanding of functions and services. This distinction is important because the processes or functions of ecosystems such as soil formation may be crucial for their existence but not necessarily directly utilized by humans while a service per definition requires human beneficiaries (Fisher et al. 2009). Therefore, functions are discussed, for example, as “intermediate products” of ES (Boyd and Banzhaf 2007). This distinction is elaborated in the so-called ES cascade model by Haines-Young and Potschin (2010) (see Fig. 1). In this model, biophysical structures or processes (e.g., wetlands or net primary productivity) are the base for functions (e.g., slow passage of water). The functions can be the origin of services for humans (e.g., flood protection). These services lead to human benefit and valuation of those services (e.g., willingness to pay for wetland protection).

The cascade model could be applied to GI planning in order to better differentiate functions and services in GI approaches where functions are currently used in a fuzzy way, often meaning the same as services. Adopting a consistent use of terms and a clear distinction between functions and services would ensure that double counting due to overlaps between particular functions and services can be more easily detected (Hein et al. 2006). To avoid mixing GI functions and the concept of ES in the following sections, whenever feasible, the term “services” is used while “functions” refer to the ecological functioning of GI elements.

Spatial Levels in GI Planning

Three spatial levels that should be considered in GI planning are suggested by Davies et al. (2006) (see Fig. 2). Individual elements such as parks or rivers are the basis of GI. Site-specific assessments of multifunctionality can be applied for these single GI elements (Pauleit et al. 2011).

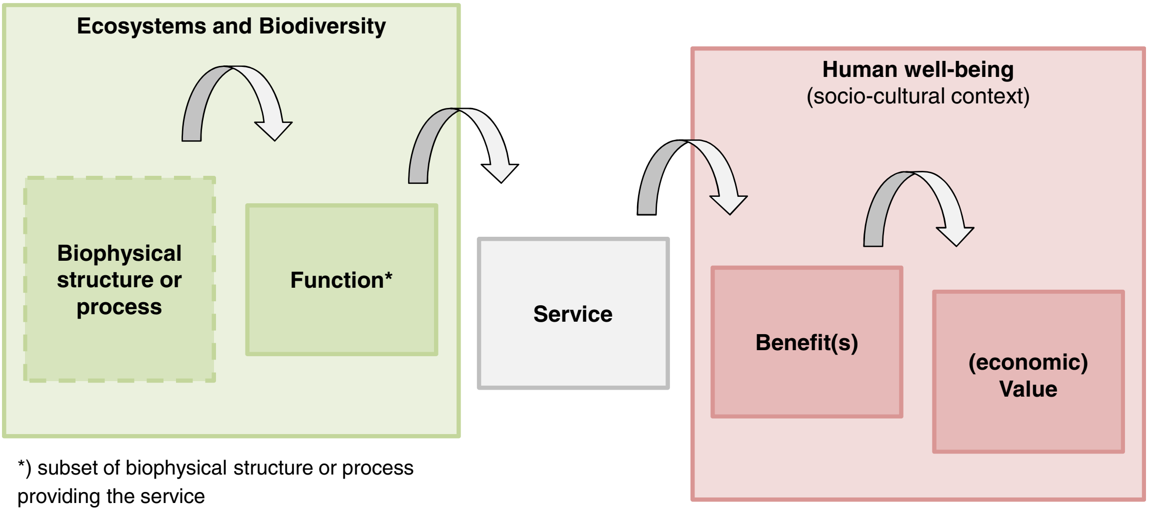

Fig. 1 Cascade model for linking ecosystems to human well-being (adapted from Haines-Young and Potschin 2010 and de Groot et al. 2010)

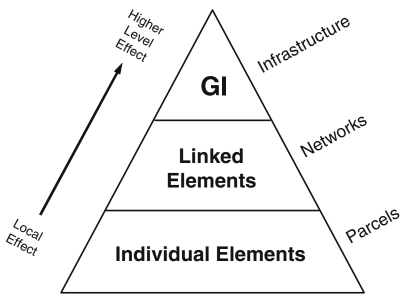

Fig. 2 Multifunctionality can be assessed at different spatial levels (reproduced from Davies et al. 2006 with kind permission by the authors)

On the next spatial level different GI elements and the linkages between them are represented. They form a network that enables movement of species and flows of matter. These networks can be considered for areas of different sizes (e.g., neighborhood or city). At the highest level is GI, which is composed of interlinked networks of GI elements on the regional level. On these higher levels, multifunctionality can be used to assess this interrelated system of different types of green and open space that in its entirety provides multiple benefits (Ahern 2007).

The framework for the assessment of multifunctionality proposed in this paper makes no distinction between this highest level and the network level because, especially in urban areas, it is difficult to determine where the boundary between a network and (regional) GI lies. Thus in the following, GI elements are considered on one hand and on the other are networks as systems of individual elements and links between them in a defined area. These areas can range from a neighborhood to an entire urban region.

Existing Frameworks for GI Planning

A couple of existing theoretical frameworks for GI planning offer a starting point to discuss which conceptual components should be integrated in GI planning. Tzoulas et al. (2007) propose a framework for GI in urban areas that provides the ground for linking ecological concepts such as ecosystem health to social concepts such as individual or community health. On this basis, Lafortezza et al. (2013) describe a framework for GI planning with five interlinked conceptual components: ES, biodiversity, social and territorial cohesion, sustainable development, and human well-being. The components of these frameworks, while illustrative, require further operationalization with methods that allow their systematic assessment and valuation in planning.

In contrast, practice-oriented outlines of GI planning can be found in publications of GI initiatives from the UK and US (e.g., Benedict and McMahon 2006; Davies et al. 2006; The North West Green Infrastructure Think Tank 2008). For instance, the “Five Steps to Green Infrastructure Planning” from The Mersey Forest (2011) consists of (1) partnerships and priorities; (2) data audit and resource mapping; (3) functional assessment; (4) needs assessment; and (5) intervention plan. These planning frameworks are usually more focused on the structuring of planning processes and inspired by case studies rather than on theoretical foundations.

A combination of elements from theoretical frameworks and planning process guidance can contribute to the scientific discourse on GI as well as inform practitioners on planning process design. This dual purpose is the aim of the proposed conceptual framework for multifunctionality.

A TENTATIVE CONCEPTUAL FRAMEWORK FOR ASSESSING MULTIFUNCTIONALITY IN GI PLANNING

In the following, an attempt is made to outline a framework for assessing multifunctionality in GI planning that is linked to ES theory. The framework shall combine the current knowledge on GI and ES assessment and inform plan-making on how to determine options to conserve, strengthen, or enhance multifunctionality of urban green space. After introducing the structure of the framework the different dimensions are explained.

Structure of the Framework

The overall frame for the assessment of multifunctionality is based on concepts for ES with a social–ecological perspective by Bastian et al. (2012), Diaz et al. (2011), and Ernstson (2013) as well as de Groot et al. (2010). The framework is structured in four dimensions: to determine the status quo in the analysis of the system, and the ecological and the social perspective are surveyed separately (dimension I and II). The ecological perspective aims at data collection on the capacity of the existing GI network to provide services. The social perspective covers the demand side. In valuation (dimension III), both perspectives are integrated and used to determine priorities for strategies and actions (dimension IV).

The different dimensions are filled with conceptual components from GI and ES research that can support a comprehensive determination of multifunctionality. Each component of the framework is represented by a number in Fig. 3. The lines between the components indicate how information on one component is combined with other information in the subsequent step of assessment. Black lines represent major relations while the gray lines illustrate additional data that can be used to underpin specific aspects. The conceptual components are discussed in the following sections.

System Analysis Taking the Ecological Perspective

The first dimension addresses the status quo of the system in question from an ecological perspective. Here the spatial elements and structures that constitute the GI as well as the functions and services they provide are determined.

GI Elements

A broad spectrum of types of green and blue spaces such as nature reserves, agricultural land, woodland, parks, greenways, gardens, allotments, cemeteries, vacant land, wetlands, and all kinds of water bodies is suggested as basic spatial elements of GI (e.g., Davies et al. 2006). In ES research, the spatial elements that deliver ES are named service providing units (SPU) or service providing areas (for a detailed discussion of SPU and related concepts, cf. Wurster and Artmann 2014). For an assessment of multifunctionality that builds on ES, the distinction of GI elements (component 1) should be based on a classification suitable for the analysis of ES.

Spatial Relations and GI Networks

Multifunctionality for a GI network needs to take connectivity into account, because connectivity represents the spatial distribution and relations of GI elements and consequently the distribution of benefits they provide (component 2). Connectivity is often referred to as ecological connectivity (e.g., Ahern 2007; Chang et al. 2012). Ecological connectivity is not only meant in a physical sense but also functionally. In the urban matrix, for instance, the distribution of GI elements can impact functions like mitigation of the urban heat island effect, ventilation, and access to green space for recreational use (Pauleit et al. 2011). Here it is suggested to assess connectivity separately for different functions according to the relevance of physical and functional connections.

The spatial dimension of ES is discussed in relation to their provisioning and received benefits. Fisher et al. (2009) distinguished between "service production areas" and "service benefit areas." They proposed a three-part classification scheme: "in situ" when services are provided in the same location as the benefits received, "omni-directional" when services benefits the surrounding landscape without a specific directional bias, and "directional" if services provided by one area benefit another location. Based on this approach, Syrbe and Walz (2012) suggested to distinguish between "service providing areas," "service benefiting areas," and "service connecting areas" that can be mapped. Such frameworks can be used to explore the spatial relations of specific ES and lay the foundation for evidence-based planning of a connected GI network.

Supply of ES

An often used example for the classification of ES is promoted by the MA (2005) and TEEB studies (Kumar 2010), which distinguish between provisioning (e.g., food or fresh water), regulating (e.g., local climate regulation), habitat or

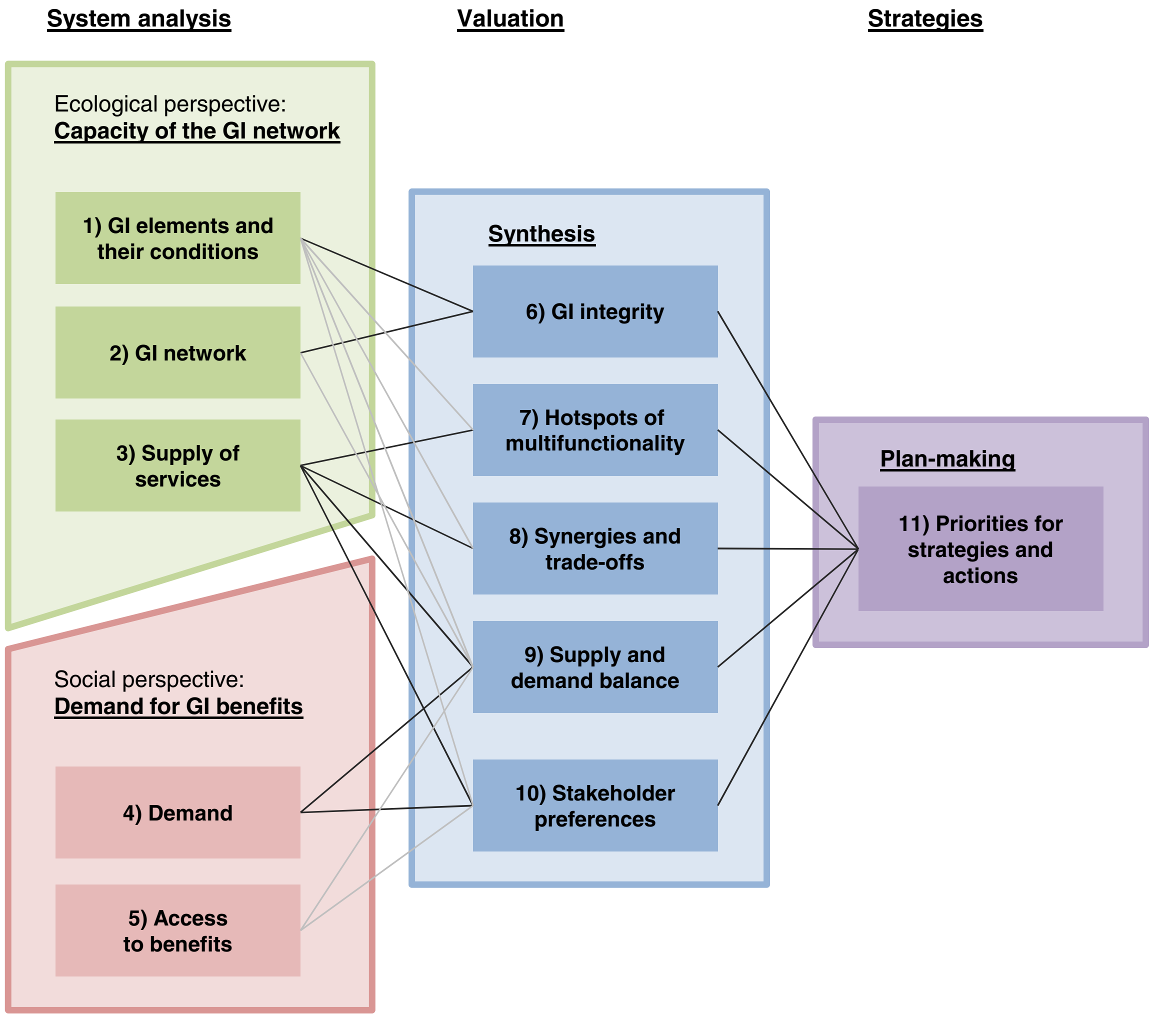

Fig. 3 Conceptual framework for assessment of GI multifunctionality. The *boxes with numbers* represent different conceptual components derived from GI and ES literature. The *lines* map data flow from *left to right*. *Lines in black* indicate main relations between components while *gray lines* illustrate supporting relations

supporting (e.g., habitats for species), and cultural services (e.g., mental and physical health). Bolund and Hunhammar (1999), Niemelä et al. (2010), and Gómez-Baggethun and Barton (2013) suggest classifications of ES adapted to urban areas.

After deciding which services shall be considered the capacity of GI elements to provide these services is an important component of an assessment of multifunctionality. Supply of ES (component 3) can be understood as the capacity of a particular area to provide these goods and services for which there is an actual demand (Burkhard et al. 2012).

Assessing the supply requires spatial data and appropriate indicators for quantification. For city regions several examples of ES assessments can be found in literature (e.g., Burkhard et al. 2012; Haase et al. 2012), where land cover classes such as those defined by satellite-based CORINE land cover are taken as service providing areas. Measuring units for the assessment are often derived from expert knowledge. Examples for indicators and proxies to quantify the supply ES also have been compiled by de Groot et al. (2010), as well as especially for urban areas by Gómez-Baggethun and Barton (2013). Recommendations for systematic indicator selection are given by van

Oudenhoven et al. (2012) and can be used to adapt lists of indicators found in the literature for specific cases.

For quantification of ES not based on measuring units but on relative supply, Burkhard et al. (2012) developed a matrix for linking ES (and ecological integrity indicators) to land cover types. For each land cover type the capacity to provide a particular service was determined based on expert estimations on a scale of 0 (not relevant) to 5 (very high relevant capacity). By linking the matrix within GIS, the spatial distribution of supply could be illustrated (ibid.).

Ecosystem Conditions

Emphasizing supply and demand bears the risks of neglecting important properties and processes of ecosystems that are not of immediate or current use but of intermediate or potential use and, moreover, are important for the functioning of the ecosystem. Therefore, Burkhard et al. (2012) developed a conceptual framework of ES supply and demand that includes ecosystem integrity as an overall measure of the system's condition.

Ecosystem integrity, representing vital ecosystem functions, can be assessed by indicators such as abiotic heterogeneity, biodiversity, or reduction of nutrient loss (ibid. based on Müller 2005). Alternatively, Bastian et al. (2012) suggest including indicators for ecosystem/landscape properties and potentials. Properties should, for example, cover processes of ecosystems/landscape elements and spatial interactions of different elements. Indicators for ecosystem properties (e.g., for land cover and landscape structure, soil, flora, and fauna), functions (e.g., for production functions), and services (e.g., dairy production) have been explored by van Oudenhoven et al. (2012).

Frameworks to integrate a perspective on the condition of ecosystems can also be found in GI literature. Tzoulas et al. (2007) included ecosystem health represented by, for example, air and water quality and ecosystem resilience. Lafortezza et al. (2013) consider biodiversity as a conceptual element in their GI framework.

In line with the above, we recommend that important properties and functions of GI elements not covered by actual supply of ES should be included in a multifunctionality assessment. We, therefore, suggest "condition" of the existing GI elements as a generic term (taking into account concepts like ecosystem integrity and ecosystem health) that can be determined by indicators for specific ecosystem functions or biodiversity and integrated in component 1.

System Analysis Taking the Social Perspective

The second dimension of the framework takes a social perspective. In ES and GI literature, positive impacts of ES or GI on human well-being such as health benefits are often emphasized (e.g., Tzoulas et al. 2007; Niemelä et al. 2010). However, planning needs to be informed about the actual demand for ES to avoid measures that fail to meet societal needs. Additionally, access to benefits should be considered to prevent unintentional effects that can increase environmental injustice.

Demand

GI is often referred to as a collaborative approach that includes local stakeholder perspectives and their demand for GI benefits (component 4). However, the discourses remain on a very general level of acknowledging that social inclusion is an important planning principle (e.g., Kambites and Owen 2006; Pauleit et al. 2011). The question of how to determine demands is still rarely touched. As an exception, Davies et al. (2006) propose standards from green space planning such as ANGST (Accessible Natural Greenspace Standard; Natural England 2010). Such standards define, for example, maximum distances to parks or hectares of local nature reserves per population number that can be transferred into maps and illustrate if the demand is covered.

In ES approaches, demand is crucial because per definition ES do not exist without demand by humans (Fisher et al. 2009). Demand is often determined by expert judgment or politically agreed upon standards. An overview of approaches to derive ES demand such as statistical analysis, modeling, or interviews can be found in Burkhard et al. (2012).

An example for measuring demand on the regional level is given by Kroll et al. (2012). Indicators based on statistical data such as water consumption were used to assess demand of different land cover types (e.g., demand for water per hectare agricultural area). The approach by Burkhard et al. (2012) based on relative values was also applied for assessing demands of ES for different land cover types. The demand for every ES per land cover type was given on a scale ranging from 0 (no relevant demand) to 5 (very high relevant demand). Such approaches can be used to derive spatially explicit representations of the distribution of ES demands at a regional scale based on land cover types and, respectively, GI elements.

Other ES approaches aim at actively including stakeholder groups to derive demands. Diaz et al. (2011) suggest an ES framework that includes stakeholders with direct or indirect claims on land and/or ES. The framework was tested for rural areas with different kind of farmers and conservation agencies as stakeholders. The authors of this study identified together with stakeholder groups how these groups perceive, access, and use ecosystems. Afterward they assessed which priorities the stakeholders have for specific land cover types and the services these provide. Such an approach could be transferred to urban areas. Yet, it needs to be decided for each case whether applying a stakeholder-inclusive approach or an expert-based approach is more adequate.

Furthermore, ecosystem disservices, understood as "functions of ecosystems that are perceived as negative for human well-being," such as fear stimulated by dense vegetation or damages in gray infrastructure due to growth of tree roots, need to be dealt with (Lyytimaki and Sipila 2009). Concerns articulated by stakeholders related to GI should be considered early in the planning process to avoid conflicts in the subsequent stages.

Access to Benefits

Mell (2009) promotes access to green space (component 5) as one major objective for GI planning. Lovell and Taylor (2013) note that GI measures such as greenway or park development and restoration of degraded green and open space such as waterfronts can lead to a displacement of marginalized populations to areas that provide less attractive living conditions than the renewed areas. Distributional impacts are also considered a major social issue for ES implementation since land-use decisions inherently enhance the provision of some ES while reducing others (Robards et al. 2011). Furthermore, access to the benefits from these services may shift between social groups and individuals (Rodríguez et al. 2006).

To operationalize the question of access, Fisher et al. (2009) discuss the public–private good aspect of ES. Services can be rival or non-rival as well as excludable and non-excludable. Rival implies that use of one individual or group reduces the good for others (e.g., crops). Excludable implies that one individual or group can block others from access to an ES (e.g., fruits in a private garden; for further examples and different combinations of private–public goods aspects see ibid.). Such an approach can be a first step to consider the consequences that the enhancement of particular ES can have on societal groups.

Valuing Multifunctionality

In the third dimension of the approach outlined here, the components for the system analysis are brought together. The valuation determines how the different data set from the analysis can be combined to gain a comprehensive basis for decision-making and priority-setting.

The valuation covers a broad range of approaches, from nominal value scales to decision-support matrixes to less tangible verbal assessments. A synthesis to one aggregated value is not an aim since the effects of normalization (e.g., loss of accuracy) would need to be carefully tested. Additionally, the discourse on advantages and disadvantages of monetary compared to non-monetary valuation in ES (cf., Hein et al. 2006; de Groot et al. 2010; Gómez-Baggethun and Barton 2013) is not integrated because this would exceed the scope of the paper. This does not mean to say that economic approaches could not provide a useful addition to GI planning.

GI Integrity

Valuing overall GI integrity is suggested to combine information on GI elements and their conditions (component 1) with that on the spatial relations between them (component 2). The aim is to determine which ecological functions that are relevant for the capacity to supply services of the GI network are crucial for the overall functioning and health of the system.

Davies et al. (2006) developed a matrix that links the quality of GI elements with the connectivity of the GI network (Fig. 4). Here "quality" is replaced by "integrity" of GI elements. The integrity can be assessed based on indicators presented in the section "ecological conditions" and valued from low to high. Based on data for component 2 the network of GI elements within a particular area can be valued from weak to strong. Such a matrix can be used to derive priorities for improving GI elements as well as the links and gaps between them.

