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A review of urban ecosystem services: six key challenges for future research

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ABSTRACT

Global urbanization creates opportunities and challenges for human well-being and transition towards sustainability. Urban areas are human-environment systems that depend fundamentally on ecosystems, and thus require an understanding of the management of urban ecosystem services to ensure sustainable urban planning. The purpose of this study is to provide a systematic review of urban ecosystems services research, which addresses the combined domain of ecosystem services and urban development. We examined emerging trends and gaps in how urban ecosystem services are conceptualized in peer-reviewed case study literature, including the geographical distribution of research, the development and use of the urban ecosystem services concept, and the involvement of stakeholders. We highlight six challenges aimed at strengthening the concept's potential to facilitate meaningful inter- and transdisciplinary work for ecosystem services research and planning. Achieving a cohesive conceptual approach in the research field will address (i) the need for more extensive spatial and contextual coverage, (ii) continual clarification of definitions, (iii) recognition of limited data transferability, (iv) more comprehensive stakeholder involvement, (v) more integrated research efforts, and (vi) translation of scientific findings into actionable knowledge, feeding information back into planning and management. We conclude with recommendations for conducting further research while incorporating these challenges.

Contents

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1. Introduction

Urbanization is increasing on a global scale, creating both opportunities and challenges for fostering people's quality of life and managing the transition towards sustainability. Today, the majority of the world's population lives in urban areas, and two-thirds of the world's population is expected to be urbanized by 2050 (United Nations, 2012). It has been argued that urban living has the potential to fulfill basic human needs at the least cost due to economies of scale (Bettencourt et al., 2007). Urban development plays a significant role in the transition to lower birth rates and lower childhood infections while increasing life spans (Dye, 2008), and in fostering economic development and facilitating innovation (Johnson, 2008; UN-Habitat, 2012). However, urbanization processes may also have adverse effects on many aspects of human well-being, including increasing crime rates (Bettencourt et al., 2007) and growing human ill-health (Frumkin, 2003; Lederbogen et al., 2011), thus benefits and drawbacks of urban development may differ among cities and regions. Moreover, although urban areas cover a small fraction of Earth's terrestrial surface, they account for a significant portion of global carbon emissions, energy and resource consumption (IEA, 2008), contributing to climate change, ecosystem degradation and biodiversity loss on a global scale (Grimm et al., 2008; Mcdonald et al., 2008; Seto et al., 2012).

In the context of a rapidly urbanizing world, understanding complexity and managing human–environment interactions within urban areas is vital if we are to balance the interdependent social and ecological goals of sustainability (Ash et al., 2008; Bettencourt and West, 2010; Clark, 2007). Urban planning can tackle these sustainability challenges by addressing the inherent linkages between the interacting economic, environmental and social components in coupled human-environment systems (Wilkinson et al., 2013; Wu, 2013). A comprehensive planning approach has the potential to harmonize human–environment interactions and mitigate the harmful impacts of urbanization (Andersson, 2006). Such an approach requires planners to understand and value nature's multiple contributions to the quality of urban life (Hubacek and Kronenberg, 2013).

The concept of ecosystem services, here defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life" (Daily, 1997, p. 3) provides a framework for conceptualizing and managing human–environmental interactions (Daily et al., 2009) within the broader context of sustainability. Applied to urban planning, the ecosystem services concept reveals urban populations' dependence on the goods and services appropriated from ecosystems (Elmqvist et al., 2013; Gómez-Baggethun and Barton, 2013). However, the question as to what constitutes an 'urban ecosystem service' is contested, in part, due to the spatial and temporal mismatches between the physical boundaries of urban areas and the resources drawn into and used within them (Borgström et al., 2006; Ramalho and Hobbs, 2012). Ecosystems – both within and outside urban areas – are frequently modified to provide specific ecosystem services to urban dwellers (Gutman, 2007; Sandhu and Wratten, 2013). Following McGranahan et al. (2005), Gutman (2007) and Jansson (2013), we define urban ecosystem services as those services that are either directly produced by ecological structures within urban areas, or peri-urban regions. For example, rural food production can be 'delivered' to either rural or urban dwellers and therefore does not, in our definition, constitute an urban ecosystem service.

Although the notion of ecosystem services and its application to urban environments potentially provides a useful conceptualization for further understanding the human-nature interface (Söderman et al., 2012; Tobias, 2013), its operationalization is fraught with difficulties. In this review we identify some of the operational challenges of urban ecosystem services research.