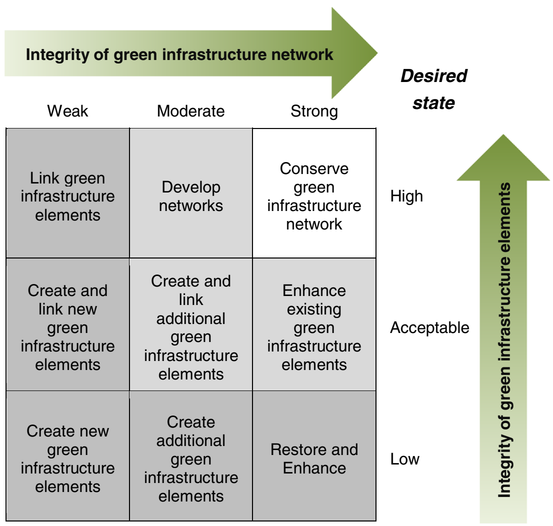

Fig. 4 Decision support matrix based on the connectivity of the green infrastructure network and the quality of its elements (adapted from Davies et al. 2006)

Hotspots of Multifunctionality

Services provided by GI elements (component 3) can be not only displayed in separate maps but also summed up to reveal "hotspots" for multifunctionality (component 7). Approaches have been developed to illustrate the overall ES supply of GI elements. Lovell and Taylor (2013) presented a "Multifunctional Landscape Assessment Tool" to survey the performance of ES of small-scale landscape features such as lawns, community gardens, or playgrounds in a park. The value for each service and feature can be added up to an overall performance value for a single green space. For larger areas, The Mersey Forest (2011) developed a city-wide approach (applied for Liverpool) to map functions of GI elements and display how many functions each element provides.

Such tools can reveal which elements provide a high degree of multifunctionality and can be used to explore options for improvements of elements with a lower value. However, priorities for GI improvement based on number of services should not be set without considering synergies and trade-offs between ES (component 8) because increasing particular services should not unintendedly reduce the value for others.

Synergies and Trade-Offs

On one hand, the realization of synergies and thus an increase of benefits for humans represent a major objective of GI planning. On the other hand, trade-offs also occur and must be taken into consideration; for instance, conflicts between intensive recreation and the protection of sensitive species from disturbance (Pauleit et al. 2011).

Haase et al. (2012) provide a matrix to assess the relation between two ES (Fig. 5). They define a "synergy" as a win–win situation that is determined by an improvement of both ES while a "trade-off" is a loss of one service in exchange for gaining another. "Loss" is a mutual decline in both services. The zero point of either axes represents relations that either improve ("win-no change") or degrade ("lose-no change") the provision of one service while the other remains unaffected. Such a matrix can be used to determine synergies and trade-offs of GI strategies (component 8). The relation between important ecological properties and functions should be determined likewise, because otherwise negative effects on GI integrity might be overlooked.

For a comparison of different trade-offs, Rodríguez et al. (2006) suggest a valuation of three factors: spatial scale, temporal scale, and reversibility. The spatial scale is classified in local or large-scale relevance. The temporal scale covers whether a trade-off is of short or long-term effect. Reversibility is determined as reversible or irreversible. In a three-dimensional matrix, trade-offs can then be ordered

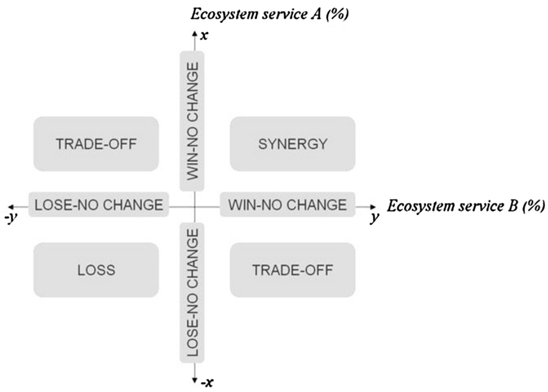

Fig. 5 Matrix to determine synergies, trade-offs, and other interrelations between ES (reproduced from Haase et al. 2012 with kind permission by the authors)

between least severe (local, short-term effect and reversible) to most severe (large-scale, long-term effect and irreversible). Such a valuation can support decisions between different measures that influence the provision of ES.

Supply and Demand

For a comparison of supply and demand (component 9), the data on services provided (component 3) and demand (component 4) are brought together. An important question for the design of such a comparison is if data for supply and demand that have been assessed in the system analysis are comparable. Burkhard et al. (2012) developed an assessment based on matrices of ES and land cover types in which the supply and demand for each service was determined separately for each land cover type and given a rating using a relative scale ranging from 0 to 5. This assessment approach essentially creates relative units for supply and demand of each service. When combined, these values express the supply and demand budgets for each land cover type (e.g., $-5 =$ strong undersupply; $5 =$ strong oversupply). These values can be transferred to a GIS to spatially reveal the balance of supply and demand for each land cover type. Related to knowledge on flows (which ES can only be experienced "in situ" and which are transferable to other parts; component 2) and questions of access (e.g., maximum distance to recreation areas; component 5), such approaches can inform the overall balance between ES supply and demand of the existing GI and reveal needs for improvement.

Stakeholder Preferences

The preferences and interests of different stakeholder groups are often actively elicited in planning processes to aid knowledge transfer and ensure environmental justice. Furthermore, stakeholders can play a vital role as land owners and land managers who can either impede or aid planning decisions, and are thus crucial partners for GI implementation. Therefore, stakeholder preferences hold a separate position in the framework (component 10).

Including stakeholder values requires appropriate methods and detailed knowledge of the case study based on stakeholder insights. Accordingly, engaging stakeholders iteratively is recommended for the identification of crucial ES and values (Chan et al. 2012). The framework by Diaz et al. (2011) already mentioned suggest a weighting by stakeholders: In the step of valuation the information on each stakeholder's preferences for ES (component 4; also component 5) and the capacity of land cover types to provide those ES (component 3) can be integrated in a multidimensional matrix.

Sanon et al. (2012) developed a multi-criteria decision analysis framework to quantify ES trade-offs for different land-use scenarios of an urban floodplain. They assessed the management objectives different stakeholder groups had for the study area and how stakeholder groups would benefit or be disadvantaged by different wetland restoration scenarios. Such a framework can be used to assess the consequences of specific GI measures, especially from the perspective of different groups of land users such as farmers or fishers.

Such scenario approaches can also be further developed and supported by tools for visualization. For instance, Grêt-Regamey et al. (2013) developed a 3D-GIS modeling environment to illustrate ES trade-offs of three park designs for Masdar City in Abu Dhabi. Photorealistic renderings linked to a visualization of trade-offs can be used to better inform stakeholders on the effects of alternative planning projects.

Priorities for Strategies and Actions

The last dimension of the assessment is the definition of priorities for GI implementation (component 11). Priorities are understood here as strategies and specific actions that aim at improving the multifunctionality of the GI network. This can include measures for particular GI elements to increase the provision of particular services, to broaden the spectrum of ES provided, or to create new elements where there is a demand. Strategies and actions to close gaps or enhance connectivity in the GI network can also be recommended.

The results for component 6–10 provide the knowledge base that can be used to derive particular strategies and actions. Additionally, best practice studies (e.g., Ahern 2007; Mazza et al. 2011; Pauleit et al. 2011) can inspire GI implementation.

DISCUSSION

This paper has demonstrated that GI and ES are closely related and may strengthen each other in the development of a common framework for research as well as for implementation. These linkages as well as limitations in the proposed framework for multifunctionality are presented below, along with challenges for mainstreaming the framework in planning and future research to be addressed.

Possible Linkages Between GI and ES Research

While the concept of ES is still young, its theoretical foundations appear to be already more advanced than GI theory and capable to advance the concept of multifunctionality. Main potentials for integration of the two concepts are seen in the following:

Conceptual frameworks such as the cascade model by Haines-Young and Potschin (2010) or the synergy and trade-off matrix by Haase et al. (2012) can be adapted in GI planning and support a more differentiated consideration of functions, services, and benefits as well as the interrelations between different ES.

Qualitative assessments that, for instance, define ES supply relatively based on expert knowledge can be used to harmonize data from different sources and cover a range of ES (Burkhard et al. 2012; Busch et al. 2012). However, these qualitative assessments are based on proxies and are thus far limited in their precision and scale of application. For instance, the regional-scale indicators tested by Kroll et al. (2012) based on land cover types revealed potential supply and the potential supply–demand ratio but not the actual supply and demand. The more knowledge and relevant indicators developed in the future, the better quantitative approaches will be able to provide more accurate information (e.g., Busch et al. 2012; Bastian et al. 2013).

Next to the assessment of ES provision, approaches for demand have been explored (e.g., Burkhard et al. 2012; Kroll et al. 2012). These approaches can be applied to broaden the GI perspective from demand for recreation to regulating or provisioning services. Additionally, ES approaches that examine demands in cooperation with stakeholder groups (e.g., Diaz et al. 2011) can be adapted to strengthen the social perspective in GI planning. Scenario development can be included in stakeholder group discussions to facilitate an informed discussion (e.g., Ahern 2010; de Groot et al. 2010).

Due to the exponential increase in publications and ongoing high attention to ES, a relatively rapid advancement of theory can be expected. GI planning can on one hand profit from this development. On the other hand, GI research should aim at integrating existing GI concepts and work to strengthen its claims as a distinctive approach to green space planning. For instance, GI contributes a spatial network perspective that can support the determination of spatial relations between ES supply and demand.

Limitations of the Framework

While there are opportunities for systematically linking the GI and ES concepts, there are also limitations to the suggested framework for multifunctionality which require further discussions. The diverging GI and ES terminology of functions and services is apparent. A broad understanding of functions has the advantage that it can also cover ecosystem properties and processes important for ecological functioning but not of direct use. ES approaches focused on services in direct relation to actual demand might overlook the importance of ecological functioning to secure the long-term capacity to provide services (Bastian et al. 2012).

The integration of ecosystem integrity (Burkhard et al. 2012) or ecosystem health (Tzoulas et al. 2007) as separate assessment components with a set of particular criteria seems suitable to consider ecological conditions. However, Burkhard et al. (2012) note that ecological integrity variables and regulating services inherently overlap. Thus, in assessments double counting or merging of different aspects needs to be considered.

ES classifications such as MA (2005) integrate ecological functioning through the group of supporting services and thus also consider ES for which there is no direct demand. In this regard, testing in case studies is recommendable to get a better picture of advantages and disadvantages of different approaches to integrate ecological functioning in multifunctionality assessments. For implementation in planning practice, research could explore which of these concepts are easier for stakeholders to understand.

Additional limitations occur due to the recent development of ES research and variety of parallel evolving approaches. Assessment standards and widely shared conceptual framework are lacking which hinders comparability and transferability (de Groot et al. 2010).

Several studies from Europe have been applied on a regional scale based on CORINE land cover data (e.g., Haase et al. 2012; Koschke et al. 2012). Not all ES can be adequately assessed based on land cover classes because they depend on particular qualities of GI elements (de Groot et al. 2010). It has to be carefully determined if land cover is an adequate proxy variable for the calculation of various ES and if the resolution of data is detailed enough on a case-by-case basis (Kroll et al. 2012).

Further limitations of the suggested framework occur due to the review approach taken. To narrow the scope of the study the focus lies on literature explicitly related to the concept GI or ES. Other scientific fields such as landscape ecology might provide additional useful methodological elements. For instance, the determination of ecological connectivity could be extended (for a review see, Mazza et al. 2011). An integration of the different components that allows a more structured and comparable valuation such as multi-criteria assessments (e.g., Koschke et al. 2012; Sanon et al. 2012) or Bayesian Belief Networks (cf., de Groot et al. 2010) could also be explored in the future.

Placing a stronger weight on GI in economically driven, cost-oriented decision-making could be furthered by monetary assessment of the multiple benefits GI provides (Mell 2009). The advantages and disadvantages of economic evaluations such as Total Economic Value should be tested in regard to GI (cf., de Groot et al. 2010; Gómez-Baggethun and Barton 2013).

Regarding questions of environmental justice, the assessment of supply and demand proposed in the framework does not capture access to benefits. For example, services provided by a private garden may allow recreation only for a very small group of people, while a larger group still benefits from improved air quality (Ernstson 2013). The theoretical basis for the consideration of undesirable side effects of GI planning, including ecosystem disservices, across social groups also needs to be advanced (Lovell and Taylor 2013).

With regard to stakeholder inclusion, GI and ES approaches will face similar challenges to all stakeholder engagement processes. To build a sound base for decision-making, stakeholder participation needs to be inclusive, legitimate, and informed (cf., Fish 2011). As a tool to empower a local community, for example, Berbés-Blázquez (2012) explored Photovoice, an approach where participants take photos that represent their individual views or views of their social group. Alternative methods could be collaborative mapping with tools such as Public Participation GIS (PPGIS; Brown et al. 2014). Further testing and advancement of these methods could help to strengthen the social perspective in GI planning.

Implications for Mainstreaming GI Planning

The conceptual framework for multifunctionality proposed here contributes to scientific discourses on GI and ES while supporting the mainstreaming of GI, including informing practitioners how they can design GI planning processes based on the best available knowledge. However, in its complexity the framework might be challenging to implement. Thus, it shall not be viewed as a rigid concept that should be transferred as a whole into planning. Instead, it can and should be tailored for planning tasks on different spatial levels and with particular thematic issues. For example, the methods for analysis need to be adapted according to data availability and, respectively, the capacity to collect data.

A further challenge of GI planning is that it requires knowledge from different professions being brought together, which necessitates establishing new ways of systemic thinking and cross-disciplinary cooperation. Traditional departmental structures in municipalities might hinder such approaches (Kambites and Owen 2006; Primmer and Furman 2012). Interview-based approaches considering institutional processes of learning and adoption of new concepts can help to gain a better understanding of barriers (e.g., Sandström et al. 2006; Niemelä et al. 2010).

What pitfalls and gaps may occur in the implementation of the proposed framework for assessing multifunctionality needs to be explored in case studies. Ahern (2011), for example, advocates project-based collaborations involving various disciplines and adoption of a "Learning-By-Doing" approach. Such approaches based on science–practice cooperation can support the understanding of limitations in practice.

CONCLUSION

Planning for multifunctionality aims to create synergies that can be realized in order to increase the overall benefit of GI. However, if multifunctionality would be understood only in a quantitative sense of "the more functions the better," potential conflicts between different ES might be overlooked. Furthermore, if the capacity of ecosystems to provide services is assessed detached from social questions of demand and access to those benefits, planning for multifunctionality might unintendedly increase environmental injustice for particular groups of society. Thus, multifunctionality needs to be understood as a normative concept and take a broad perspective on urban areas as interrelated social–ecological systems.

From this paper it can be concluded that multifunctionality can be underpinned with a conceptual framework that integrates a broad range of ecological and social aspects and thus meets the holistic thrust of GI planning. The suggested framework for multifunctionality hopefully can foster a discourse on potential linkages and further development of GI and ES approaches. Collaborating more closely could support closing gaps in both concepts. In the future, a combined GI and ES approach could be further developed into innovative planning concept that captures the complexity and dynamic of social–ecological systems in urban areas and supports policy objectives such as sustainable development, environmental justice, social cohesion, or resilience.

Acknowledgments We would like to thank our colleague and URBES-team member Emily Lorance Rall for constructive discussions as well as for proofreading the manuscript. We also thank Jaan-Henrik Kain and Annette Voigt for their very helpful review of an earlier version of this manuscript. This work was financially supported by the EU BiodivERsA through the German Federal Ministry of Education and Research project "Urban Biodiversity and Ecosystem Services" (URBES).

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Electronic Supplementary Material

From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas

Rieke Hansen and Stephan Pauleit

Appendix S1: List of reviewed publications

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Paper II

Hansen, R., Franzeskaki, N., McPhearson, T., Rall, E., Kabisch, N., Kaczorowska, A., Kain, J.H., Artmann, M., and Pauleit, S., 2015. The uptake of the ecosystem services concept in planning discourses of European and American cities. *Ecosystem Services* 12: 228–246. DOI 10.1016/j.ecoser.2014.11.013

Ecosystem Services 12 (2015) 228–246

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

The uptake of the ecosystem services concept in planning discourses of European and American cities

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ARTICLE INFO

Article history:
Received 17 March 2014
Received in revised form
9 October 2014
Accepted 24 November 2014
Available online 6 January 2015

Keywords:
Ecosystem services
Urban planning
Discourses
Human–nature relations
Resilience
Policy-making

ABSTRACT

Ecosystem services (ES) are gaining increasing attention as a promising concept to more actively consider and plan for the varied benefits of the urban environment. Yet, to have an impact on decision-making, the concept must spread from academia to practice. To understand how ES have been taken up in planning discourses we conducted a cross-case comparison of planning documents in Berlin, New York, Salzburg, Seattle and Stockholm. We found: (1) explicit references to the ES concept were primarily in documents from Stockholm and New York, two cities in countries that entered into ES discourses early. (2) Implicit references and thus potential linkages between the ES concept and planning discourses were found frequently among all cities, especially in Seattle. (3) The thematic scope, represented by 21 different ES, is comparably broad among the cases, while cultural services and habitat provision are most frequently emphasized. (4) High-level policies were shown to promote the adoption of the ES concept in planning. We find that the ES concept holds potential to strengthen a holistic consideration of urban nature and its benefits in planning. We also revealed potential for further development of ES approaches with regard to mitigation of environmental impacts and improving urban resilience.

1. Introduction

Emerging from ecological economics in the 1990s, ecosystem services (ES) represent an important and still evolving concept that has the potential to redefine perspectives on human–nature relations towards a more holistic view that highlights our dependence on and responsibility for healthy ecosystems (Norgaard, 2010). An underlying hope of ecology and environmental economics is that the concept of ES can change the way ecosystems are considered in policy and planning and promote policy actions that will reduce environmental degradation and biodiversity loss while enhancing human well-being (e.g., MA, 2005; Schröter et al., in press).

Only recently have ES been discussed as a concept to aid *urban* planning and policy-making (Niemelä et al., 2010; Colding, 2011; Gómez-Baggethun et al., 2013). Particular barriers for integration of the ES concept as a heuristic tool for urban planning and policy-making are to be expected considering the need for (1) a change of planning paradigms and routines towards more systemic and holistic thinking, e.g., by linking ecological, social, and economic considerations (Norgaard, 2010; Scarlett and Boyd, in press); and (2) a shift towards more interdisciplinary thinking and coordination given that different fields in administration are usually in separate departments (Cowling et al., 2008; Primmer and Furman, 2012; Ahern et al., 2014). With the exception of these barriers, urban planning seems well positioned to adopt ES approaches, since consideration of multiple conflicting demands on use of land and natural resources has been a primary goal of the field since its emergence (Wilkinson et al., 2013).

So far, research on ES has primarily considered the relation to planning practice and stakeholder needs (Cowling et al., 2008; Gómez-Baggethun et al., 2013). A very small number of urban ES studies analyzed in a review by Haase et al. (2014) targeted implementation such as considering information needs of city authorities, integrating

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http://dx.doi.org/10.1016/j.ecoser.2014.11.013
2212-0416/

study results in planning processes, or developing assessment tools for planning (e.g., Li et al., 2005; Rall and Haase, 2011; McPhearson et al., 2013a). The perception of the ES concept by planning practitioners has been analyzed for several developed countries (Hauck et al., 2013; Albert et al., 2014; Matzdorf and Meyer, 2014), though few focused on professionals from planning and management of urban green space (Niemelä et al., 2010; Young, 2013). Most methodological approaches to assess the uptake and operationalization of the ES concept in urban planning include interviews with stakeholders and content analyses of plans and policies. These studies consider one to two cases such as Stockholm, Melbourne or Rotterdam (Wilkinson et al., 2013; Frantzeskaki and Tillie, 2014) or execute multiple-case studies within the same planning frame such as coastal cities in Poland (Piwowarczyk et al., 2013). However, a broader comparison for different urban contexts and planning cultures is missing. We undertook an analysis of different policy and planning contexts to better understand the gaps and linkages between the concept of ES and its implementation in urban plans and policies.

This analysis uses a discursive approach where explicit and implicit references to the ES concept are identified. Explicit reference indicate a conscious uptake of the ES concept while implicit references are understood to be based on similar conceptual understandings or underpinnings of urban ecosystems and their benefits without conscious linkages to the ES concept (Hauck et al., 2013; Wilkinson et al., 2013; Matzdorf and Meyer, 2014).

Therefore, this study seeks to answer the following questions based on a discourse analysis of planning documents comparing cities from Northern America as well as Western and Northern Europe:

1. How is the ES concept, in explicit and implicit terms, represented in different urban planning contexts?
2. To what extent are individual ES such as particular regulating or cultural ES represented in the planning documents? Which ES are referred to and how broad is the thematic scope within planning documents?

We suggest that discursive representation and explicit use of ES in different urban contexts indicates a new ecological approach to urban planning.

2. Material and methods

A cross-case comparative analysis of planning documents from five cities, supplemented by local expert knowledge, was conducted to explore the relationship between the ES concept and planning practice. We focus on European and US cities because these two regions represent different periods of time for entering discourses on ES as well as different planning cultures and paradigms. In the United States (US), there has been a surge in ES research in the past decade by federal governmental organizations such as the USDA Forest Service and the US Environmental Protection Agency which have supported awareness, and ES valuation studies have been conducted that are considered in planning and policy-making in some regions (Molnar and Kubiszewski, 2012; Scarlett and Boyd, in press; McPhearson et al., 2014). In Europe, the ES concept has only recently been promoted through European Union (EU) policy, for example in the Biodiversity Strategy to 2020 (EC, 2011) and the Green Infrastructure Strategy (EC, 2013). Attention in EU-member states has risen and scientific knowledge related to ES implementation and policy-making is recently evolving (Hauck et al., 2013; Albert et al., 2014; Matzdorf and Meyer, 2014)

The five case studies analyzed here including Berlin in Germany, New York City and Seattle in the US, Salzburg in Austria, and Stockholm in Sweden, represent different planning contexts, biogeographic regions and population sizes. They were selected based on the authors' local expertise and their role as case studies in the URBES project (Urban Biodiversity and Ecosystem Services), which helped secure in-depth knowledge of local governance contexts. The city of Seattle is not part of the URBES project but was included as a second case study from the US planning context since the city is well known for its innovative, participatory planning approaches and its efforts in sustainable urban development (Karvonen, 2010; Rouse and Bunster-Ossa, 2013).

During the URBES project and an additional research stay in Seattle the researchers had several points of interactions with stakeholders from the case study cities including interviews, discussion groups, workshops with urban planners and policy makers, and in-situ observations of decision-making processes where the ES concept was explored (for detailed information see Frantzeskaki and Tillie, 2014; McPhearson et al., 2014; Kabisch, 2015). Furthermore, a desk study on the biogeographic and historic context, the current planning system and important drivers of change such as adaptation to climate change or demographic change was conducted for each case study city based on review of literature and planning documents.

2.1. The case study cities and their planning contexts

The case study cities range in population size from 0.15 million in Salzburg to 8.2 million in New York City (Fig. 1). Berlin and New York are amongst the largest cities in their geographical regions. Berlin is a mono-centric and moderately dense city which represents the Germanic planning tradition, with a strong emphasis on formal land use planning based on federal law. However, the city is increasingly using informal strategic planning approaches. Situated along the northeast coast of the US, the New York metropolitan region encompasses an urban core with a high population density of 10,430 people/km² (US Census Bureau, 2010), surrounded by suburban and exurban housing development. To tackle the city's future challenges a landmark strategic plan, PlaNYC, was launched in 2007 with a mission of providing a vision for sustainable development. With its integrated and practical scope, PlaNYC has since gained international attention (Newman and Thornley, 2013).

Seattle and Stockholm represent medium-sized cities in coastal regions, which face immediate pressures from the effects of climate change. Seattle is located in the Puget Sound region in the Pacific Northwest of the US. Low-density development has led to urban sprawl in its urban metropolitan area. The planning system of the city and surrounding region is based on collaborative approaches and characterized by a high number of (informal) visions and strategies with regular plan updates and broad community participation.

The City of Stockholm is the capital of Sweden and is situated on a number of islands between the fresh water lake Mälaren and the brackish Baltic Sea. The city is dense and polycentric with a main central core. It is largely built up along metro lines and with substantial green and blue wedges entering into the city from different directions. Stockholm is a forerunner in Europe for sustainable urban development (Colding, 2013; Metzger, 2013). It also stands out in Europe for early adoption of the ES concept, since the concept was introduced in Swedish policy in the early 2000s and has since grown in importance (Lewan, 2000; Granath et al., 2012).

Salzburg was chosen to represent a small city in our sample. The city's Green Space Declaration, implemented in 1985 as a result of public pressure and increased environmental consciousness, is a crucial instrument aiming at protecting of the city's green space (57% of the whole area; Amt für Stadtplanung und Verkehr, 2009). The declaration is incorporated into the city's development concept of 2007 which is used in accordance with the Salzburg Regional Planning Act as the basis for the city's development.

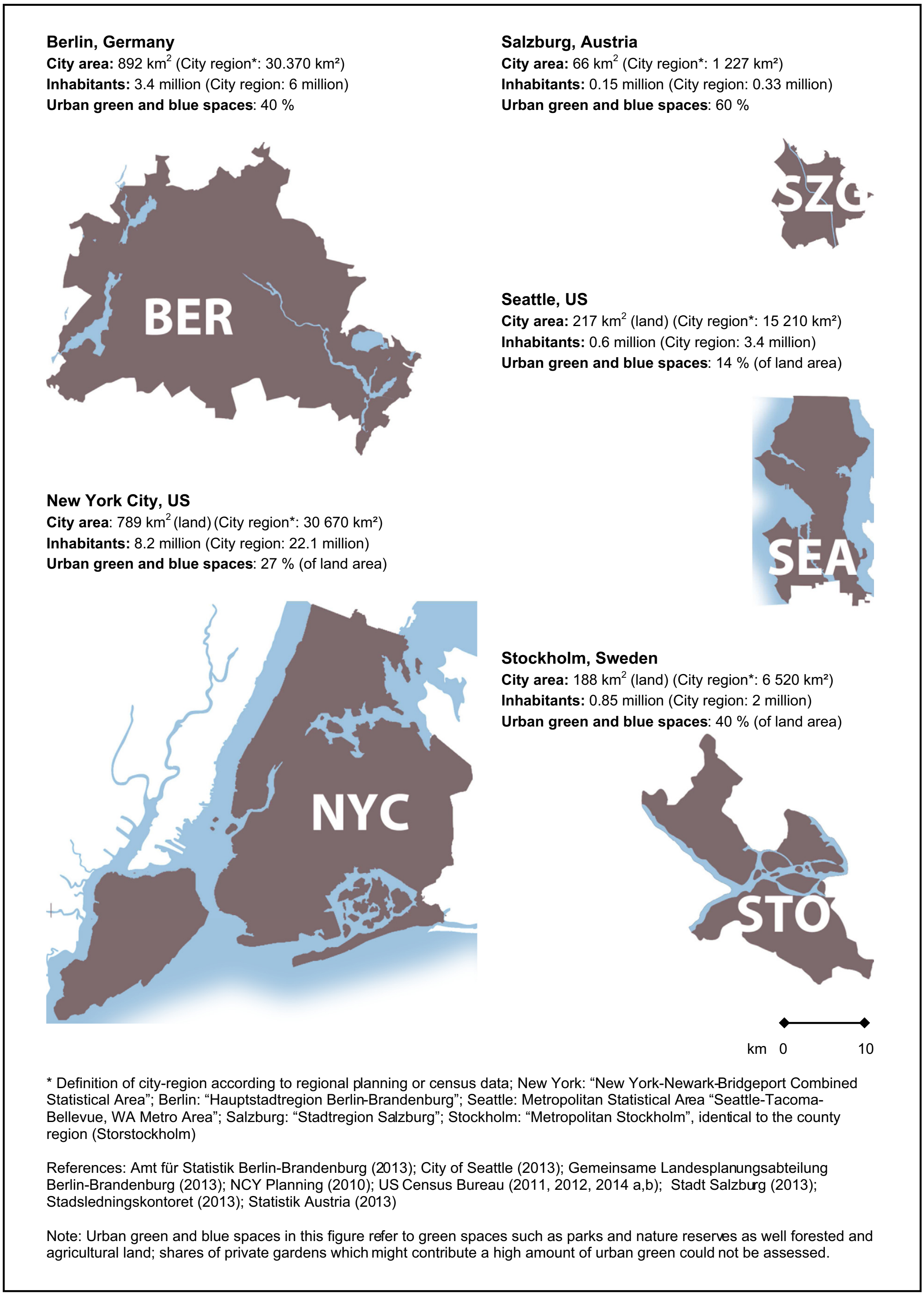

Fig. 1. The five case study cities in comparison (Amt für Statistik Berlin-Brandenburg (2013); City of Seattle (2013); Gemeinsame Landesplanungsabteilung Berlin-Brandenburg (2013); NCY Planning (2010); Stadsledningskontoret (2013); Stadt Salzburg (2013); Statistik Austria (2013); US Census Bureau (2011, 2012, 2014a, 2014b)).

2.2. Document research and selection

For each case study city, planning documents were selected and analyzed for ES related content that represent strategies and principles for spatial organization, land use or built form arrangement, and aim to actively influence the urban structure on a city and city-region level. The selected documents belong to strategic planning since they provide long-term visions, objectives and measures for the further development of the planning area (Albrechts, 2006).

The documents were collected between April and August 2013 through the cities' official websites and after consultation with local planning officers and experts. As urban green (and blue) spaces are the spatial elements capable of providing ES each document was assessed as *high*, *medium* or *low* with regard to its relevance for the future development of urban green space (*high*: urban green space is among the main topics; *medium*: one of several less important topics or only a particular type such as forest or community gardens is considered; *low*: addressed only indirectly, e.g. by sectorial land use decisions). Planning documents from three thematic clusters – regardless of the legal status in its particular planning context – were assessed as most relevant for the future quantity or quality of green and blue space:

1. comprehensive planning as constituting the general direction of spatial development,
2. green space, landscape, and/or biodiversity planning as sectorial planning directly addressing green space,
3. environmental planning as sectorial planning focusing on a single environmental issue or gray infrastructure planning with significant indirect influences on green space (e.g., water management, climate change adaptation, traffic planning).

Depending on the number of existing relevant plans up to seven documents for each city were selected. All plans were put into force between 1996 and 2012 and are still in action.

2.3. Document analysis with regard to the discursive representation of the ES concept and perspectives on human–nature relations

Planning and policy documents can be considered as agreed upon planning paradigms and principles. They capture and represent the discourses of each city's urban planning practice at a certain point in time (Faludi, 2000). Research suggests that shifts of policy discourses can signal changes in policy paradigms (Gunder and Hillier, 2009; Howlett and Cashore, 2009; Roe, 1994).

To answer our first research question, the first step of our document analysis aimed at identifying explicit references to the ES concept and related concepts (e.g., using exact wording; Roe, 1994). Related concepts are, e.g. ‘landscape/ecological functions’ which are applied, for example, in Germany (Bastian et al., 2012; Haaren and Albert, 2011) and the Netherlands (de Groot, 1992). General references to ‘benefits’ nature provides for humans were also identified because the notion that humans obtain benefits from nature is central to the ES concept (MA, 2005; Kumar, 2010). Specifically, each document was analyzed with regard to the following questions:

1. Is the term ‘landscape function/s’ or ‘ecological function/s’ mentioned?
2. Is the term ‘ecosystems services’ mentioned?
3. Are ‘benefits’ humans derive from nature mentioned?

The data were filled in a document analysis inventory (Table A2; presence/absence of terms; description of how the concepts were addressed) and supplemented by quotes from the planning documents.

The second step of the documents analysis aimed to identify perspectives on human–nature relations and to compare those to the perspective represented by the ES concept. The concept of ES implies an anthropocentric framing by highlighting the benefits humans obtain from nature. It aims to raise awareness for the

Table 1
The 21 analyzed ecosystem services.

Ecosystem services (adapted from TEEB, 2011; Niemelä et al., 2010; Piwowarczyk et al., 2013; Gómez-Baggethun et al., 2013)
Provisioning services: material outputs from ecosystems • food supply • raw materials supply • water supply • medicinal resources
Regulating services: ecosystem processes that serve as regulators of ecological systems • local climate regulation • air quality regulation • carbon sequestration and storage • noise reduction • run-off mitigation • moderation of extreme events • waste-water treatment • erosion prevention and maintenance of soil fertility • pollination • biological control
Habitat or supporting services: the provision of living spaces and maintenance of plant and animal diversity (serve as the foundation for all other services) • habitat for species • maintenance of genetic diversity
Cultural services: non-material benefits obtained from human contact with ecosystems • recreation and mental and physical health • tourism • esthetic appreciation and inspiration • spiritual experience and sense of place • education and learning

dependency of human well-being on ES (MA, 2005; Daily et al., 2009).

Furthermore, it was assumed that additional perspectives on human–nature relations will be present in planning practice which, for instance, emphasize nature's intrinsic value (Schröter et al., in press). To explore these perspectives more specifically the inventory included one additional question:

4. In which way are humans and nature, ecosystems, and/or landscape seen as interrelated?

Identified quotes for all four questions were analyzed hermeneutically and grouped by meaning.

2.4. Document analysis with regard to individual ES

To answer the second research question, the second part of the analysis addressed content related to specific ES classes and also the thematic scope in different planning documents. The TEEB classification of ES with some modifications based on literature for urban areas was used to assess the thematic ES coverage. This means that each document was analyzed hermeneutically. Notations were made for any reference to one of 21 ES grouped into provisioning, regulating, habitat/supporting, and cultural services (Table 1), whether or not the service was directly stated. The notations were supplemented with five coding categories to assess the level of detail to which a particular service refers (Tables 2 and A3). To be considered at least as 'acknowledged', all services had to be related to a green space type or ecosystem. For example, if noise reduction is mentioned as a political aim but not related to the potential of vegetation to act as a buffer to noise, it was not counted as a service (code P), while objectives to protect agricultural areas were seen as related to the service "food supply". The coding categories A, I, and E represent different levels of elaboration.

In the content analysis for all steps, the findings were collected for each city in Excel spreadsheets following a coding protocol (Appendix, Tables A2 and A3). All results across cases were reviewed for plausibility and consistent use of the coding categories by the lead researcher to guarantee consistent coding.

3. Results

In total 33 documents were analyzed, 14 from the US and 19 from Europe (Table 3, Appendix Table A1).

3.1. Discursive representation of the ES concept

To answer the first research question we examined explicit references to the ES concept and related concepts such as benefits provided by nature. Fig. 2 shows that most US documents refer to benefits people obtain from nature. Three documents from New York also mention ES compared to none from Seattle. However, three documents from Seattle (SEA_3, 4 and 7) refer to ES assessment tools using the term benefits instead of services or define 'ecosystem benefits' with the same meaning as ES. In the US plans, landscape or ecological functions are mentioned almost as often as benefits.

In the European cases, there is no mention of the terms ES, landscape/ecological functions or benefits in three documents from each city. These documents frequently belong to comprehensive planning such as the State Development Plan Berlin-Brandenburg (BER_2) or Salzburg's Regional Program (SZG_1). Benefits are mentioned in comparably few documents. While the concept of landscape or ecological functions is mentioned in each European city, only four documents from Stockholm, two from Berlin, and none from Salzburg refer to the concept of ES.

Overall, it is striking that the term 'benefits' is explicitly mentioned in most of the US planning documents while in documents from other countries benefits are referred to implicitly – without actually calling them benefits. This use of terms may be caused by language differences. For example, in German the term 'Leistungen' can be used for 'services' as well as 'benefits', which makes it partly impossible to differentiate which is meant. Additionally, in different documents from, for example, Salzburg specific functions such as soil functions are referred to while not explicitly mentioning the term landscape or ecological functions

Regarding expressions of human–nature relations, different perspectives were identified that range from a notion of benefits people obtain from nature to concerns about negative impacts on nature or risks through natural disasters. Table 4 provides examples of perspectives frequently found in the documents.

Perspectives that overlap with the concept of ES such as a description of benefits humans obtain from nature or the dependence of humans on urban nature can be found in several documents (benefit and dependence perspectives). Especially documents from Seattle emphasize the interdependence between humans and nature (interdependence perspective), which can be seen as a continuation of the dependence perspective. An impact perspective refers to the fact that humans may cause environmental problems such as damaging riparian areas or causing

Table 2
The coding categories to assess the level of detail an ecosystem services (ES) is addressed.

Category	Code	Explanation	Examples
Not mentioned	N	ES is not mentioned at all.	
Problem mentioned but not linked to ES	P	Aspects related to ES (e.g. air pollution, storm water management) are named but they are not related to urban green/ecosystems/natural areas etc. It might be the case that an improvement of the situation is focused on technical solutions or remains open.	"Improving water quality" mentioned as a task for planning. "Habitat loss" mentioned as an issue.
Acknowledged	A	An ES is only mentioned. It links urban green/ecosystems/natural areas to a specific services/function	"Trees sequester carbon." "Soil infiltrates storm water." "Parks provide recreation opportunities."
Indirectly elaborated	I	ES is mentioned in the same way like "A" but loosely related to goals/activities/target. Usually the service/function is used as an argument to introduce the goal/policy etc. But goal/policy is very general – e.g. protection open land/forests	"Trees sequester carbon" and later on "Forests shall be protected".
Elaborated	E	An ES is further elaborated. That means ES is directly linked to goals/targets/objectives. It can also be: mapped or otherwise quantified, or monetary or non-monetary valued (e.g. avoided "gray" infrastructure costs; the most valuable habitats)	"Protection of forests in areas with risks of erosion." "Establish wildlife corridors to improve habitats." Maps with areas that should be greened because of strong heath island effect.

Table 3
List with analyzed documents from the five case study cities. Each document had a code consisting of the IATA airport code (BER=Berlin, NYC=New York City, SZG=Salzburg, SEA=Seattle, STO=Stockholm) and a digit to indicate the plan number.

Berlin	New York City	Seattle	Stockholm	Salzburg
Comprehensive planning				
BER_1 Landesentwicklungsprogramm der Hauptstadtregion Berlin-Brandenburg/LePro[a] 2007 (State Development Program for the Berlin-Brandenburg Region)	**NYC_1** A Region at Risk: The Third Regional Plan For The New York–New Jersey-Connecticut Metropolitan Area[a] 1996	**SEA_1** Vision 2040[a] 2008	**STO_1** Regional utvecklingsplan för Stockholmsregionen/RUFS[a] 2010 (Regional development plan for the Stockholm region)	**SZG_1** Regionalprogramm Salzburg-Stadt und Umgebungsgemeinden[a] 1999/2007 (Regional Program for the City of Salzburg and Surrounding Communities)
BER_2 Landesentwicklungsplan Berlin-Brandenburg/LEP[a] 2009 (State Development Plan Berlin-Brandenburg)	**NYC_2** PlaNYC 2011	**SEA_2** City of Seattle Comprehensive Plan 2005	**STO_2** Vision 2030: Framtidsguiden 2007 (Vision 2030: A guide to the future) **STO_3** Promenadstaden: Översiktsplan för Stockholm 2010 (The Walkable City – Stockholm City Plan)	**SZG_2** Das räumliche Entwicklungskonzept der Stadt Salzburg/REK 2007 (City of Salzburg's Spatial Development Plan)
Green space/landscape/biodiversity planning				
BER_3 Strategie Stadtlandschaft Berlin 2012 (Berlin's Urban Landscape Strategy)	**NYC_3** New York State Open Space Conservation[a] 2009	**SEA_3** Seattle Parks and Recreation Strategic Action Plan 2008	**STO_4** Stockholms parkprogram 2006 (Stockholm Park Program)	**SZG_3** Gruenes Netz der Landeshauptstadt Salzburg 2007 (Green Network of Salzburg)
BER_4 Landschaftsprogramm /Artenschutzprogramm 1994/2004 (Landscape Program/Species Protection Program)	**NYC_4** Vision 2020: New York City Comprehensive Waterfront Plan 2011	**SEA_4** Open Space 2100: Envisioning Seattle's Green Future 2006	**STO_5** Sociotopkarta för Parker och Andra Friytor I Stockholm Innerstad 2002 (Sociotope Map)	**SZG_4** Studie Salzburger Stadtlandschaften 2009 (Study on Salzburg's Urban Landscapes)
BER_5 Berliner Strategie zur Biologischen Vielfalt 2012 (Berlins Biodiversity Strategy)	**NYC_5** New York City Wetlands Strategy 2012	**SEA_5** Puget Sound Salmon Recovery Plan[a] 2007	**STO_6** Stockholms Biotopkarta 2009 (The Habitat Map)	
Environmental/Gray infrastructure planning				
BER_6 Stadtentwicklungsplan Klima 2011 (Urban Development Plan Climate)	**NCY_6** NYC Green Infrastructure Plan 2011	**SEA_6** City of Seattle 2013 NPDES Storm Water Management Program 2012	**STO_7** The Stockholm Environment Program 2012–2015 2012	**SZG_5** Verkehrsleitbild der Stadt Salzburg 1997 (City of Salzburg's Leitbild/concept for traffic)
BER_7 Wasserversorgungskonzept für Berlin und für das von den BWB versorgte Umland 2008 (Water supply plan for Berlin and surrounding)	**NYC_7** Sustainable Stormwater Management Plan 2008	**SEA_7** City of Seattle Food Action Plan 2012		

[a] Regional level.

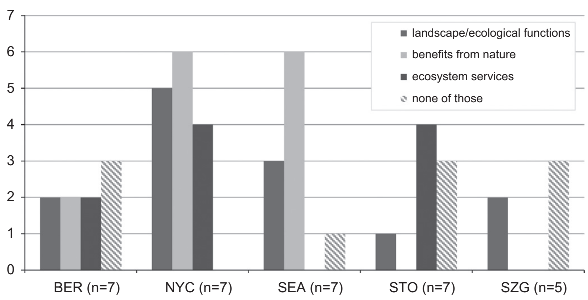

Fig. 2. Number of concepts related to ecosystem services that were explicitly mentioned in the analyzed planning documents from the five case study cities ('*n*' refers to the total number of documents for each case study city).

habitat loss. A general responsibility of humankind to protect ecosystems or biodiversity is also emphasized in several documents, often leaving open if conservation efforts are based on anthropocentric or nature-intrinsic values (conservation perspective). Additionally, some documents, especially from coastal cities, refer to human vulnerability to and risks of extreme nature events (vulnerability/risk perspective).

3.2. Individual ES in planning documents

The ES concept covers a broad range of services humans can benefit from ranging from provisioning, regulating, habitat/supporting to cultural services. We analyzed which types of ES are already considered and, hence, how broad the overall thematic scope is with regard to ES.

Fig. 3 shows that 14 of 21 ES are mentioned in at least half of the documents. With the exception of medicinal resources all provisioning services are mentioned frequently. Amongst the regulating services local climate regulation, run-off mitigation, air quality regulation, erosion prevention/soil fertility, and moderation of extreme events can be found in at least half of the documents. The most rarely mentioned among the regulating services are pollination and biological control. The group of habitat or supporting services consists of two ES. While genetic diversity is rarely addressed, habitat for species is the most often mentioned ES and only absent in one document (STO_2). All five cultural services are mentioned in at least half of the documents, with recreation/mental and physical health as the second most mentioned ES.