The ecosystem services concept conceptualizes human–environmental interactions through a series of linked components that relate ecological processes to human well-being. Here, we use a particular conceptual model of those components and their linkages referred to as the 'ecosystem services cascade' (Haines-Young and Potschin, 2010; Potschin and Haines-Young, 2011), where ecological structures generate ecological processes and

functions that may be appropriated by humans (as ecosystem services) that increase human well-being (benefits). While not all research on urban ecosystem services can, or should, address every aspect of the ecosystem service concept (from ecological structure through to appropriated benefits), knowing which components and linkages are, or are not, studied is vital in order to understand the current state of urban ecosystem services research. An integrative approach to urban ecosystem services research is required if it is to generate the encompassing understanding of human–environmental interactions needed for the concept to contribute effectively to sustainable urban planning.

Given the inherently complex and interdisciplinary nature of ecosystem services research (Daily et al., 2009) there is a need to ensure that urban ecosystem services research covers the wide range of research perspectives from which such research can be conceptualized and undertaken. Discipline-bounded approaches have failed to address the integration of ecosystem services into planning practice, which requires integrated understanding of ecological, economic, political and social domains of knowledge (Carpenter et al., 2009; Hubacek and Kronenberg, 2013). Therefore, urban ecosystem services research needs to address not just ecological modeling and economic valuation but also issues such as governance, planning and stakeholder engagement.

Urban ecosystem services research needs to be carefully contextualized in relation to the specific locations in which such services arise and are appropriated. Since values ascribed to ecosystem services are not fixed, but vary between urban locations due to contextual features (Ernstson, 2013) cultural identity (Chan et al., 2012) and individual and institutional perceptions (Raymond et al., 2013), the value ascription of relevant (urban) stakeholders in the valuation process is crucial in understanding the actual benefits of urban ecosystem services. Moreover, the identification of structures that provide services, the specification of the system boundaries, and scale specific examination of synergies and trade-offs need to be based on local knowledge and contextual features (Hauck et al., 2013; Martín-López et al., 2014; Naeem et al., 2015). Carefully contextualized urban ecosystem services research is particularly important if the insights from a relatively small number of urban ecosystem services studies are to be generalized to a wider understanding of the role of ecosystem services research as a crucial input to 'real world' sustainable urban planning. For example, the use of benefit transfer approaches—taking estimates of value from one site and 'transferring' them to another site—to assessing ecosystem services values depends on the similarity among the sites considered (Plummer, 2009). If the assessments of urban ecosystem services do not capture the contextual diversity of urban ecosystem service provision and consumption, or do not reflect the range of urban structures that provide ecosystem services, then there will be serious knowledge gaps regarding the relations between urban ecosystem services and human well-being.

The concept of ecosystem services and its application to urban environments has gained increasing attention during the last decade (Bolund, and Hunhammar, 1999; Hubacek, and Kronenberg, 2013; Kremer et al., 2015). Recent reviews on ecosystem services in urban environments have focused on specific issues such as water (Lundy and Wade, 2011) or indoor environment (Wang et al., 2014). However, it is currently unclear to what extent peer-reviewed literature is generating integrated and comprehensive research, or covering the diversity of research perspectives that need to be considered in urban ecosystem services research. Similarly, it is unknown if the coverage of urban ecosystem services research reported in the literature is sufficiently broad to capture contextual diversity (region, city size, etc.) between different urban settings and therefore allow for meaningful generalizations regarding the relations between urban ecosystem services and human well-being. Moreover, a recent review (Haase et al., 2014) has highlighted the importance of stakeholder engagement in urban ecosystem services research, reflecting the broader call for a greater focus on the normative and ethical aspects of the ecosystem services concept (Abson et al., 2014; Jax et al., 2013). Without addressing these concerns (stakeholder engagement; conceptual and contextual coverage) urban ecosystem services research is unlikely to fulfill its full potential to inform sustainable urban planning.

In this study we examined the emerging trends in urban ecosystem services research in the peer-reviewed literature. In order to identify research gaps or systematic bias (i.e. insufficient focus on particular components of the ecosystem services concept, particular types of urban areas, or particular research perspectives) in the current knowledge base, we performed the first quantitative review on the topic, including reviewing linkages to stakeholder involvement and sustainability. We focused on case study research as this allows for the investigation of both the conceptualization and operationalization of the urban ecosystem services concept. In reviewing the literature we considered the following key aspects:

1. *The geographical location and distribution as well as contextual settings of the case studies:* to which extent existing research is biased towards particular continents, countries or urban areas (including the physical and population sizes of those urban areas).
2. *Research perspectives and development of research over time*: from which perspective research has been undertaken, and in which ways the concept of urban ecosystem services is applied and investigated.
3. *Operationalization of the concept*: how research in urban environments uses the concept of ecosystem services, which concept components are most frequently examined, which types of ecological structures are commonly investigated, and how the services of ecosystems are examined.
4. *Stakeholder involvement*: to what extent case study research engages with people from outside academia.