Several environmental issues such as local climate regulation or run-off mitigation are mentioned in the analyzed documents

Table 4
Examples of human–nature perspectives expressed in the analyzed documents.

Human–nature perspectives	Document code and quote
Perspectives closely related to the concept of ecosystem services	
Benefit perspective: (Urban) nature provides benefits for human well-being/quality of life/(Urban) nature provides economic benefits.	BER_3, p. 3: "This nature in the middle of the city, these green spaces in Berlin are a precious resource for every one of us. It increases the quality of life for a people of Berlin as well as for visitors from all over the world. The multifaceted urban green spaces represent wealth and likewise an economic factor for the metropolis Berlin." [translated from German] NYC_2, p. 44: "We are becoming more and more aware of the multiple benefits of urban trees. Today, a growing body of knowledge identifies trees as assets to a city's economic and environmental health. City trees cool summer air temperatures, filter air pollution, conserve energy by providing shade, and reduce stormwater runoff. STO_1, p. 106: "Proximity to nature is an important quality in a metropolitan city. Access to varied nature, the shoreline and aquatic environments encourages physical activity, and provides opportunities for relaxation, peace and quiet, play as well as natural and historic environment experiences close to the home. Activity centres, outdoor facilities and events in the natural environment contribute towards more meetings between people. The function of the wedges as natural treatment facilities improves the living environment in the city, for example by purifying water and air, evening out temperature and water flows such as storm water, temperature regulation and air exchange. Proximity to urban green spaces therefore offers considerable added value for the residents, and is important from a public health perspective."
Dependence perspective: Humans are depending on (urban) nature	BER_5, p.6: "Human survival depends on the manifold functions delivered directly or indirectly by biodiversity. It this ecosystem, services that make the earth a inhabitable place for humans." [translated from German] NYC_1, p.88: "The time has come to strike a new balance with nature and not just because healthy ecosystems, mighty rivers, and lofty mountains give us clean air and pure water. The region should develop, and redevelop, around its natural systems, instead of at their expense." SEA_3, p. 1: "People rely on Seattle's parks, open spaces, and recreation programs for many benefits, ranging from the pursuit of health and fitness to the desire for self-education, finding a connection with nature, or simply seeking a sense of belonging. Taken as a whole, these parks and open spaces create a green infrastructure that provides a refuge from the bustle of urban life, making Seattle a more beautiful and livable city."
Additional perspectives	
Interdependence perspective: Humans and (urban) nature are closely interrelated and depending on each other.	SEA_2, p. vii: "Sustainability is the common-sense notion that the health of our environment, our economy, our bodies, and our community as a whole, are not only closely linked, but dependent on one another." SEA_5, p. 9: "As a whole, people take pride in the fact that our region is built on a sustainable economy and healthy natural environment. In short, the region has become a world model for how our ecosystem and economy can both flourish to the benefit of all who share it."
Impact perspective: Humans cause environmental problems through emissions, land use etc.	NYC_3, p. 17: "Riparian areas are often severely damaged during the land development process, leading to unintended negative impacts to our streams and rivers." STO_6, p. 7: "The most important influencing factor is the exploitation of natural and park land. The effects described are loss and alteration of plant and wildlife habitats. It in turn leads to loss or degradation of the species populations and ecosystem features – and thus reduced ecosystem services."
Conservation perspective: Humans have the responsibility to preserve (urban) nature	NYC_5, p. 5: "To maintain healthy urban wetlands in the face of sea level rise, the City will evaluate which wetlands are vulnerable and how to improve the resilience of these areas through restoration or protection efforts." BER_2, p. 70: "Another important factor for the preservation of biological diversity is the biotope network. A biotope network has also to be suitable for the migration and population exchange of mammals with larger area claims and thus requires the conservation and restoration of corridors and large areas of unfragmented landscape. In particular, the in international comparison very dense road network in Germany has led to a decrease of Undissected Areas ($>$ 100 km²) With Low Traffic Density (UZVR) with at least 100 km² area size, i.e. habitats with sufficient size for wild animals and plants have decreased dramatically." [translated from German]
Vulnerability/risk perspective: Humans need to be protected from extreme nature events	SEA_4, p. 11: "Continue to make the city a safe and healthful place to live. Reduce the risk of natural hazards (slides, flooding, earthquake, soil and water contamination) while reclaiming and treating previously toxic sites." STO_3, p.33: "Climate change is expected to cause higher water levels in the Baltic Sea and prolonged, intensive rain will become more common. This may cause flooding of Lake Mälaren and other lakes and watercourses, which could affect low-lying areas and their utilities infrastructure. Groundwater levels are also expected to vary more, which could lead to landslides and damage to buildings.

when examining the ES that were classified as 'P' for 'Problem mentioned but not linked to ES' (Appendix, Fig. A1). This means that it was noted that this particular issue needs to be mitigated or solved but without explicit relation to urban green as one possible contributor to the improvement of the current situation. At least six documents refer to problems with water supply, air quality, noise, wastewater, and lack of biological control (e.g., pests or invasive species) without explicit connection to urban green.

Regarding the depth to which ES are considered in the planning documents, habitats for species as well as recreation/mental and physical health are the most often elaborated (Table 2) which means supplemented by, e.g., particular measures or targets. 'Indirectly elaborated' services, representing a more loose relation between the notion of the service and means for actions, were less commonly found. 'Acknowledged' as a category where the existence of this ES is expressed but with no traceable relation to actions is most often

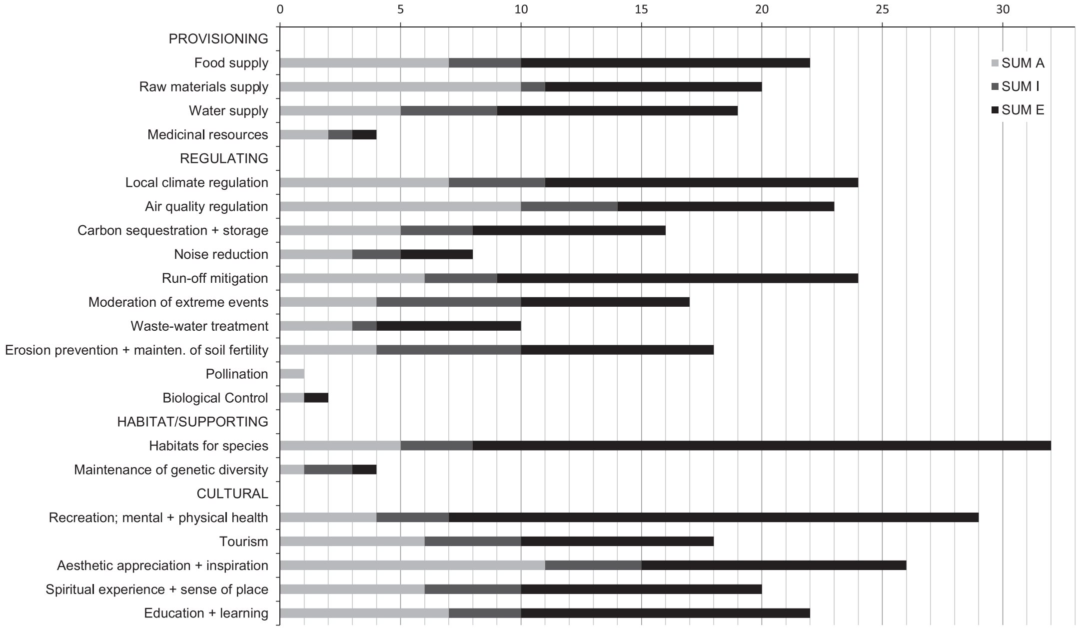

Fig. 3. Total number each ecosystem service is mentioned in the analyzed documents of all five case study cities (total number of documents, $n=33$). The different colors represent the depths a service was discussed (A=acknowledged; I=indirectly elaborated; E=elaborated).

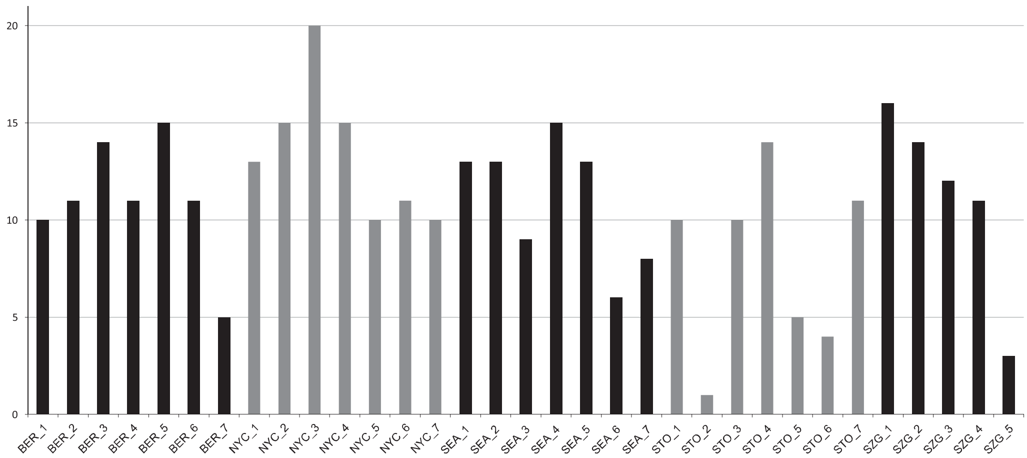

Fig. 4. Total number of ecosystem services ($n=21$) mentioned in the 33 analyzed documents from five case study cities.

used (at least in ten documents) for raw materials supply, air quality regulation, esthetic appreciation and inspiration.

Regarding the overall scope of ES, on average eleven ES were at least mentioned (Fig. 4). In Berlin the informal plans Urban Landscape Strategy (BER_3) and the Biodiversity Strategy (BER_5) are above this value. Also from New York, PlaNYC (NYC_2), the Open Space Conservation Plan for the New York State (NYC_3) and the city's Waterfront Plan (NYC_4) are above the average with NYC_3 as the one document referring to 20 services. The highest number of ES for Seattle can be found in the grass-roots green space plan Open Space 2100 (SEA_4).

Although the concept of ES was introduced quite early in Sweden, the lowest discursive representation of different ES types can be found in Stockholm's documents. Only the Stockholm Park Program (STO_4) is above the average. Around five ES can be found in the Sociotope Map (STO_5) and the Habitat Map (STO_6). Both documents refer to social, cultural (STO_5) and ecological (STO_6) values of urban green spaces but address only few ES explicitly. From Salzburg, the regional and the city's comprehensive plans (SZG_1 and 2) are above average.

For all cities, functional plans often have low numbers of ES references such as Berlin's Water Supply Plan (BER_7), Seattle's Stormwater Management Plan (SEA_6) or Salzburg's Concept for Traffic (SZG_5). In the group of comprehensive plans the Vision 2030 (STO_2), a very short strategic document of eleven pages, refers to only one ES.

4. Discussion

4.1. *Implementation according to explicit ES references*

While we found only few references to individual ES types in Stockholm, most explicit references to ES as a concept can still be found in documents from Stockholm and New York, both from countries that started ES discourses early. Furthermore, two of the recently adopted plans and policy documents from Berlin also note the ES concept (BER_3 and _5, the Urban Landscape Strategy and the Biodiversity Strategy, both published 2012). The example of Berlin indicates that planning organizations are able to adopt new terminology from (international) scientific discourses relatively quickly.

However, the example of Seattle reveals that a lack of explicit references does not mean the ES concept is not adopted. While the term of ES is avoided in favor of ecosystem 'values' or 'benefits', several planning documents from Seattle refer to economic valuation of natural assets or mention ecosystem benefits. Economic ES valuations are considered as an additional tool to inform planning and policy-making and communicate the value of natural assets. In the Seattle and surroundings, ES valuations have been conducted for the Puget Sound (Batker et al., 2008) and the City's urban forest (Ciecko et al., 2012).

These findings indicate two possible ways for mainstreaming ES: (a) ES as a supporting concept for plan and policy-making which is, for example, used to explain the importance of biodiversity protection (e.g., BER_5) or to structure plans and policies conceptually (Matzdorf and Meyer, 2014) and/or (b) as an additional tool that supplements existing planning and policy instruments without necessarily changing them (Ruckelshaus et al., in press). Even if a straightforward implementation in planning and policy cannot taken for granted, the ES concept has high potential as a framework for guiding policy development (Matzdorf and Meyer, 2014; Schewenius et al., 2014).

4.2. Implementation according to human–nature relations

The anthropocentric perspective is partly criticized in ES literature as excluding valuable intrinsic nature values and in this way disregarding the value of nature independently from its actual usability for human purposes (Schröter et al., in press). Our results reveal that an anthropocentric framing is already embedded in urban planning of the case study cities but also the perspective that humans depend on urban nature is present in the analyzed documents. It is, for example, described that biodiversity and ecosystems are shown to provide a foundation for human well-being and therefore require protection, regardless of the immediate use values. Especially, the discourses embedded in the documents from Seattle but also in more recent documents from the European context such as Berlin Landscape Strategy reveal broad similarities with the ES concept in terms of human–nature framing.

Additional perspectives such as the impact perspective (Table 4) should be given greater consideration in ES discourses and the methodological development of ES assessments. ES mitigate human impacts on nature by, e.g., regulating air quality, reducing noise, mitigating run-off or treating waste-water. Thus, these mitigation effects could be highlighted in ES approaches to illustrate consequences of further environmental degradation or potential benefits through improvements in ES delivery (Artmann, 2014; Schwarz et al., 2011).

The perspective that humans are vulnerable to or endangered by extreme natural events is expressed in some of the documents. The anticipated impacts of climate change as well as actual natural disasters such as Hurricane Sandy will likely raise attention for the vulnerabilities, not only but especially, in coastal cities. For example, the 2013 update of PlaNYC "A Stronger, More Resilient New York" (The City of New York, 2013) focuses not only on recovering from the impacts of Sandy but also on increasing the resilience of infrastructure and buildings. Urban planning for resilience should operationalize the ES concepts for increasing the delivery of services such as storm water retention, prevention of erosion and landslides that contribute to the mitigation or avoidance of extreme events (Ahern, 2011; McPhearson et al., 2014; Schewenius et al., 2014).

4.3. Implementation according to thematic scope

The concept of ES encourages the consideration of a broad spectrum of services humans can benefit from including non-marketed values (e.g., Kumar, 2010). Concerning thematic scope (in our case represented by numbers of ES addressed on average in planning documents) New York represents the broadest perspective, while the other cities are comparable addressing often at least half of the analyzed 21 services. This might relate to the country's longer history of using the similar concept of green infrastructure, combined with local factors in New York such as strong political support, high population density and diversity (Rall et al., in review).

With its focus on cultural ES and biodiversity, Stockholm reveals the narrowest scope on average. In Stockholm there has been strong political support for preserving the green wedges of the city with regard to biodiversity and recreational values, influencing the strong consideration of these ES while downplaying other potential ES. A strong thematic focus on the service "habitat for species" and cultural services was also found for other cities. As habitats for species as well as cultural meanings of parks and other urban green spaces – especially for recreation – are themes long discussed in nature conservation or planning for green and open space their representation in planning concepts is not surprising (e.g., Barthel et al., 2005; Randolph, 2012; Lachmund, 2013).

These findings on the one hand reveal a potential to broaden the thematic scope represented by multiple ES, on the other hand they indicate an already comparably holistic perspective as, overall, none of the four groups of provisioning, regulating, habitat/supporting or cultural services is significantly weakly represented. Accordingly, the concept of ES can be applied to further strengthen the holistic perspective and sustainable use of ecosystems in urban planning by using it as a framework for conceptually structuring plan- and policy-making processes (Schröter et al., in press; Matzdorf and Meyer, 2014).

Concerning individual ES, an analysis of plans from Polish cities, representing a country that entered the discourse on ES recently, revealed that ES which already have a market orientation such as tourism and food production have a stronger focus in planning (Piwowarczyk et al., 2013). These results can only partly be supported by our study. The influence of national policies seems more prominent than market orientation. For example, ES related to stormwater management, which is connected with an important binding policy in the US (The Clean Water Act), are strongly represented in the US documents analyzed, while ES related to air quality are frequently addressed in European and American planning documents, both having policies on air quality that impose binding requirements (US: Clean Air Act; EU: Air Quality Directive).

One recommendation for mainstreaming the ES concept is to integrate environmental issues that are of high relevance in planning or political agendas into ES frameworks to better meet the demands of urban planners and managers (Baró et al., 2014).

4.4. Implementation according to planning systems and plan types

Overlaps of planning approaches with features of the ES concept can be found in planning documents from all cities, for example, in terms of anthropocentric framing, holistic thematic scope or focus on benefits provided by nature. Similar results have been found for some planning systems from developed countries (Wilkinson et al., 2013; Hauck et al., 2013), while for others the gaps between the ES concept and planning practice appear comparably large (Piwowarczyk et al., 2013). An influence of high-level policies for mainstreaming of the ES discourse can be noted for the US and Europe, in Europe especially through the implementation of policies and strategies that promote the ES concept such as the EU Biodiversity Strategy to 2020 (European Commission 2011).

Differences in the uptake of the ES concept between the case studies can be seen in relation to the time period when planning documents where developed and when national ES discourses evolved, more so than in relation to the particular planning system. For some of our case studies such as Stockholm it can be assumed that, on one hand, implementation of ES elements such as the holistic scope may only be a matter of time as planning experts from the City of Stockholm expressed high interest in the ES concept during their participation in the URBES project. The same appears for Salzburg, as a case study from Austria – a country, which quite recently conducted first the ES studies for including agricultural areas or rivers in course of the implementation of the European Biodiversity Strategy (Getzner et al., 2011; Götzl et al., 2011). Urban planning experts expressed interest in in-depth assessments of ES, e.g., for a more detailed functional structuring of the urban landscape within the study on Salzburg's Urban Landscapes (SZG_4) (Brunauer, 2014).

On the other hand, planners from Salzburg expressed concern that such assessments are often not able to capture the reality and complexity of urban nature (Brunauer, 2014). Planners and other stakeholders from Berlin valued the potentials of the ES concept cautiously especially in terms of monetization of ES, while there seems to be a comparably wide openness for economic ES valuations in New York and Seattle (Rall et al., in review; McPhearson et al., 2013b). Planners from Stockholm commented that the emerging ES concept confronts the planners with new challenges of widening the scope of benefits from urban nature and of translating ES as a scientific and policy concept into concrete planning activities. Therefore, we argue that for the implementation of the ES approach into practice further efforts by science are necessary to provide valid and user-friendly assessment methods and to inform urban planning about them (Daily et al., 2009; Fisher et al., 2009).

In terms of plan types, the analyzed documents were distinguished into three groups – (1) comprehensive planning; (2) green space/landscape/biodiversity planning; (3) environmental/gray infrastructure planning. Plans from group 1 or 2 cover a broader range of ES. This is not surprising as plans from the third group often deal with a comparably narrow issue such as transport, food or fresh water supply. Nevertheless, Berlin's Urban Development Plan Climate (BER_6) or the New York's Stormwater Management Plan (NYC_7), refer to a relative high number of ES. Likewise, some plans from group 2 partly have a specific thematic scope such as Stockholm's Sociotope and the Habitat Map (STO_ 5 and _6), and only refer to a low number of ES. It can be concluded, that all kinds of plans or policies can integrate several ES (Hauck et al., 2013). We see potential to put more emphasis on this holistic approaches provided by the ES concept. However, we suggest that different planning instruments of a city need to be coordinated and not all kinds of plans of a city necessarily need to cover all services in-depth.

4.5. Implications for future research

Comparative case studies can help to better understand governance arrangements that foster or hinder the implementation of new planning approaches in different geographic, political and social contexts. An analysis of policy and strategic planning documents can be applied to explore agreed upon policy paradigms for a particular period (Faludi, 2000; Wilkinson et al., 2013). Since planning documents are relatively easy to access, analysis of their content can lead to comparable data. For a quite recently developed concept such as ES, the results derived from a document analysis can be influenced by the time period in which the surveyed document were developed as the principles, ideas and concepts fixed in documents can differ from current planning practice. As document analyses are restricted to information presented in this format (Honrado et al., 2013; Piwowarczyk et al., 2013), in our study the knowledge of the researchers based on several forms of interactions with urban planners and a desk study delivered context and expertise for discussion and validation of the findings from the document analysis. Additional interviews and questionnaires would strengthen the assessment of the current state of ES awareness and understanding as well as the perceived opportunities and limitations. Our study focusing on comparative analysis provides a foundation for such in-depth exploration of stakeholder perspectives (Kabisch, 2015; others in preparation).

Explicit references are an obvious but nonetheless relevant indicator for the entry of the ES concept in policy discourses. Implicit ES references or less tangible similarities with the ES concept may be caused by overlaps between ES and other concepts such as landscape functions (Albert et al., 2014) and cannot be considered as evidence for conscious uptake of the ES concept, as we found, for example, in Berlin's Landscape program from 1996 (BER_4), even if they indicate a similar understanding of nature's benefits (Wilkinson et al., 2013).

Conversely, the uptake of terminology may just pay lip service to ES and is not a sufficient indicator on its own for the application of the concept (Primmer and Furman, 2012). Additionally, this study shows that a lack of explicit references to a concept does not mean that is not embedded (e.g., for Salzburg specific landscape functions are discussed without naming the concept). Furthermore, the findings from Seattle reveal that linguistic preferences (ecosystem benefits or values instead of services) can impede such analyses. Analyzing both explicit and implicit references allows more comprehensive insight and should be pursued in future research. For cases from non-English speaking countries, linguistic characteristics must be taken into careful consideration when applying ES terminology (Niemelä et al., 2010).