Following the description of the methods (Section 2), this empirical review sought to determine gaps both within and between the coverage of the four key aspects of urban ecosystem services research; including: location, research perspectives, operationalization and stakeholders (Section 3). We then discuss the lessons learned from this review (Section 4) and conclude with recommendations for further research identifying avenues that would allow the urban ecosystem services concept to contribute more effectively to sustainable urban planning (Section 5).

2. Methods

The research approach was based on a literature review including quantitative statistical and qualitative content analyses. Our research protocol broadly followed the approach of Newig et al. (2009). While our review cannot be considered exhaustive, we consider it to cover the largest parts of the available literature, since we collected data from scientific articles published in English from the Scopus and ISI web of knowledge databases (see supplementary material A for the search string), resulting in the identification of 3266 unique scientific articles.

2.1. Case study selection

We define a case study as a location specific empirical study that can investigate varying levels of analysis by collecting

quantitative and/or qualitative data at single or multiple cases and/or points in time (Eisenhardt, 1989; Yin, 2009). The following three criteria were used to identify relevant case studies from the initial pool of 3266 articles:

1. Focus on urban areas.
2. Investigation with focus on ecosystem services or benefits provided to an urban population.
3. Explicit use of the term 'ecosystem services' or, alternatively, described link between the investigated ecosystem and a benefit provided to the urban population. The investigated ecosystems can be located within an urban area or beyond its boundaries, but the benefits have to directly serve human needs in urban areas.

Using the listed selection criteria, we identified 201 relevant case studies for our review (see Supplementary material B). The term 'urban area' is often defined either with regard to a particular population size, a ratio of population density to area size or as an administratively defined boundary, or to the size of locality. There are consequently different definitions (Forstall et al., 2009) that vary depending on country (UN Statistics Division, 2012) or research purpose (Parr, 2007). Since administrative boundaries might not necessarily coincide with ecological functions (Borgström et al., 2006; Gómez-Baggethun et al., 2013), we considered a broader definition for urban ecosystem services research as more useful (e.g. Niemelä et al., 2010). Accordingly, case studies were selected if any information was given defining the target area as urban, suburban or peri-urban. If no such term or definition was used to describe the study area, we reviewed the abstract for implicit references, for instance names of cities, population size or density, boundaries of the research area, or other terms referring to urban or peri-urban surroundings. In order to ensure consistency each paper was reviewed independently by two reviews, using an explicit selection protocol, and any disagreements regarding whether the paper should be included in the review discussed and resolved in a larger group based on a reproducible documentation.

2.2. Main steps of the review process

Table 1 Illustrates the review protocol. The variables used to review the case studies are summarized in detail in supplementary material C.

All statistical analyses and graphics were made using the R 2.14 software (R Development Core Team, 2010). Relations between categorical data such as involvement of stakeholders within the different key elements of the cascade model after Haines-Young and Potschin (2010) and Potschin and Haines-Young and (2011) (Fig. 1) were tested with chi-square tests for significance (with a significance threshold of $p < 0.05$). Geographic locations of case studies were analyzed and mapped using ArcGIS 10.1 (ESRI, 2011).

2.3. Analytical framework: classification of the identified case studies

2.3.1. Classification of ecosystem services and related ecological structures

Ecosystem services can be classified into four broad categories: (i) *supporting services* such as water cycling and biodiversity, (ii) *provisioning services* such as the supply of food and fiber; (iii) *regulating services* such as water purification and the regulation of local and global climate, and (iv) *cultural services* such as social relations and good health (MEA, 2005). These will hereafter be referred to as the 'MEA ecosystem service categories'.

Following Srnka and Koeszegi (2007), we conducted a systematic qualitative content analysis of each case study to obtain coded data. To classify ecosystem services according to the MEA categories, we adopted the ecosystem services coding protocol developed by Wilkinson et al. (2013, Appendix 1). When analyzing a case study, any text chunk, that contained some information about a specific ecosystem service, was assigned to the coding protocol with a binary value.

In the analysis we differentiated between ecosystem services "mentioned" and "examined". Mentioned ecosystem services are defined as ecosystem services that are only named in the introduction or in the discussion of a case study whereas examined ecosystem services are also studied in the results section. The mentioned/examined distinction is important because the ecosystem services that were actually examined show which ecosystem services categories matter the most for which perspective. This cannot be shown by only counting the mentioned ecosystem services, because it might be possible that one case study mentions many different ecosystem services without explicitly studying them.