While we consider the thematic scope used in urban planning, other studies focus on the integration of conceptual or structural ES elements into plans and policies, e.g. based on a model for "ideal" ES-driven policy with indicators, e.g., for ecosystem capacity or cross-sector cooperation (Matzdorf and Meyer, 2014) or for operational features such as mapping or valuation (Hauck et al., 2013; Primmer and Furman, 2012). To provide a holistic picture, a policy analysis should cover awareness based on terminology as well as understanding represented by conceptual and/or operational features.

Our results suggest that urban planning is strongly influenced by policies, e.g. through legal frameworks or incentive programs. Some plans such as Berlin's Biodiversity Strategy (BER_5), New York's PlaNYC (NYC_2) or Seattle's Open Space 2100 plan (SEA_4), which have a broad thematic scope and discursive ES references, were developed by or in cooperation with local universities. Therefore, we need to better understand the role of research agencies and universities in fostering knowledge exchange between research and practice and perhaps especially for the implementation of concepts such as ES (Kopperoinen et al., 2014).

5. Conclusion

Considering the different dimensions of discursive representation and uptake of ES in urban planning, our case studies provide a multifaceted picture of gaps and linkages between the ES concept and its implementation into planning. Evidence for uptake of the concept of ES could be determined for more than half of the case study cities. Three already use ES terminology and a fourth refers to conceptual ES elements such as economic valuation of ecosystem benefits. Concerning overlaps between the ES concept and planning approaches, in all cities an anthropocentric framing of human–nature relations was detected. We also identified clear expressions of the dependence of human well-being on urban ecosystems in planning discourses. However, the concept of ES could be applied to strengthen the holistic perspective on urban nature to represent additional benefits from the environment.

Overall, we conclude that promotion of the ES concept on high policy levels will contribute to the mainstreaming of ES in a relatively short time span if the planning organization of the cities have the capacity to react to new concepts. However, skepticism of some practitioners has to be considered, and research needs to provide proof of the validity and added value of ES approaches.

It is still an open question whether integration of ES features such as the terminology, thematic scope or a holistic perspective on human–nature relations can be considered sufficient for mainstreaming ES, or even whether the aim for mainstreaming ES should go further to implement ES methods for measuring and valuing urban ecosystems. Our results indicate that both forms of implementation take place in urban planning. A holistic perspective fostered by ES without applying ES assessment, mapping, or valuation methods could still have positive effects on urban ecosystems and human well-being. In both cases, adoption of normative foundations of the ES concept in policies and planning is crucial if the ES concept aims to reconnect humans with urban nature and the sustainable use of natural resources. We find that the ES concept is, perhaps finally, beginning to become more mainstream in urban planning in the US and Europe and because of this, increases the potential of urban planning to utilize green infrastructure to address needs for climate change resilience and meet goals for urban sustainability.

Acknowledgment

This paper was funded by the EU FP7-ERA-NET project URBES (Urban Biodiversity and Ecosystem Services, 2012–2014), which aims to fill scientific gaps on the relationship between biodiversity and ecosystem services for human well-being and to strengthen the capacity of European cities to adapt to climate change and other future challenges. A research stay in Seattle was supported by the Technische Universität München Graduate School, resp. Graduiertenzentrum Weihenstephan. We thank Nancy Rottle for valuable insights into the planning system of Seattle and Daniel Wurster for contributing to the Salzburg case study.

Appendix A

See Fig. A1 and Tables A1–A3.

Ecosystem Services		BERLIN							NEW YORK CITY						
		BER_1	BER_2	BER_3	BER_4	BER_5	BER_6	BER_7	NYC_1	NYC_2	NYC_3	NYC_4	NYC_5	NYC_6	NYC_7
PROVISIONING	Food supply	E	E	E	A	E		A	E	E	E	A	A	E	
	Raw materials supply	E	E	A	A	A	A	A		E	E	E	A		
	Water supply	A	P	E	E	E	I	E	E	E	E	A		P	A
	Medicinal resources							P							
REGULATING	Local climate regulation		A	E	E	E	E	P	E	I	E	A		E	E
	Air quality regulation	P	A	E	E	E	E		E	I	I	A	A	E	E
	Carbon sequestration + storage	P	E	E		E	E		P	I	E		A	A	A
	Noise reduction	P	P		P		A							E	
	Run-off mitigation			A	E		E	P	I	E	E	E	E	E	E
	Moderation of extreme events	E	E	A			A		I	I	E	E	I	P	I
	Waste-water treatment				P		P	A	E	E	E	E	P	E	P
	Erosion prevention + mainten. of soil fertility	I	E		E	E	A			I	I	I	P		E
	Pollination														
	Biological Control					A		P			P				
HABITAT/ SUPPORTING	Habitats for species	I	E	A	E	E	E	E	E	E	E	E	E	A	E
	Maintenance of genetic diversity				I	A					I				
CULTURAL	Recreation; mental + physical health	E	E	E	E	E	A		E	E	E	E	E	I	E
	Tourism	I	E	E		E			I	E	E	E			
	Aesthetic appreciation + inspiration	A	E	E	E	A			E	I	E	E	A	I	A
	Spiritual experience + sense of place	I		A		I			I		E	E			
	Education + learning			E		E			I	E	E	E	E	A	E

Ecosystem Services		SEATTLE							STOCKHOLM						
		SEA_1	SEA_2	SEA_3	SEA_4	SEA_5	SEA_6	SEA_7	STO_1	STO_2	STO_3	STO_4	STO_5	STO_6	STO_7
PROVISIONING	Food supply	E	I		E	I		E	A			A			I
	Raw materials supply	I			E	A			E		A				A
	Water supply	I	P	A	I	P		P	E		P	I			
	Medicinal resources				A							I			
REGULATING	Local climate regulation		E		I	E		A	A		E	A		A	I
	Air quality regulation	A	E	A	**P**		A	P	A	P	P	A			P
	Carbon sequestration + storage	I	E	E	I			A	P		P	A		E	P
	Noise reduction	P	E	**P**	**P**	P			P		P				P
	Run-off mitigation	A	E	E	E	I	E	I	A		E	A		P	E
	Moderation of extreme events	I	A		P	E	P		P		I			P	
	Waste-water treatment	P			E	P			P		P	A			I
	Erosion prevention + mainten. of soil fertility	I	E		A	E	E	P	P						
	Pollination														
	Biological Control	P	E	**P**		P	P	P							
HABITAT/ SUPPORTING	Habitats for species	E	E	E	E	E	E	A	E		E	E	A	E	E
	Maintenance of genetic diversity					E									
CULTURAL	Recreation; mental + physical health	I	E	E	E	A	P	A	E	A	E	E	I		E
	Tourism	A			I	A			E		I	A			
	Aesthetic appreciation + inspiration	I	E	E	I	A	A		I		A	E	I		
	Spiritual experience + sense of place	E		A	E	E		A			A	E	I		A
	Education + learning		E	E	E	A	E	I			I	A	A	A	

Ecosystem Services		SALZBURG				
		SZG_1	SZG_2	SZG_3	SZG_4	SZG_5
PROVISIONING	Food supply	E	P		A	
	Raw materials supply	E	A		E	
	Water supply	E	E	A		
	Medicinal resources		E			
REGULATING	Local climate regulation	E	E	I	A	
	Air quality regulation	E	I	I	A	P
	Carbon sequestration + storage					
	Noise reduction	E	I	I	P	P
	Run-off mitigation	A	E	A		
	Moderation of extreme events	E	E	A		
	Waste-water treatment	A	P			P
	Erosion prevention + mainten. of soil fertility	A	E		A	I
	Pollination					
	Biological Control					
HABITAT/ SUPPORTING	Habitats for species	E	E	I	A	I
	Maintenance of genetic diversity					
CULTURAL	Recreation; mental + physical health	E	E	E	E	
	Tourism	E	A	A	I	
	Aesthetic appreciation + inspiration	A	E	A	E	
	Spiritual experience + sense of place	E	E	A	E	I
	Education + learning	A		A	E	

	not mentioned
P	problem mentioned but not linked to ES
A	acknowledged
I	indirectly elaborated
E	elaborated

Fig. A1. ES related content in the analyzed 33 planning documents of all five case study cities.

Table A1
List of all analyzed planning and policy documents.

BER_1: State Development Program for the Berlin-Brandenburg Region/Landesentwicklungsprogramm der Hauptstadtregion Berlin-Brandenburg/LePro. 2007. Available from: http://gl.berlin-brandenburg.de (accessed 3 November 2013) [in German]
BER_2: State Development Plan Berlin-Brandenburg/Landesentwicklungsplan Berlin-Brandenburg. 2009. Available from: http://gl.berlin-brandenburg.de (accessed 3 November 2013) [in German]
BER_3: Urban Landscape Strategy Berlin/Strategie Stadtlandschaft Berlin. 2012. Available from: www.stadtentwicklung.berlin.de (accessed 6 November 2013) [in German]
BER_4: Landscape and Species Protection Program/Landschaftsprogramm/Artenschutzprogramm. 1994/2004. Available from: www.stadtentwicklung.berlin.de (accessed 3 November 2013) [in German]
BER_5: Berlin's Biodiversity Strategy/Berliner Strategie zur Biologischen Vielfalt. 2012. Available from: www.stadtentwicklung.berlin.de (accessed 6 November 2013) [in German]
BER_6: Urban Development Plan Climate/Stadtentwicklungsplan Klima. 2011. Available from: www.stadtentwicklung.berlin.de (accessed 6 November 2013) [in German]
BER_7: Water supply plan for Berlin and surrounding/Wasserversorgungskonzept für Berlin und für das von den BWB versorgte Umland. 2008. Available from: www.stadtentwicklung.berlin.de (accessed 6 November 2013) [in German]

NYC_1: A Region at Risk: The Third Regional Plan For The New York-New Jersey-Connecticut Metropolitan Area. 1996. [printed version]
NYC_2: PlaNYC. A greener, greater New York. Update April 2011. Available from: www.nyc.gov (accessed 5 November 2013)
NYC_3: New York State Open Space Conservation. 2009. Available from: www.dec.ny.gov (accessed 12 March 2014)
NYC_4: Vision 2020: New York City Comprehensive Waterfront Plan. 2011. Available from: www.nyc.gov (accessed 5 November 2013)
NYC_5: New York City Wetlands Strategy. 2012. Available from: www.nyc.gov (accessed 5 November 2013)
NCY_6: NYC Green Infrastructure Plan. 2011. Available from: www.nyc.gov (accessed 5 November 2013)
NYC_7: Sustainable Stormwater Management Plan. 2008. Available from: www.nyc.gov (accessed 5 November 2013)

SEA_1: Vision 2040. 2008. Available from: www.psrc.org (accessed 12 March 2014)
SEA_2: City of Seattle Comprehensive Plan: Toward a Sustainable Seattle 2004–2024. 2005. Available from: www.seattle.gov/dpd (accessed 3 November 2013)
SEA_3: Parks and Recreation Strategic Action Plan. 2008. Available from: www.seattle.gov/parks/ (accessed 3 November 2013)
SEA_4: Open Space 2100: Envisioning Seattle's Green Future. 2006. Available from: www.open2100.org/ (accessed 3 November 2013)
SEA_5: Puget Sound Salmon Recovery Plan. 2007. Available from: www.psp.wa.gov (accessed 3 November 2013)
SEA_6: Storm Water Management Program. 2012. – Available from: www.seattle.gov/util/ (accessed 3 November 2013)
SEA_7: City of Seattle Food Action Plan 2012 – Available from: www.seattle.gov/environment/food (accessed 3 November 2013)

STO_1: Regional development plan for the Stockholm region/Regional utvecklingsplan för Stockholms-regionen/ RUFS. 2010. Available from: www.tmr.sll.se/rufs2010/; www.tmr.sll.se/english/RUFS-2010/ (accessed 12 March 2014) [in Swedish and English]
STO_2: Vision 2030: A guide to the future/Vision 2030: Framtidsguiden. 2007. Available from: www.stockholm.se/OmStockholm/Vision-2030/; http://international.stockholm.se/Future-Stockholm/ (accessed 12 March 2014) [in Swedish and English]
STO_3: The Walkable City – Stockholm City Plan/Promenadstaden: Översiktsplan för Stockholm. 2010. www.stockholm.se/oversiktsplan; http://international.stockholm.se/Future-Stockholm/Stockholm-City-Plan/; (accessed 12 March 2014) [in Swedish and English]
STO_4: Stockholm Park Program/Stockholms parkprogram. 2006. Available from: www.stockholm.se (accessed 12 March 2014) [in Swedish]
STO_5: Sociotope Map/Sociotopkarta för Parker och Andra Friytor I Stockholm Innerstad. 2002. Available from: www.stockholm.se (accessed 12 March 2014) [in Swedish]
STO_6: The Habitat Map/Stockholms Biotopkarta. 2009. Available from: www.stockholm.se (accessed 12 March 2014) [in Swedish]
STO_7: The Stockholm Environment Program 2012–2015. 2012. Available from: http://international.stockholm.se/ (accessed 12 March 2014)

SZG_1: Regional Program for the City of Salzburg and Surrounding Communities/Regionalprogramm Salzburg-Stadt und Umgebungsgemeinden.1999/2007. Available from: http://www.rvs.salzburg.at/regionalprogramm.htm (accessed 12 March 2014) [in German]
SZG_2: City of Salzburg's Spatial Development Plan/Das räumliche Entwicklungskonzept der Stadt Salzburg/REK. 2007. Available at: www.stadt-salzburg.at (accessed 12 March 2014) [in German]
SZG_3: Green Network of Salzburg/Gruenes Netz der Landeshauptstadt Salzburg. 2007. Available at: www.stadt-salzburg.at (accessed 12 March 2014) [in German]
SZG_4: Study on Salzburg's Urban Landscapes/Studie Salzburger Stadtlandschaften. 2009. Available at: www.stadt-salzburg.at (accessed 12 March 2014) [in German]
SZG_5: City of Salzburg's Leitbild/concept for traffic/Verkehrsleitbild der Stadt Salzburg. 1997. Available at: www.stadt-salzburg.at (accessed 12 March 2014) [in German]

Table A2
Coding protocol for the analysis in regard of the discursive representation of the ES concept with shortened example.

	Example: SEA_1 Vision 2040		***Doc_1*** **Findings**	**Quotes/ examples**
	Findings	**Quotes/Examples**		
1. Is the term 'ecosystems services' mentioned?	no			
Coding: yes=1; *no*=0	*0*			
2. Is the term 'landscape' or 'ecological function/s' mentioned?	Yes, ecosystem/ecological functions are mentioned several times	e.g., p. 35: Stewardship means managing those resources in a manner that is […] protective of key ecological functions.; p 36: Critical areas, such as wetlands, floodplains, aquifer recharge areas, wildlife conservation areas, and certain geologic areas perform key functions that enhance both the natural and built environments, and also protect us from floods and other hazards.		
Coding: yes=1; *no*=0	*1*			
3.Are 'benefits' humans derive from nature mentioned?	Benefits are often mentioned in relation to reducing impact (benefits FOR the environment); benefits through nature are more rarely addressed	p. 34: VISION 2040 stresses the importance of the natural environment in providing ecological and esthetic benefits, and protecting our water and air.		
Coding: yes=1; *no*=0	*1*			
4.In which way are humans and nature, ecosystems,	They are seen as strongly connected; the notion that human health and well-being as well as economic prosperity depend on natural resources and healthy/	the document has an "environmental framework" which explains the interrelation supported with illustrations of "natural ecosystem conditions", "humans impacts" and		

Table A2 (*continued*)

	Example: SEA_1 Vision 2040		*Doc_1* Findings	Quotes/ examples
	Findings	**Quotes/Examples**		
and/or landscape seen as interrelated?	functioning ecosystems is underlying the argumentation of the whole document. Reducing environmental impacts as human responsibility is the underlying argument of most goals and policies	"Ways to Improve Ecosystem Conditions"— p. vi: The phrase conveys that the people of the region, our economic prosperity, and our relationship to the planet are tied together in a mutually supportive and interdependent way. Social and environmental goals cannot be achieved without economic prosperity — and achieving prosperity is highly related to social well-being and environmental quality. […]		
Assessment				
Perspectives on human–nature relations	dependence perspective: humans and nature are interdependent — protection/impact perspective: reduction of pollution and avoidance of environmental degradation as well as protection and restoration are major objectives – benefit perspective: the regions prosperity depends on natural resources and healthy/functioning ecosystems			

Table A3
Coding protocol for the analysis in regard of ES related content with shortened example (ES description based on TEEB, 2011; Niemelä et al., 2010; Piwowarczyk et al., 2013; Gómez-Baggethun et al., 2013; assessment: N=Not mentioned; P=Problem mentioned but not linked to ES; A=Acknowledged; I=Indirect; E=Elaborated).

Ecosystem Service	Description	Example: SEA_22 Vision 2040				Doc_1			
		Findings	Quotes/Examples	Assessment	Review	Findings	Quotes/ Examples	Assessment	Review
Provisioning									
1. Food supply	*Agriculture, food, crops, grain/dairy/vegetables produced, vegetable/fruit garden, allotment, fish, fishery, game, mushrooms, berries, fruit, honey*	The importance of environment/ natural areas for food production is mentioned several times; fishing is also mentioned several times regional goal: rural lands/ resource lands shall be preserved to provide this services in the future; health related policy: agriculture and fishery shall be supported to enhance the regional food system	P. 6: The area's natural environment […] creates economic opportunities through traditional industries such as fishing […]; p. 10: There is a growing understanding of the role the environment plays in […] food production […] —— p. 15: Natural Resource Lands: agricultural lands that have long-term significance for the commercial production of food or other agricultural products (see also p. 27 – no urban growth in these areas) […]	E					
2. Raw materials supply	*Timber, energy (from biomass)*	"Resource lands" and "forest lands" as important for the provision of raw materials are mentioned several times; regional goal: "natural resource lands" shall be preserved (indirect link to the provisioning function mentioned earlier); renewable energy is mentioned, too	P. 6: The area's natural environment […] creates economic opportunities through traditional industries such as fishing, timber harvest […] —— p. 15: Natural Resource Lands: forest lands that have long-term significance for the commercial production of timber, and mineral lands that have long-term significance for the extraction of minerals. (see also p. 27 – no urban growth in these areas) […]	I					
3. Water supply	*Fresh water, drinking water, water supply, groundwater, water infiltration, water suspension, water storage*	Water quality/pollution is mentioned several times; it is stated, that ecosystems and clean water are interrelated; Service goals and policies to promote better management of water resources	p. viii: "improving water quality" as regional task mentioned; p. 10 There is a growing understanding of the role the environment plays in […] water quality […]" — p. 8: Water is and will remain a challenge for the region. What was once a seemingly abundant resource has become polluted, diverted, and, in some instances, a health risk. There have been changes to water quality, the quantity of water flowing through natural ecosystems, and even to water temperature. […]	I					
4. Medicinal resources	*Biotechnological and pharmaceutical use of plants* etc.	Not mentioned		N					
Regulating									
5. Local climate regulation	*Local climate regulation, microclimate regulation, mitigating heat island effect, evapotranspi-ration, cooling, shading, reflecting solar radiation, wind blocking*	Only in relation to climate change (rain, draughts, snow cover)		N					
6. Air quality regulation	*Air quality, air pollution purification, absorption of pollutants, cleaning the air*	Air pollution is mentioned as an environmental problem several times; reducing gas emissions and air pollutants as regional task mentioned; loss of vegetation/ sealing are mentioned as	p. 39: Air quality is primarily a public health concern, but it also affects plant and animal life, as well as visibility. […] today – and into the future – the region's most problematic pollutants are and will continue to be fine particles and toxic emissions, along with	A					

		problems –potentials of forests so filter air are mentioned; goals are only related to reduction of emission	ground-level ozone. Greenhouse gases are also major air pollutants. […]	
7. Carbon sequestra-tion and storage	*Gas cycles, carbon sequestration and storage, biomass/soils as carbon sinks*	"Addressing potential climate change impacts" as regional task mentioned (p. viii); goals and policies are mainly related to reduction of harmful elements, but one policy suggest tree planting to reduce carbon; importance of forest lands for carbon dioxide is mentioned——goal: protection of natural resource land (forests)	p. 39: CLIMATE CHANGE GOAL AND POLICIES: Goal: The region will reduce its overall production of harmful elements that contribute to climate change. —————Policy MPP-En-24: Take positive actions to reduce carbons, such as increasing the number of trees in urban portions of the region. […]	E
8. Noise reduction	*Noise reduction, noise cushioning*	Noise is mentioned as environmental problem that needs to be mitigated	p. 35: Environmental Stewardship: policy MPP-En-7: Mitigate noise caused by traffic, industries, and other sources, also p. 48	P
9. Run-off mitigation	*Stormwater regulation/ retention, rain water infiltration/ absorption, rain water drainage, balancing storm water peaks, reducing stormwater runoff*	Stormwater management is discussed as important issue. Green streets and vegetation in general are mentioned as one solution.	p. 60: Innovative techniques: Low-impact development relies on more environmentally sensitive approaches to how land is developed and used, especially in managing stormwater runoff. […] Reducing stormwater drainage infrastructure – pipes, ponds, and other structures – can actually lower infrastructure costs. […]	A
10. Moderation of extreme events	*Flood prevention, buffering from damage through storms/ floods/ waves*	Flooding is mentioned several times (also see fresh water); surface sealing/vegetation loss are mentioned as problematic; climate change as driver; forests and so called "critical areas" are mentioned as important areas for precipitation to limit flood——policies: protection of natural resource land (forests) (but not directly related to the ES) and of critical areas such as wetlands and floodplains	p. 8: Climate change will probably create severe pressure for the already stressed Puget Sound salmon population by affecting its physical environment, including the availability of food. The Clean Air Agency's research suggests that as the region's average temperatures continue to rise, warmer summer weather, accompanied by reduced runoff in spring, could increase drought, water shortages, and the risk of forest fires, affecting air pollution and human health. A hotter climate could also lead to more noxious pest infections and damage to the food chain […]	E
11. Waste-water treatment	*Waste water treatment, filtering waste water, sewage*	Impact on water quality; policies for reducing waste water/ improving sewers –but not related to ES	p. 80: Policy: MPP-PS-6: Obtain urban services from cities or appropriate regional service providers, and encourage special service districts, including sewer, water, and fire districts, to consolidate or dissolve as a result. […]	P
12. Erosion prevention and mainte-nance of soil fertility	*Erosion prevention, humus production, maintaining nutrient content*	Forests are mentioned as areas to control erosion——goal: protection of natural resource land (forests) (but not directly related to the ES)	p. 55: Forest Lands. Forests […] absorb precipitation, which limits flooding and controls erosion.	I
13. Pollination	*Pollination, bees, seed dispersal*	Not mentioned		N
14. Biological control	*Biological control, pest control, disease control*	Pest are mentioned as a problem (see ES 9); insect damage is also mentioned in relation to forests (p. 55)		P
Habitat or supporting				
15. Habitats for species	*Habitats, maintenance of habitats, maintenance of*	Habitat protection/development as regional task is mentioned	p. viii: conserving habitat; p. 6: The area's natural environment provides habitat; also p.	E

Table A3 (*continued*)

Ecosystem Service	Description	Example: SEA_22 Vision 2040				Doc_1			
		Findings	Quotes/Examples	Assessment	Review	Findings	Quotes/ Examples	Assessment	Review
	biodiversity, refugee for species	several times; Salmon as target species for habitat protection is mentioned several times—————————ecosystem/ habitat protection as a regional goal: wildlife corridors and preservation/restoration of native vegetation are mentioned; counties shall develop habitat assessments	34; p. 36 theme "Earth and Habitat": The central Puget Sound region hosts a wide diversity of native wildlife and habitats. The loss and degradation of terrestrial habitat threatens the region's biodiversity. Fragmentation of habitat, especially in forests, is also a major threat to biodiversity and species sustainability. […]						
16. Mainte-nance of genetic diversity	*Genetic diversity*	Not mentioned		N					
Cultural services									
17. Recreation and mental and physical health	*Outdoor recreation, mental and physical health, tranquilizing effects, sports, walking, gardening, fishing, hunting, sunbathing, boating*	The value of the landscape for recreation is mentioned several times; environmental health and human health are seen as related; ecosystem/environmental protection as a policy to ensure human health – but no specific suggestion related to health; parks are one policy goal	p. 5: The central Puget Sound region's surroundings create stunning backdrops for our cities and towns, contribute to our economic prosperity and quality of life, and lend themselves to many recreational activities, including hiking, fishing, boating, and wildlife watching. […]	I					
18. Tourism	*Tourism, sights*	The value of natural areas for tourism is mentioned	P. 6: The area's natural environment […] creates economic opportunities through traditional industries such as […] recreation, and tourism	A					
19. Esthetic apprecia-tion and inspiration	*Esthetic appreciation, inspiration for culture, art and design*	The beauty of the landscape and its value for the quality of life are mentioned several times; goal and policies for "Regional design" relates to this aspect	p. 1: The region's physical geography is one of its greatest assets. Its mountain ranges, waterways, lush forests, and greenery offer a stunningly beautiful natural environment; p. 10: There is a growing understanding of the role the environment plays in […] visual and esthetic features. […]	I					
20. Spiritual experience and sense of place	*Identity, spiritual experiences, sense of place*	The regions identity is mentioned as important; two policies of "Regional design" address sense of place (preservation of archeological sites, historic and cultural landscapes, and areas of special character)	p. 10: There is a growing understanding of the role the environment plays in […] sense of place" —— p. 75: Policy regional design: Puget Sound Regional Council 58 MPP-DP-33: Identify, protect and enhance those elements and characteristics that give the central Puget Sound region its identity, especially the natural visual resources and positive urban form elements. […]	E					
21. Education and learning	*Learning, education, environmental education, social learning, perception of nature, nature experience*	Not mentioned		N					
Comments									

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Paper III

Hansen, R., Olafsson, A.S., van der Jagt, A., Rall, E. and Pauleit, S. (In Press). Planning multifunctional green infrastructure for compact cities: What is the state of practice? *Ecological Indicators*: Available online 6 November 2017.
DOI 10.1016/j.ecolind.2017.09.042

Corrected Proof

ARTICLE IN PRESS

Ecological Indicators xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original Articles

Planning multifunctional green infrastructure for compact cities: What is the state of practice?

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ARTICLE INFO

Keywords:
Multifunctionality
Urban green space
Urban planning
Ecosystem services
Ecological functions
Densification

ABSTRACT

Urban green infrastructure planning aims to develop green space networks on limited space in compact cities. Multifunctionality is considered key to achieving this goal as it supports planning practice that considers the ability of green spaces to provide multiple benefits concurrently. However, multifunctionality is an elusive concept and little information is available on how it is perceived and actioned by planners. Therefore, this paper will examine the application of the multifunctionality concept in urban planning based on a semi-quantitative study, including interviews with chief planners and analyses of planning documents, in 20 European cities as well as three qualitative good practice case studies. The semi-quantitative study revealed a broad awareness of the variety of social and ecological functions provided by green spaces in planning. Yet, the analysed strategic plans contained little information on how to enhance multifunctionality. Regardless of the lack of details, cities facing growth were more likely to consider promoting multifunctionality as a planning aim. The qualitative case studies in Germany (Berlin), the United Kingdom (Edinburgh) and Denmark (Aarhus) provided a detailed insight into how multifunctionality is handled on different spatial scales and revealed great differences from academic multifunctionality approaches that were developed in the context of ecosystem service assessments. The approaches applied in practice include audits based on indicators for multiple green space functions or the purposive design and management of multifunctional parks. Based on the findings, we arrive at five recommendations for promoting multifunctional urban green infrastructure in densifying urban areas: 1) undertake systematic spatial assessments of all urban green (and blue) spaces and their social, ecological and economic functions; 2) include standards and guidelines for multifunctionality in city-wide strategic planning; 3) encourage design and management for multifunctionality at the site-level while considering that not all sites must deliver the same set of functions. Further, spatial assessment, strategic planning and site design need to 4) consider synergies, trade-offs and the capacity of urban green spaces to provide functions as part of the wider green infrastructure network; and 5) largely benefit from cooperation between different sectors and public departments. These recommendations can also be instructive for research on ecosystem service assessments in order to develop approaches that more strongly correspond to the demands of planning practice.

1. Introduction

Due to the current pressure of global urbanization, quality of life and sustainability of cities have gained political momentum (UN, 2015a; McDonnell and MacGregor-Fors, 2016). The UN's New Urban Agenda (2017) calls for sustainable but also compact urban development. The compact city ideal is aimed at increasing sustainability and avoiding urban sprawl by promoting high-density housing, mixed-use, efficient public transport systems and walking or cycling (Burton, 2000). Green spaces and other public spaces are also considered fundamental to achieving quality of life and sustainability in compact cities (Smart Growth Network, 2003; Ramaswami et al., 2016). In line with the understanding of green spaces as important urban infrastructure, goal 11 of the UN's 17 Sustainable Development Goals is to "make cities inclusive, safe, resilient and sustainable" which includes providing access to green and public spaces for all strata of society (UN, 2015b).

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http://dx.doi.org/10.1016/j.ecolind.2017.09.042
Received 30 November 2016; Received in revised form 12 August 2017; Accepted 25 September 2017

Please cite this article as: Hansen, R., Ecological Indicators (2017), http://dx.doi.org/10.1016/j.ecolind.2017.09.042

However, synergies between urban compaction and the availability of green space cannot be taken for granted. Urban compaction usually includes increased land use intensities and densities, conversion of existing development and re-use of brownfields (Burton, 2000). These processes can put pressure on green and open spaces, either by increased use intensity or even loss through conversion (Jim, 2004; Dallimer et al., 2015). To compensate for declining quantity, increasing the quality and multifunctionality of green spaces are seen as important strategies (Beer et al., 2003; Haaland and Konijnendijk, 2015).

The basic meaning of multifunctionality is that green infrastructure — or more generally, green space — provides a variety of functions, for example ecological, social and economic ones (Pauleit et al., 2011). Multifunctionality is also described as the capacity of green infrastructure to provide multiple ecosystem services (e.g., Mazza et al., 2011; Liquete et al., 2015). Equating multifunctionality with multiple ecosystem services can create confusion as the term 'function' has different meanings in both concepts (Hansen and Pauleit, 2014). Multi'-functionality' in the context of green infrastructure stands for a broad understanding of functions (including, for example, buffering of climatic extremes, biomass production, provision of habitats and species movement routes or opportunities for social interaction and nature experience; Ahern 2007), while 'functions' in the ecosystem services concept are understood as an intermediary step describing capabilities or functions provided by biophysical structures and processes, which become ecosystem services if there is a demand from human beneficiaries (Fisher et al., 2009). For instance, the function 'slow passage of water' will only constitute an ecosystem service if it provides flood protection for humans (Haines-Young and Potschin, 2010). Nevertheless, planners often regard ecosystem services and green space functions as interchangeable concepts and planning documents likewise reveal a broad understanding of 'functionality' to including functions, services or, more generally, benefits provided by green infrastructure without strict separation (Hansen et al., 2015; Rall et al., 2015). In the following, we take into account this ambiguity of the multifunctionality concept, using "function" in a broad sense and the term "ecosystem services" only when explicitly meant.

In the context of green infrastructure and ecosystem services, multifunctionality is generally considered in three different ways: (1) for spatial assessments of green space functions on various scales; as a principle for (2) strategic planning of urban green spaces (on the city or neighbourhood-level) and (3) the design and management of green spaces (on the site level).

(1) Spatial assessments of green space functions: in the context of ecosystem services in particular, multifunctionality is often understood in a basic sense as the provision of different functions or ecosystem services (Madureira and Andresen, 2013). However, Pulighe et al. (2016) revealed that only a fraction of about 80 papers on mapping urban ecosystem services dealt with multiple services within one study. The spatial analysis of interrelations between urban ecosystem services (e.g., synergies and trade-offs) appears to be in its infancy (Hansen and Pauleit, 2014; Sussams et al., 2015). A complicating factor is that interrelations between different ecosystem services have been shown to be complex and often non-linear (Rodríguez et al., 2006; Bennett et al., 2009; Raudsepp-Hearne et al., 2010).
(2) Planning principle: In the context of land use planning, multifunctionality has been considered as a principle for transforming land use practices towards more sustainable ones (Brandt and Vejre 2004; Galler et al., 2015). This can be achieved by developing land use regimes that simultaneously promote, for instance, nature conservation, recreational use and agriculture or forestry. To avoid unintended effects and to promote beneficial solutions, green infrastructure planning must aim at optimal outcomes for all of the parties involved or affected (von Haaren and Reich, 2006). In the context of urban green infrastructure, multifunctionality means that multiple ecological, social and economic functions too are strategically considered. As a planning principle, it guides policies, plans and measures towards not only promoting those multiple functions but also increasing synergies and avoiding conflicts between them (Madureira and Andresen, 2013; Demuzere et al., 2014; Hansen and Pauleit, 2014). Combining different functions in order to use limited space more effectively is particularly important in urban areas, where green space is scarce, and even more so in compact cities (Ahern, 2011; Haaland and Konijnendijk, 2015).
(3) Design and management principle: multifunctionality on the site level follows the planning principle definition, but is considered more along the lines of a spatial arrangement at a specific site. Multifunctionality on the site level is discussed as a careful balancing of different functionalities and uses, including the spatial segregation of some of these (von Haaren and Reich, 2006). Multifunctional landscapes can be developed and managed aiming at (a) 'tessellated multifunctionality', with a spatial segregation of functions within one area, (b) 'partial multifunctionality', by combining functions at the same location, with one or two dominant ones, or (c) 'total multifunctionality', with an equal balance of different functions at the same location (Rode, 2016). Other authors have suggested similar strategies, such as 'interweaving' or 'intertwining' functions at the same site, or adding a temporal dimension by promoting different functions at different moments in time (Ahern, 2011; Westerink et al., 2013).

While the capacity of urban green spaces to provide multiple benefits is widely acknowledged, the focus of research on green spaces in compact cities is more generally on green space preservation and allocation as well as corresponding strategies (Haaland and Konijnendijk, 2015). Altogether, the multifunctionality of urban green infrastructure remains an elusive and poorly conceived concept (Sussams et al., 2015). Moreover, little is known about the degree to which cities are actually dealing with the challenges of urban densification in terms of providing multifunctional green spaces (Hansen and Pauleit, 2014). Indeed, we only know of a few case study-based papers (Beer et al., 2003; von Haaren and Reich, 2006; Pauleit et al., 2011) and practitioner-oriented publications (Ahern, 2007; Rouse and Bunster-Ossa, 2013) that touch upon the practical application of the multifunctionality concept. Hence, approaches for planning, site design and management or spatial analyses developed by scientists may not necessarily have been translated in the way planners regard multifunctionality.

The gaps in research, both in terms of how cities currently promote multifunctionality in increasingly compact cities and of how multifunctionality may be optimally considered for planning on the local scale, call for an examination of current practice. By combining semi-quantitative and qualitative methods, this paper will:

(1) Establish the general consideration of multifunctionality in planning, based on awareness among planners and representation in planning documents,
(2) Explore the real-world application of multifunctionality in the context of spatial assessments, strategic planning as well as site design and management, and
(3) Make recommendations for considering multifunctionality in compact cities.

2. Material and methods

We surveyed 20 European cities to identify the awareness and representation of multifunctionality in current urban green space planning (research objective 1), whereas case studies from three of these cities are used for a more detailed investigation of how approaches for promoting multifunctionality are applied in practice (research objective 2). Combining our findings with the literature, we then developed recommendations (research objective 3, see Fig. 1). The data was

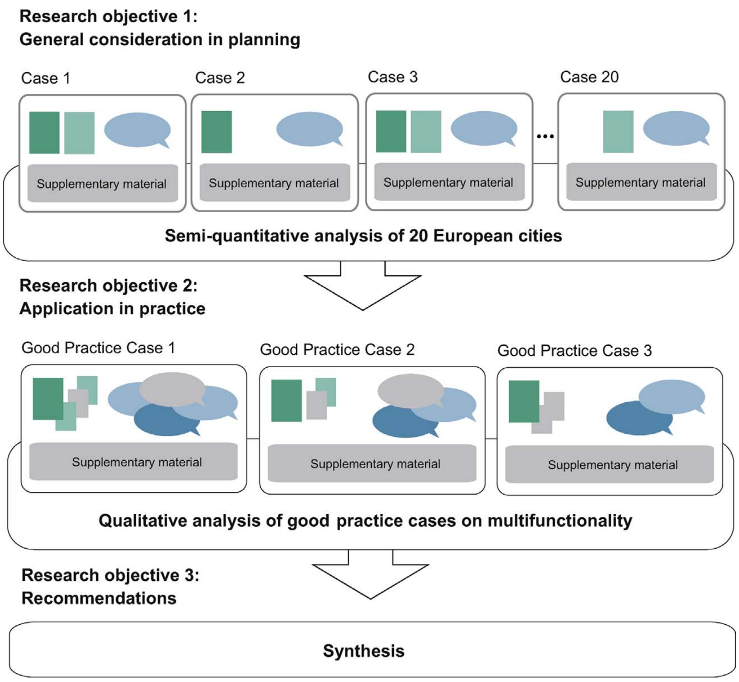

Fig. 1. According to the research objectives, the research design involves three stages. The first two stages differ not only in case numbers but also in study depth. The icons represent the analysed material: the coloured rectangles planning documents and the speech bubbles interviews. The variations among cases within one stage indicate variances in data availability.

collected within the EU-funded GREEN SURGE research project.

2.1. *Semi-quantitative analysis of green space planning in 20 European cities*

To address the first research objective, we used data from a 20-city survey across 14 countries in Europe, including formally adopted planning documents and working knowledge of planning professionals. To achieve some degree of representativeness, the selected cities were of different sizes with varying economic and demographic situations, and included five shrinking and 15 growing cities (reference frame 2001–2014; s. Fig. 2).

A document analysis of up to two important plans or policies related to urban green space was performed for each city. A total of 32 documents from 19 cities were analysed as not all cities had two up-to-date plans and plans in the development or revision stage during our research period could not be considered (see Appendix 1 in Supplementary material).

The document analysis included two questions related to multifunctionality:

1) Does the plan consider multifunctionality or the delivery of multiple benefits/ecosystem services of urban green space?

2) Does the plan consider *enhancing* the multifunctionality or the delivery of multiple benefits/ecosystem services of urban green space?

The researchers read the documents carefully, looking for not only explicit but also implicit references to the two questions (such as references to a broad range of green space functions for question 1; for a positive answer for question 2 it needed to be evident that there is an intention to increase multifunctionality). If the answer to one or both of these questions was positive, the local researchers provided a brief explanation using citations from the original document.

A structured expert interview with the chief planner of the city planning or green space department in each city was held to gain additional insights into local planning approaches not necessarily evident from the analysis of plans, such as implicit processes (Healey, 1992). The interviews included the question, “Green space planning in my city/urban region considers multiple functions or benefits of urban green spaces (e.g. for human health, biodiversity, cooling)”, which the interviewees ranked between 1 (strongly disagree) to 5 (strongly agree).

Because supplementary data helps us better understand the local planning and governance context and aids in data triangulation (Yin, 2010), researchers also carried out desk studies of written material from newspapers, official websites and other relevant material.

The data was collected between May and October 2014 and entered into a profile matrix, where results for each case were coded across each topic. The semi-quantitative data was triangulated using categorical aggregation (Creswell, 2007). Additionally, data collected through the different methods was synthesized in the form of case study portraits for each case, which allowed a more comprehensive view on each city’s unique context and formed the basis for the later qualitative analysis of good practices described in the next section (see http://greensurge.eu/products/case-studies/). A more detailed description of the methodology used as well as the full questionnaire and document analysis guidelines can be found in Davies et al. (2015).

Furthermore, the results from the document analysis for each city were linked to population development within the cities to explore the findings in the context of urban development trajectories. While the relation between population dynamics and land consumption is complex, population growth can be considered as a driver for pursuing the compact city model (cf. Haase et al., 2013; Dieleman and Wegener, 2004). Population development between 2001 and 2014 was examined based on Eurostat’s Urban Audit. The period was selected due to data availability for most cities, though population figures for alternative years still had to be used for five cities (see Appendix 1 in Supplementary material). The calculation of the annual growth rate was adapted accordingly for these cases.

2.2. *Qualitative analysis of three good practice cases*

To answer our second research objective, the 20 cities were ranked in terms of innovation regarding multifunctionality. In a structured evaluation by researchers involved in the semi-quantitative survey, a

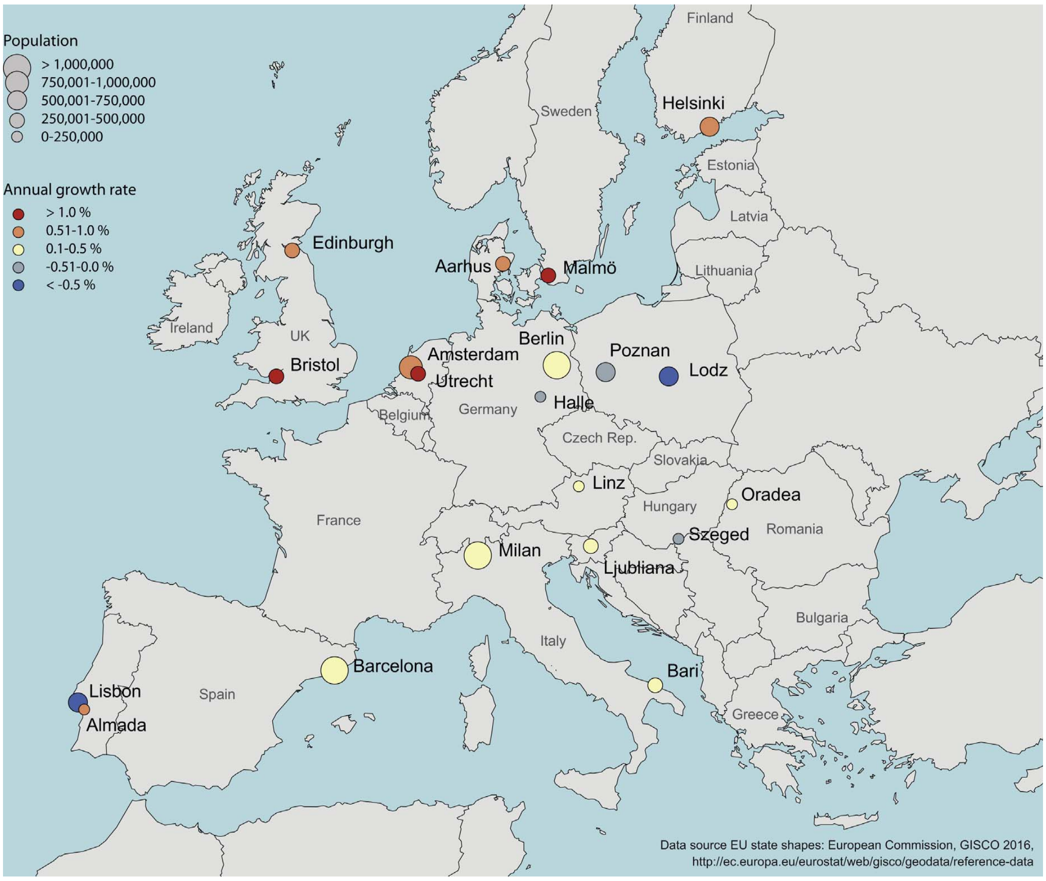

Fig. 2. Map with the 20 case study cities. The size of each bubble corresponds to the population size (for 2014 and 2013 or 2012 if unavailable for 2014), the colour represents the strength of the annual population growth rate (calculation for 2001–2014/2013/2012; based on Urban Audit available at http://ec.europa.eu/eurostat/web/cities/data/database).

shortlist was prepared and discussed in a workshop. Edinburgh and Aarhus were selected as good practice approaches for multi-functionality; the case from Berlin was added in a second step when it became obvious that the new Landscape Programme strongly refers to multifunctionality.

The methodology for the case studies included semi-structured interviews with local stakeholders and reviews of planning documents, supplemented by additional sources (see Appendix 2 in Supplementary material). The semi-structured interviews, conducted with two to four local stakeholders concerned with each case, were guided by a list of questions adapted slightly for each interviewee, and explored how they perceived the approach in question, including its development and implementation, contextual factors, effects, and barriers. The interviews were supplemented by a content analysis of at least one core planning document per case, which was either the subject of the case study itself or closely related to this. Supplementary material such as websites and scientific or grey literature was used for added context.

The data was collected between February and October 2015, with additions in the period from April to July 2016 to accommodate plan updates. Similar to the analysis approach for the 20 city-survey, the results for each case were summarized in two formats: 1) case tables listing data from all sources across research questions, and 2) a narrative providing a concise summary of the information collated in each case. The cross-case analysis was qualitative in nature, using a content analysis approach aimed at complementary rather than comparable information (Yin 2010). Further details of the methodology including research questions can be found in Hansen et al. (2016). For this paper, the focus was on content related to multifunctionality in the context of spatial assessments, strategic planning and site design and management.

2.3. The good practice case study cites

The three good practice cases, differing in terms of plan or strategy type, spatial scale and application of multifunctionality, include Edinburgh's Open Space Strategy (UK), Berlin's Landscape Programme (Germany) and a green space restoration project in Aarhus (Denmark). Berlin is one of the largest cities in Europe, while Edinburgh and Aarhus are medium-sized. While none of them can be considered as particularly dense compared to the average population densities of cities such as Paris or Barcelona, each of them has some very dense neighbourhoods and is facing the need to host a growing population (see Table 1).

2.3.1. Edinburgh

Edinburgh is a major UK city well-known for its history, heritage and architecture. The city also has a number of prominent open hills and wooded waterways within the city boundaries and the highest number of Green Flag (a national standard for high-quality green spaces) parks in Scotland, all of which contribute towards a unique and much appraised townscape. However, Edinburgh also hosts some of the densest neighbourhoods in the UK (CEC, 2013), and has the 7th highest net international and within-UK migration rate of all UK cities between 2001 and 2011 (Champion, 2014). As a result of this and the expected continued population growth, the City of Edinburgh Council (CEC)

Table 1
Aarhus, Berlin and Edinburgh by numbers and basic description of the selected good practice cases.

	Edinburgh (UK)	Berlin (Germany)	Aarhus (Denmark) (6)
Municipal area	264 km^2 (1)	891.7 km^2 (3)	468 km^2 (7) Urban area: 93.7 km^2 (7)
Municipal Population	497,282 (2015) (1)	3,520,031 (2015) (4)	330,639 (2016) (8) Urban population: 264,716 (2016) (8)
Density	1894/km^2 (1)	3947/km^2	702/km^2 Urban density: 2825/km^2
Need for additional residential units	36,000 by 2025, or 3600 per year (2)	Approx. 137,000 by 2025 or 10,000 per year (5)	Approx. 37,000 by 2039 or 2650 per year (9)
Good practice cases			
Core plan/project	Open Space Strategy	Landscape programme	Green space restoration project
Spatial scale	City, Neighbourhood, and Site	City, Site	District, Site
Application of mulifunctionality	Mainly for spatial assessment	Mainly as a strategic planning principle	Mainly as a principle for site design and management

(1) CEC, 2016; (2) CEC, 2011.
(3) Amt für Statistik Berlin-Brandenburg, 2015a; (4) Amt für Statistik Berlin-Brandenburg, 2015b; (5) SenStadtUM, 2015a.
(6) The numbers for Aarhus are listed for both the city administrative area (the municipality) and the urban area because of significant size differences; (7) Own calculation based on available GIS-data from the Danish Geodata Agency; (8) Statistics Denmark, 2016; (9) Aarhus City, 2016.

plans to build houses in four 'Strategic Development Zones' by 2024, including two zones (City Centre and Waterfront) that predominantly involve the regeneration and redevelopment of vacant and derelict land (CEC, 2014).

The main objectives of urban green space planning in Edinburgh are to improve the standard of existing green space (i.e. quality and accessibility), minimize the loss of green space to urban development and provide adequate open space provisions in new developments. Under Scottish Planning Policy (Planning Advice Note 65), each local authority has a duty to audit their open space (including green spaces, water features and public spaces such as squares or market places) by assessing whether it meets the needs of the community, and to prepare an Open Space Strategy (OSS) to outline a vision and objectives for protecting and enhancing this resource (Scottish Government, 2008). The Edinburgh OSS was prepared in 2010 and is currently subject to a review and update.

The OSS comprises three core components: the audit, the standards, and action plans (CEC, 2009, 2010). The *audit* took place in 2008-9, classifying all significant open spaces of 500 square meters and more and providing basic information about the quantity and quality of different open space categories. The *standards* were introduced to provide all citizens with adequate access to a high-quality local green space, large green space and play space. Along with the OSS, 12 neighbourhood action plans were introduced to stipulate the approach towards improving individual green spaces in line with the standards.

2.3.2. Berlin

Berlin is the second largest city in the European Union. With nearly 44% of the municipal area classified as green and blue spaces it is also seen as a very green city (SenStadtUM, 2015b:43). However, there is great pressure on open spaces in Berlin as a result of recent urban development. The projected population increase is around 7.5% by 2030 (to 3.8 million inhabitants, not yet including an influx from asylum seekers; SenStadtUM, 2016a:23). Although the compact city is the central guideline for urban development (SenStadtUM, 2015a,b), there is also an awareness of the need to secure and improve quality-of-life in dense areas. The compact city vision thus includes plans to provide an adequate share of green and open space (SenStadtUM, 2015b).

The Berlin Landscape Programme (LaPro) is an important strategic instrument to ensure that ecological concerns are incorporated into urban development and has been used as the basis for developing the city's green spaces since the 1980s. The LaPro applies to the whole city area and is closely connected to the city's land use plan; both plans are updated in concert and complement each other. It is legally binding for public administration in land use and landscape planning on a district and local level. The current 2016 version of the LaPro has a strongly integrative approach, seeking to create close links with land use planning (SenStadtUM, 2016b).

The LaPro contains four thematic plans, together delivering a multifunctional, city-wide green system: 1) the 'Natural environment' plan; 2) a 'Habitat and species protection' plan to protect urban biodiversity, including a habitat network 3) the 'Scenery' plan; and 4) the 'Recreation and use of green spaces' plan. In addition, a fifth plan, the 'General Urban Mitigation Plan' (Gesamtstädtische Ausgleichskonzeption – GAK), defines Berlin's city-wide green space system (consisting of two 'rings' and two 'axes' including four large landscape areas at the urban fringe) and the densely built-up city centre as a priority area for implementing integrated actions from the other plans. The GAK measures are systematically implemented with funding from the legally binding impact mitigation and compensation regulation under the Federal Nature Conservation Law (SenStadtUM, 2016b).

2.3.3. Aarhus

Aarhus is the second largest city in Denmark and is known as 'the capital' of the Jutland peninsula. It has a current growth of app. 4000 inhabitants per year (Aarhus City, 2016). The current Plan Strategy envisions a compact city with a population of 450,000 by 2050, to be realized without urban sprawl (Plan Strategy, 2015:5). Instead, urban densification and urban renewal are described as the key approaches. The future compact city should ensure a high quality of life and support carbon-friendly mobility linked to the city's goal of becoming CO_2 neutral by 2030 (Plan Strategy, 2015). In the following, a local case of urban renewal and green space restoration in Gellerup/Aarhus will serve as an example of how this strategy is implemented.

In 2007, the municipality of Aarhus decided to develop a new masterplan to transform Denmark's largest social housing area for approximately 7000 people, Gellerup-Toveshøj (established in 1968-72), into an attractive urban area (Aarhus Municipality, 2011). The masterplan was to radically transform the Gellerup area from a deprived urban area with high unemployment into a new, coherent urban district with low crime rates, improved perceived safety, new residences, institutions and workplaces, and more attractive green spaces. The plan involved the demolition of six apartment blocks (out of 30, i.e. a total of 2400 apartments), construction of a new road structure and, finally, the restoration of the central green space into a new city park.

The park restoration activities were an important part of the project, and the overall approach of increasing urban multifunctionality was directly linked to restoring green space functions and adopting a place-making approach. The development of the green space restoration project was informed by four workshops involving architects and

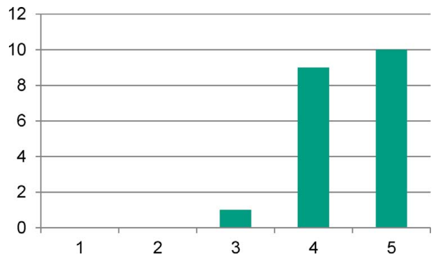

Fig. 3. Chief planners from 20 European cities rated whether green space planning in their city considers multiple functions or benefits of urban green spaces. Rank 1 = strongly disagree, Rank 5 = strongly agree (n = 20).

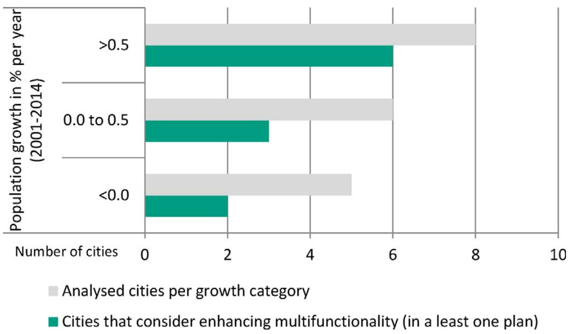

Fig. 4. The consideration of multifunctionality in planning documents from 19 European cities (excluding Oradea due to a lack of analysed planning documents), according to population development trends (calculated based on Urban Audit). Depending upon availability, up to two documents were analysed for each city; one count was made per city if at least one document referred to enhancing multifunctionality.

residents discussing proposals and making suggestions. The approach was informed by an extensive participatory processes that helped to understand the needs and demands of different social groups and influenced the redesign of the park (e.g., using an 'open stand', guided tours, and 30 interviews with different users; Gellerup Masterplan, 2013a,b,c).

3. Results

3.1. Multifunctionality as planning concept in 20 European cities

Our semi-quantitative analysis revealed a strong, widespread recognition of the ability of urban green space to provide a variety of social and environmental functions. This was apparent from the interviews with planners, where almost all respondents agreed or strongly agreed with the statement that their green space planning takes into account multiple functions of green spaces (see Fig. 3). Moreover, the document analysis showed that all but one of the 32 comprehensive/land use plans and green space plans recognize the multifunctionality of green space (see Appendix 1 in Supplementary material).

The stated range of functions delivered by green space indicated in the plans were mostly of a social and ecological (i.e. biotic and abiotic functions) nature. Almost every plan mentioned recreation, habitat provision and biodiversity protection, while aesthetics, stormwater regulation, flood protection, microclimate regulation, improved water quality and air circulation were frequently noted as well. Other regulative functions such as carbon sequestration, erosion prevention or pest control were rarely mentioned. Similarly, economic functions such as increased investment and tourism spurred by attractive green spaces were only noted in a few plans. Some plans also mentioned the role of green spaces as green corridors to provide mobility (i.e. walking, cycling) or as a physical buffer against the infringement of urban development into the countryside, functions that are related to the overall urban structure but are potentially relevant for the social or economic dimension too.

Although almost all the plans acknowledged green space multifunctionality, only 14 out of 32 planning documents (11 of 19 cities) referred to "enhancing multifunctionality" as a planning objective (see Appendix 1 in Supplementary material). Even some planning documents that addressed multifunctionality frequently explicitly lacked content linked to enhancing multifunctionality. Instead, many plans focused on the protection of ecologically significant green spaces in order to preserve different functions, or on improving a small range of specific functions such as stormwater regulation.

However, most of the plans focussing on enhancing multifunctionality were found in cities with an annual growth rate above 0.5% (see Fig. 4). In general, population growth in a European context is often related to increasing density, so that this result seems to indicate a relation between a planning focus on green space multifunctionality as a part of the compact city agenda.

3.2. Multifunctionality in three good practice cases

3.2.1. Multifunctionality assessments

All three good practice cases applied different approaches to assess multifunctionality, including a site visit checklist approach, sustainability diagrams for plan measures and the integration of multiple social and ecological spatial data sets, as well as the definition of priority criteria for green infrastructure investments for the whole city.

Edinburgh employed a systematic, site-based quality assessment of green spaces according to a set of criteria. Experts completed a checklist during a site visit for each green space. Audit criteria, derived from an extensive consultation of citizens and stakeholders, cover quality from a human user (access and appearance) as well as biodiversity (diversity of habitats and connectivity) perspective, all graded individually (see Table 2). Furthermore, the appropriateness of different green space uses (e.g. ball games, cycling and picnicking) given the context (i.e. size, location, adjacent use) was assessed. The results are shown in a map that indicates which spaces are above or below the standard (see Fig. 5).

In Aarhus, the multifunctionality of the new design was evaluated

Table 2
Edinburgh's Open Space Audit includes an evaluation of each green space (≥0.5 ha) based on criteria such as accessibility, appearance and biodiversity (based on audit guidance received through correspondence with the Council).

Category	Criteria (examples)	Assessment
Uses	Visual amenity, opportunities for physical activity, wildlife observation opportunities, etc.	Expert survey (ticking boxes for appropriate opportunities for different uses given green space context)
Access	Quality of the approach, access points, access for a variety of user groups (equal access), and connectivity (through routes)	Expert survey rating each item on a scale from *1 (poor)* to *5 (excellent)*
Appearance (quality and character)	Setting (i.e. contribution to character of local environment), design (i.e. appropriate and well-oriented layout), neglect/misuse, etc.	As above
Biodiversity	Number of habitat types that are of nature conservation interest), and connectivity (via natural corridors)	As above, including an overview of habitat types and a chart for scoring number of habitat types

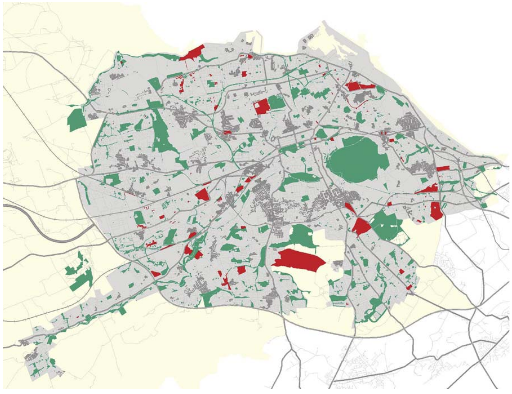

Fig. 5. The Open Space Strategy Map shows areas of green spaces that meet the local green space standard (green), deficiencies (red), and residential areas that do not meet the standard (dark grey) (Credit: CEC, 2010).

qualitatively during the planning process (SLA Architects, 2014). The green space restoration plan provided a framework for judging multifunctionality based on three dimensions: (1) social and health issues, (2) economic sustainability, and (3) ecological, climate and environmental sustainability. Each of the three sustainability dimensions consisted of a number of categories and criteria (a total of 55 criteria in 6 categories, see Table 3 and Appendix 3 in Supplementary material). While this assessment did not include spatial mapping indicators, multifunctionality criteria served as a core evaluative feature for the considered plan components, including, for instance, choice of planting, terrain layout or recreational activity opportunities.

Berlin's LaPro integrated results and policies from several environmental analyses and planning documents for all of the city area such as the city's 'Environmental Atlas', biodiversity conservation plans and maps with protected areas (SenStadtUM, 2016a:7). Although the data sets were supplemented with criteria for identifying priority action areas (see Table 4), specific multifunctionality indicators and assessments are lacking.

3.2.2. *Multifunctionality as a planning principle*

Multifunctionality as a planning principle is most visible in the case of Berlin. In Edinburgh, the OSS promotes a multifunctional perspective but is strongly focussed on social functions. Other plans such as the Local Development Plan were more relevant with regard to other functions such as flood management, air and water quality or biodiversity conservation. Ultimately, the delivery of multifunctional green spaces was informed by a combination of policies. In Aarhus, multifunctionality was a guideline for the whole urban renewal project. But the primary focus of the park project was on social values and the needs of local residents. The importance of the professional planners, who argued for and ensured the inclusion of economic and ecological aspects as advocates for multifunctionality, became clear in the stakeholder interviews.

In Berlin, target values for urban green space per inhabitant cannot be met in the densely built city centre. Thus, the LaPro called for an increased accessibility and connectivity of the urban green structure (SenStadtUM, 2016b). Multifunctionality and the high quality of urban green spaces were considered important to ensure that the different needs of the population are met and to cope with the high intensity of recreational uses. Multifunctionality was also expected to play a role in creating synergies between the four LaPro themes. This means that while actions have been formulated for each theme, all actions are supposed to deliver multiple benefits in concert with the help of the GAK (see Fig. 6).

Table 3
Excerpts from the assessment of multifunctionality in the design plan of the new park in Gellerup. The pie charts illustrate the main elements in relation to social, ecological and/or economical functions (translation based on SLA Architects 2014:43).

Category	Criteria (not complete)	Assessment results
Planting	Improved sense of safety by thinning and pruning of existing trees	
	Growing one's own fruit and vegetables creates attachment and involvement	
	High plant diversity creates the basis for rich wildlife (biodiversity)	
	The trees absorb water and CO_2 as well as increasing evaporation, providing shade and creating comfortable climate	
Terrain	More accessible and safe thoroughfares promote cycling and walking	
	Lowlands act as sink for rainwater drainage (Water Sensitive Urban Design)	
Water	Delay pools become recreational features of the landscape	
	By delaying the rainwater, expansion of the sewerage system is avoided	
Recreational network	Improved connectivity of paths and wayfinding for everyday activities, which also minimizes wear on green surfaces	
	Compatibility of use levels with surface robustness by constructing the busiest trails in concrete, and the secondary trails in gravel	
Illumination and Wayfinding	New landmarks send a positive signal of an area in transition	
	Using bright coatings reduce the use of energy to illuminate surfaces by 40%	
Recreational activities	Areas which are designed to make people feel comfortable regardless, of age, gender and culture	
	Better physical conditions increase membership in clubs and associations	
	Areas with allotment gardens will have high biodiversity	

Legend Red = ecological Blue = social Green = economic.

3.2.3. *Multifunctionality as a principle for site design and management*

Due to its spatial scale, Aarhus is the most relevant case regarding multifunctionality for site design and management. The green space restoration plan (SLA Architects, 2014), related documents (Gellerup Masterplan, 2013a,b,c) as well as interviews with stakeholders highlight how multifunctional solutions have been developed. With respect to social functions, the user consultation resulted in a design that would improve the sense of safety by creating enhanced terrain visibility, including a new trail network to ensure easy and intuitive orientation. Ecological and biodiversity considerations were included by connecting the park as a missing link between a green wedge to the north and a blue wedge to the south (Brabrand Lake and River valley). The southern side of the park closest to the lake will be converted into lowland with small ponds and meadows with high-growing grasses to promote biodiversity and create a wild, natural appearance. Moreover, the lowland is expected to contribute to climate change adaptation by improving rainwater drainage (see Fig. 7). Other components which are planned according to the principles of multifunctionality include a football pitch, a cherry grove and a parking lot that serve as areas for water retention during heavy rainstorms (Water Sensitive Urban Design). Furthermore, a diversity of new planting enclaves will be introduced in the area, including edible trees and bushes to promote biodiversity but also social functions.

Table 4
Search areas and criteria for selecting priority sites to implement Berlin's 'General Urban Mitigation Plan' (based on SenStadtUM, 2016b).

Category	Sub-category: Search areas	Criteria (for selecting priority sites)	Assessment
Natural environment	Wetlands	Wetlands that are important for soil, water balance and climate	Habitat mapping
	Forests for restructuring	Forest areas with potential for conversion to mixed forests	Assessment of potentials by the city's forest administration 'Berliner Forsten' (2010, not accessible)
	Housing areas with focus on climate change adaptation	Housing areas with high need to reduce climatic stress	Assessment from the Urban Development Plan for Climate (SenStadtUM, 2011)
Habitat and species protection	Protected landscape areas	All existing and suitable landscape protection areas	Mapping of designated and planned areas
	Habitat network	Areas with conservation status that are suitable core areas or corridors	Target species concept with 34 species, based on actual and potential core areas and corridors
Scenery	Scenery areas	Areas with needs for improving scenery	Update of qualitative landscape assessment
Recreation and use of green spaces	Close-to-home recreational space	Housing areas with low quantity of accessible public green space	Open space supply analysis
	Open space system	Gaps in the network of 20 main greenways	Mapping of gaps

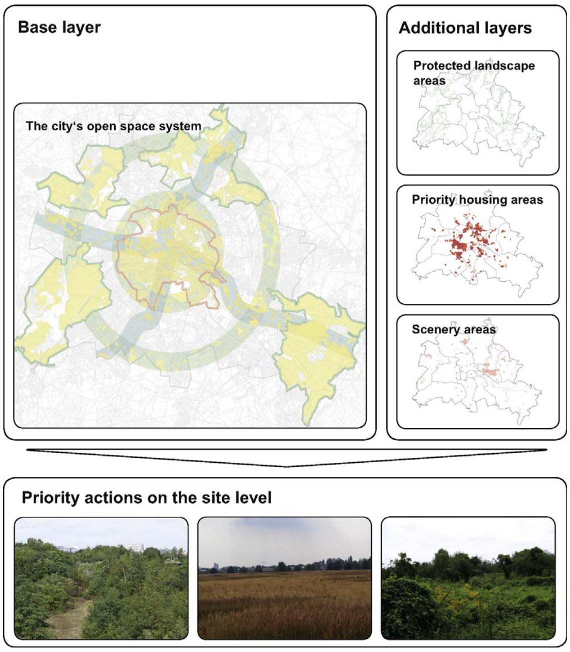

Fig. 6. Berlin's 'General Urban Mitigation Plan' guides compensation to complement the city's open space system and promotes priority actions. The open space system and search areas from different thematic plans (i.e. on housing areas with low access to green spaces) are superimposed to select priority actions on the site level. The images for the site level are only exemplary for different kinds of green spaces in Berlin (Maps: SenStadtUm 2016; images: R. Hansen).

Fig. 7. Illustration of the new lowland in Gellerup with a rainwater pond and wild grasses to promote multiple functions such as minimising flood risks, creating space for ecological values and new social functions (SLA Architects 2014:13).

Fig. 8. The 'Park auf dem Nordbahnhof' in Berlin is characterized by spontaneous vegetation with extensive use and maintenance with interspersed 'isles' for intense recreational use (R. Hansen).

In Berlin, the GAK fostered the development of several multifunctional green spaces (SenStadt, 2004). One example from the previous version of the GAK is the 'Park auf dem Nordbahnhof', which was developed to provide recreational amenities while also acting as a green corridor and playing an important role in promoting biodiversity through the provision of lush spontaneous vegetation (see Fig. 8). The site is also important for its cultural heritage; it includes remnants of its former use as a railway terminal and the Berlin Wall once stood on some of the current parkland. In Edinburgh, the OSS audit provides more general insights into green spaces that fail to meet the city's quality standards. The neighbourhood action plans provide a place-specific approach to improving the standard of such green spaces.

4. Discussion

In the following, we reflect on our findings in the light of the academic debate on multifunctionality, especially in the context of compact cities.

4.1. Multifunctionality as a principle for the strategic planning of compact cities

A broad awareness of urban green spaces' ability to provide a large range of functions is shared by planning practice and academia. The relatively low standing of enhancing multifunctionality as a planning objective in the 20 European cities studied may indicate that green infrastructure multifunctionality is often taken for granted. However, the documents from growing cities also revealed that multifunctionality enhancement may be particularly relevant under densification. Additionally, the three good practice cases all applied multifunctionality as a principle to improve urban green spaces under pressure from urban growth and densification processes.

On the strategic planning level, the good practice cases show that multifunctionality should be promoted through planning objectives or an otherwise agreed set of functions or standards that need to be considered in green space planning (cf. Ahern et al., 2014; Haaland and Konijnendijk, 2015). Such guidelines need to be linked to an operational level, as in the cases of Berlin (i.e. compensation measures) and Edinburgh (i.e. neighbourhood action plans).

However, the principle of multifunctionality alone will not be able to secure sufficient provision of green spaces in densifying cities but needs to be combined with other principles such as the conservation of valuable green spaces, securing green space quantity and quality, and increasing connectivity and the accessibility of green infrastructure (cf. Haaland and Konijnendijk, 2015). Indeed, physical and functional connectivity between green spaces is particularly important as this will increase the functionality of single green spaces. The integration of green space functions into grey infrastructure functions such as stormwater retention and discharge can further increase the multifunctionality and may help to emphasize the importance of green spaces in compact cities (Demuzere et al., 2014).

4.2. Approaches for assessing multifunctionality

The three good practice cases demonstrated to varying degrees the consideration of—mainly ecological and social—functions. The Aarhus case was the only example of a plan that additionally included the economic dimension. Many of the functions found in the analysed planning documents from the 20 cities or good practice cases, such as erosion prevention, stormwater regulation or air circulation, can be linked to a classification of ecosystem services. Thus, ecosystem service assessments appear to be promising approaches for a systematic consideration of multifunctionality, even though tools and indicators developed to date are mainly designed for the continental (e.g. Haines-Young et al., 2012), regional (e.g. Lautenbach et al., 2011), or city-wide level (e.g. Larondelle and Haase, 2013; Maes et al., 2016) as opposed to finer spatial levels. Furthermore, existing spatial assessments for ecosystem services are often too rudimentary to represent the full diversity of urban green space functions and also lack social-cultural and biodiversity aspects (Kremer et al., 2016a). In line with this, we found a number of important urban green space functions, including biodiversity conservation, promoting social cohesion, mobility or urban structure, that are not widely considered in ecosystem service assessments. If these are ignored, especially in dense cities, there is a risk that the limited green spaces will meet neither the demands of different social groups nor support biodiversity.

Although none of the three cases includes an indicator-based GIS analysis, popular in the context of ecosystem services research, they showcase how a systematic assessment of different functions helps identify areas where action is needed to increase multifunctionality and/or promote priority functions. A comprehensive information base is even more important in cities facing densification since it can help the process of making informed decisions on where to protect or invest in green spaces (Haaland and Konijnendijk, 2015). This can be created by 'layering' data on the ecological and social functions for the whole city in GIS, as in Berlin. Comparable indicator-based ecosystem services assessments have been suggested, for instance by Madureira and Andresen (2013). However, the good practice examples show that such approaches need to be able to include qualitative and fine-grained, site-specific information, e.g. on gaps in the green space network, habitat suitability for protected species or different kinds of recreational amenities, to aid planning decisions.

A comprehensive consideration of limits and trade-offs was missing. An intention to indicate synergies between functions was only found in the case of Aarhus, while the OSS in Edinburgh considered conflicts to some degree. Basic information on potential synergies and trade-offs between different functions or priority actions should at least be included to address interrelations with city-wide strategic planning too in order to avoid unintended outcomes or even an overall decline in quality when single functions are enhanced (Demuzere et al., 2014; Sussams et al., 2015; Kremer et al., 2016b). Approaches for assessing ecosystem services have great potential for evaluating not only the various benefits provided by green spaces but also synergies and trade-offs between them (e.g., Howe et al., 2014; Mouchet et al., 2014; Queiroz et al., 2015), though further work is needed before these tools enter planning practice and can account for the complexity necessitated by multifunctionality assessment.

From our study, it can be concluded that multifunctionality assessments need to be developed that deliver fine-grained results, capture the broad range of functions relevant for planning and help us understand synergies and trade-offs. The integrated assessment of urban green spaces must combine ecological, social and economic valuation methods, which are often not easily reconcilable (Kronenberg and Andersson, 2016; Castro et al., 2014; Schetke et al., 2010). Recent advancements in ecosystem service research offer initial approaches for integrating these dimensions (cf. Kenter, 2016; Saarikoski et al., 2016). From a planner's point-of-view, it can be difficult to coordinate integrated assessments that cut across ecological, social and economic dimensions, which may require expertise from different sectors of the city administration and on different levels (Primmer and Furman, 2012). However, the three good practice cases show that interdisciplinary planning promotes the integration of different kinds of expert knowledge and that citizen participation helps address the needs and interests of different social groups (cf. Kopperoinen et al., 2014). Non-governmental stakeholders might also hold important local knowledge on specific functions and services (Colding et al., 2006; Tudor et al., 2015).

4.3. Approaches to promote multifunctional green spaces

While it is relatively easy to ensure that green spaces provide a wide variety of functions within the city as a whole, the promotion of multiple functions in the same area is less straightforward. In each of the three good practice cases, the site level was crucial since this was the scale on which place-based actions needed to be developed to promote an optimal constellation of functions.

The examples for multifunctional site-design from Berlin and Aarhus indicate that after deciding on functions and their balance, multifunctionality within one urban green space can be realized by a combination of a 'partial' (i.e. combining functions at the same location with one or two dominant ones) and 'tessellated' approach (i.e. spatial segregation of functions within one area). Examples for 'partial' include hosting temporal functions such as flood retention, though land may be used for other functions such as recreation and habitat provision at other times, such as the retention areas in Aarhus (cf. Ahern, 2007). To handle conflicts and trade-offs, locally variable strategies can be applied in 'tessellated' spaces, such as zoning or visitor management (e.g. by signs or reducing accessibility to sensitive locations, as in the case of 'Park auf dem Nordbahnhof'; cf. Niemelä et al., 2010). 'Total multifunctionality' (i.e., equal balance of functions at the same location at the same time) is regarded as challenging or even impossible, especially when one function requires a relatively high land use intensity (Rode, 2016). Thus, 'tessellated' and 'partial' appear likely options for spatially and temporally arranging multifunctional green spaces in compact cities.

4.4. Implications for planning and research

The good practice cases mainly provided insights into practical applications of multifunctionality, especially under conditions of urban compaction. We can summarize five recommendations for planning:

1) Systematic spatial assessments help us consider various functions and ecosystem services in an integrated manner (e.g. by including biophysical, socio-cultural and economic assessment methods) and on different planning scales. For compact cities, such assessments for the whole city or a certain area can help identify priorities in conserving and enhancing certain functions.
2) In strategic city-wide planning, standards and guidelines are needed to promote and ensure that multifunctionality is secured and enhanced within the city and implemented on the project level. For compact cities, such strategies need to be linked with the policies for inner city development and densification and supplemented with policies that ensure a sufficient quantity and accessibility of urban green spaces.
3) Design and management need to spatially and temporally place multifunctionality on the site level allowing for interrelations between functions. Different kinds of green spaces distributed across the city must ensure that the city's green infrastructure as a whole provides a wide variety of functions.
4) Synergies, trade-offs and the capacity of urban green spaces to provide certain functions or services need to be considered in spatial assessments and when applying multifunctionality as a principle for planning and site-level development of the urban green infrastructure.
5) Inter- and transdisciplinary cooperation support multifunctionality in all three fields of application. Cooperation across authorities and departments helps identify common goals and synergies. Integrated spatial analyses in particular require expertise from different fields. Collaboration with citizens and non-governmental stakeholders is crucial for the inclusion of local knowledge and to ensure that green space development can address demands.

Our approach of mixing qualitative and quantitative methods, supplemented with three in-depth studies, gave us a comprehensive picture of how planners handle multifunctionality. From a researcher's perspective, planning documents are easily available and provide comparable study units, suitable for (semi-)quantitative studies. However, as shown in our study, they often only allow a limited perspective and lack useful information and definitions of certain terms or detailed methodologies. Our good practice cases confirmed how green space planning, like other spatial planning disciplines, is very much a "practice of knowing" (Davoudi, 2015), drawing on multiple concepts, tools, technologies, and data intermingled with planner's expertise, political decisions or moral choices in order to adapt these to the local context, which can be a challenging job. Adding stakeholder interviews and an analysis of contextual data allows a deeper understanding of the role of multifunctionality approaches within the wider planning context, as well as factors influencing development and uptake. More detailed studies in different cities are needed to learn how to develop multifunctionality assessments, including cities that already apply ecosystem services assessments. Furthermore, the strategies to handle multifunctionality on the site-level should be investigated comprehensively.

5. Conclusion

Our analysis of 20 cities sheds light on the application of multifunctionality within planning practices across Europe. While there is a general awareness of the multiple functions of urban green infrastructure and the three good practice cases suggest approaches to enhance multifunctionality from city to site-level planning, multifunctionality planning approaches vary considerably between cities. Not all cities adopted a comprehensive approach to planning multifunctionality but were strong on certain aspects, such as the evaluation of green spaces according to multiple functions or ensuring multifunctionality in strategic planning.

Our study also showed that cities facing growth consider multifunctionality more often. In the compact city model, urban growth appears to be a driver for targeting the potential of urban green spaces to deliver multiple benefits in planning. However, a sound knowledge of green space potential is needed to exploit these opportunities. This article advocates multifunctionality as an approach to considering the multiple benefits of urban green spaces and fostering synergies between the optimal provision of different functions to support green space planning in compact cities. This requires an up-front consideration of the various social, ecological and economic benefits by assessing various functions of all types of urban green spaces, applying a strategic city-wide green infrastructure perspective that enhances multifunctionality on all spatial levels, and deliberately arranging functions across space and time.

Overall, there not only seems to be potential in many cities to consider multifunctionality more comprehensively but also for scientists to deliver more practically-oriented tools and concepts. Scientific approaches based on the concept of ecosystem services might offer sound assessments of high value for planning practice if they are able to not only cover and integrate social, ecological and economic dimensions but also provide flexibility in spatial assessments.

Funding

This work was supported by the European Union's Research and Innovation funding programme for 2007–2013 FP 7 (FP7-ENV.2013.6.2-5-603567).

Acknowledgements

This research has been part of GREEN SURGE, a collaborative research project on Green Infrastructure and Urban Biodiversity for Sustainable Urban Development and the Green Economy. We are grateful to a large number of researchers who contributed to the data collection and analysis within GREEN SURGE. For the semi-quantitative study in particular Clive Davies, Raffaele Lafortezza, Yole Debellis, Artur Santos and Ivan Tosics need to be acknowledged; for the qualitative study additionally Werner Rolf, Ana Catarina Luz, Luca Száraz and Kati Vierikko; for the Aarhus case, Ole Hjorth Caspersen and Sandra Gentin; for the Berlin case, Sabrina Erlwein. Furthermore, we like to thank the practitioners from the case study cities who supported us with insights and material, in particular Holle Thierfelder from Berlin. We would also like to thank Sabrina Erlwein for developing some of the figures and the two reviewers and editors for their critical reflections and good recommendations which helped improve the paper.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecolind.2017.09.042.

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Appendix 1. Material for the semi-quantitative analysis of green space planning in 20 European cities

Tab. A1: Overview of the cities, calculated population growth rate, analysed planning documents and analysis results

City	POP (%)	Planning documents		DA				I
		Doc. A	Doc. B	Doc. A		Doc. B		
				M1	M2	M1	M2	
Aarhus, Denmark	0,90	Type1: Municipal Plan (2013)	--	x	x	--		4
Almada, Portugal	0,57	--	Type2: Review of Almada's Master Development Plan. "Characterization Studies of the Municipal Territory. Notebook 2 - Environmental System" (2011)	--		x	x	4
Amsterdam, The Netherlands	0,76	Type1: Structure Vision Amsterdam 2040 (2011)	Type2: Ecological Vision (2012)	x	0	x	0	4
Barcelona, Spain	0,49	--	Type2: Green Infrastructure and Biodiversity Plan 2020 (2013)	--		x	0	4
Bari, Italy	0,15	Type2: Regional Territorial Landscape Plan (2013)	Type1: Preliminary Planning Document (2010)	x	x	x	x	4
Berlin, Germany	0,08	Type2: Landscape Programme (2004)	Type2: Urban Landscape Strategy Berlin (2012)	x	0	x	0	5
Bristol, UK	1,12	Type1: Bristol Local Plan: Core Strategy (2011)	Type2: Bristol Parks and Green Space Strategy (2008)	x	0	x	x	5
Edinburgh, UK	0,68	Type1: First Proposed Edinburgh Local Development Plan (2013)	Type2: Open Space Strategy (2010)	x	0	x	0	5
Halle , Germany	-0,37	--	Type1: Spatial Vision Halle 2025 plus (2012)	--		x	0	5
Helsinki, Finland	0,80	Type2: Green Area Plan (2011)	Type2: Biodiversity Action Plan (2010)	x	x	x	x	4
Linz, Austria	0,36	Type2: Special Plan for Green Space (2013)	--	0	0	--		4
Lisbon, Portugal	-0,62	Type1: Lisbon's Master Development Plan (2012)	Type2: Biodiversity in the City of Lisbon, a Strategy for 2020 (2012)	x	0	x	x	5
Lodz, Poland	-0,88	Type1: The Study of Determinants and Directions of Spatial Development of Lodz (Masterplan) (2010)	Type2: Municipal Management and Environmental Protection Policy of the City of Lodz 2020+ (2013)	x	0	x	0	4
Ljubljana, Slovenia	0,43	Type1: Spatial Plan of the Municipality of Ljubljana (2010)	Type2: Environmental Protection Programme (2014)	x	x	0	0	5
Malmö, Sweden	1,41	Type1: Comprehensive Plan (2014)	--	x	x	--		4
Milan, Italy	0,41	Type 2: Forest Management Plan (2014)	Type 2: Regional Ecological Network Document (2009)	x	x	x	x	5
Oradea, Romania	0,48	--	--	--		--		5
Poznan, Poland	-0,46	Type2: Environmental Protection Programme (2013)	Type1: The Study of Determinants and Directions of Spatial Development of Poznan (Masterplan) (2014)	x	0	x	0	5
Szeged, Hungary	-0,30	Type1: Integrated Urban Development Strategy and Urban Development Concept (2014)	Type2: Local Decree on the Management of Szeged City Naturally Protected Areas (2009)	x	x	x	0	5
Utrecht, The Netherlands	1,92	Type 2: Green Structure Plan (2007)	Type 2: Trees policy (2009)	x	0	x	x	3

POP = Annual population growth (2001-2014; for Aarhus, Almada. Linz, Lisbon 2001-2013, for Malmö 2001-2012; data derived from Eurostat's Urban Audit, http://ec.europa.eu/eurostat/web/cities/data/database)

Doc. = document; Doc. A = Most important plan regarding green spaces; Doc B = Most innovative plan regarding green spaces; Type1 = comprehensive plan, Type2 = green space/landscape/biodiversity plan

DA = Document analysis; M1 = consideration of multiple functions; M2 = consideration of enhancing multifunctionality; x = yes; 0 = no

I = Interview; rank of multifunctionality consideration in green space planning, from 1 (strongly disagree) to 5 (strongly agree

Appendix 2: Material for the qualitative analysis of three good practice cases

Tab. A2: Overview of the interviews and other not accessible sources

Note: All other accessible sources are referenced in the text and included in the reference list.

Aarhus, Denmark:

- **Interview** with Special Adviser, Gellerup secretariat, Mayor's Department of Aarhus, 1th July 2015.
- **Interview** with Chairman for housing unit no. 4, 30th July 2015.
- **Interview** with head of Centre of Environment and Energy, Aquatic and Agriculture, Technology and Environment Department of Aarhus, 23th September 2015.
- Additional **email exchange** with interviewees on case narrative draft.

Berlin, Germany:

- **Interview** with landscape planning head, Senate Department for Urban Development and the Environment of Berlin, 13th of May 2015.
- **Interview** with district planner, District Tempelhof-Schöneberg, Department of Health, Social, Urban Development, 12th of May 2015.
- **Observation** of guided public cycle tour through urban renewal area in Schöneberg Südkreuz at the "Open Day of the Urban Renewal Funding Programme", led by planning consultant, on 9th May 2015.
- Additional **email exchange** with interviewees on case narrative draft.

Edinburgh, **United Kingdom**:

- **Interview** with Planning Department Principal Planner, Planning Department Natural Environment Team Manager, Planning Department Planning Officer, City of Edinburgh Council, 16th June 2015.
- **Email exchange** with City of Edinburgh Council Planning Department Planning Officer; July 2015.
- **Email exchange** with LFGNP (Lothians and Fife Green Network Partnership) Manager; August 2015.
- Additional **email exchange** with interviewees on case narrative draft.

Appendix 3

Overview of the diagramming of multifunctionality in the design plan of the new park in Gellerup (excerpt with 38 of 55 criteria). The headlines (in bold) represent main categories in the plan, and the pie charts illustrate the main elements in relation to social, ecological and/or economical functions (translatation based on SLA Architects 2014:43).

Legend

Blue = social

Green = economical

Red = ecological

Planting

Improved sense of safety by thinning and pruning of existing trees

Growing own fruit and vegetables creates attachment and involvement

Planting of both hardwoods and softwoods to obtain seasonal variation.

Large areas with natural grasses that only need mowing once per year

New tree groups are allowed to develop naturally without pruning

High plant diversity creates the basis for a rich wildlife (biodiversity)

The trees absorb water and CO2. As well as increasing evaporation, provide shade and create a comfortable microclimate

Terrain

Improved sense of safety and visual contact by remove of existing steep slopes

Improved accessibility on main streets and trails

The terrain is experienced more harmonious and organic without the steep terrain jumps.

More accessible and safe thoroughfares promotes cycling and walking

Lowland act as sink for rainwater drainage (Water Sensitive Urban Design)

Easier maintenance without the steep slopes

Water

Visibility of water surfaces creates awareness of hydrology and climate change

Delay pools become recreational features of the landscape

By delaying the rainwater expansion of the sewerage system is avoided

Photovoltaics at the waterfall and hand pumps for irrigation reduce operating costs

The water promotes biodiversity and microclimate

Climate-proofing, reduces the risk of flooding

Reusing rainwater for watering system

Recreational network

Improved sense of safety and visual contact on all trails

More life and activity along the main paths increases sense of safety

Improved connectivity of paths and wayfinding in relation to everyday life activities which also minimize wear on green surfaces

Compliance of use levels and surface robustness by constructing the busiest trails in concrete, and the secondary trails in gravel

Concrete and gravel have a minimum of joints, making it easier to maintain

Gravel and concrete are both local and recyclable materials

Illumination And Wayfinding

Better lighting increases sense of safety

Better wayfinding in terms of landmarks and signage increases sense of safety

New landmarks is to send a positive signal of an area in transition

Using bright coatings reduce the use of energy to illuminate surfaces by 40%

Conversion to LED reduces costs

Recreational activities

More activity opportunities (both organised and unorganised) improve conditions for belonging, ownership and wider social networks

More activity opportunities that encourage play and exercise which promotes health and wellbeing

More life and activity along the main paths increases sense of safety

Areas where more people can stay across age, gender and culture

Better physical conditions increase membership in clubs and associations

Areas with allotment gardens will have high biodiversity

More activities less vandalism