Ecological structures are defined as collection of species individuals, communities, functional groups or habitat types that deliver an ecosystem service (Kremen, 2005; Luck et al., 2009, 2003). To develop a finely-grained classification of ecological structures that provide ecosystem services in urban areas we applied a three step procedure to the selected case studies. Firstly, for

Table 1
Overview of the review process

Steps	Procedure	Results
1. Data Gathering	Database search on Scopus and ISI using jointly defined search string.	Bibliographical information of 3266 potentially relevant papers (duplicates excluded).
2. Data Screening	Division of data load into bundles of 320 papers per reader analyst.	Pre-classified set of potentially relevant papers.
3. Data Cleaning	Screening of abstracts, guided by the questions: • "Does the paper conduct a case study" • "Does the case study focus on urban areas" • "Does the case study analyze ecosystem services or benefits provided to humans in an urban area?" • "Explicit use of the term 'ecosystem services' or described link between ecosystems and benefits to an urban population"	Consensus amongst analyst readers about validity of joint classification. A total of 387 potentially relevant case studies identified.
4. Data scoping	Download of all papers classified as potentially relevant.	Download of 352 potentially relevant case studies (35 papers with no full-text access).
5. Paper classification	Screening of potentially relevant case studies according to guiding questions in 3., to clarify whether or not the article serves the study purpose.	$N=201$ of relevant case studies that serve the study focus.
6. Paper review	Analysis of papers classified as case studies that serve the study focus using 23 jointly defined review categories.	Coherent dataset of $N=201$ case study papers with 23 variables each.
7. Statistical analysis	Analysis of all relevant data points using R.	Results given in the section below.

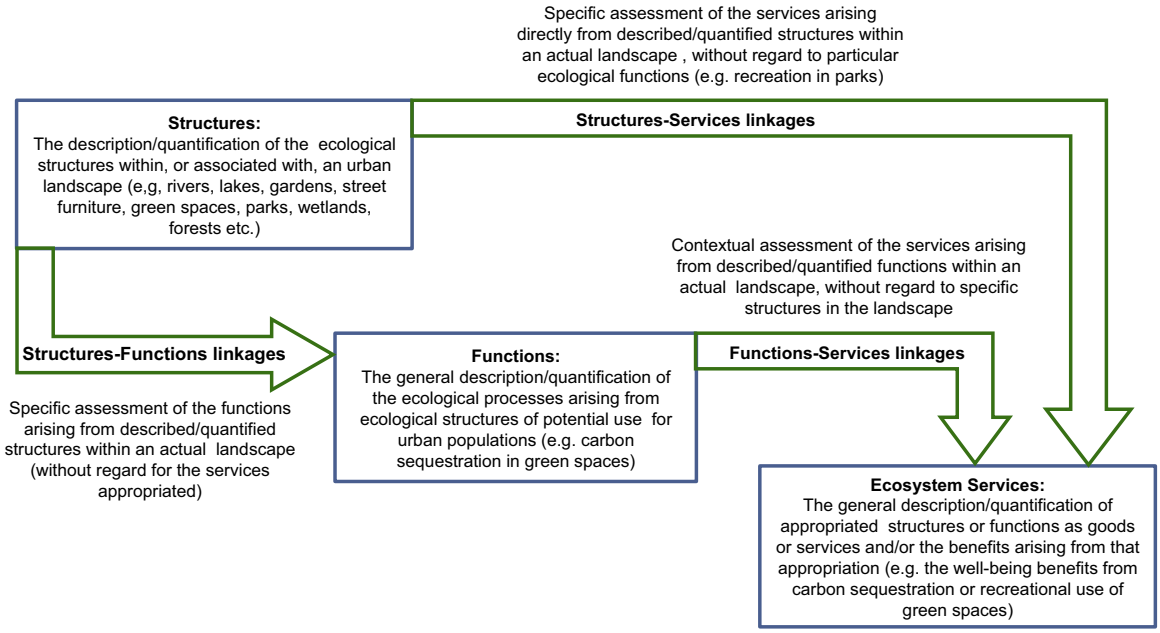

Fig. 1. The operational components of urban ecosystem services research within the ecosystem services production "cascade" (adapted from Haines-Young and Potschin, (2011)).

each paper, we noted the investigated ecological structures using the terms employed in the paper. Secondly, we rationalized the complete list of ecological structure terms, in order to identify a smaller (coherent) set of distinct ecological structures with regards to existing literature (e.g. Bolund and Hunhammar, 1999; Niemelä et al., 2010). The goal of the finely-grained classification scheme was to develop a comprehensive categorization of urban ecological structures while avoiding overlapping groups (e.g. tree stands, woods, forests). We identified 11 categories, namely coastal area, wetlands, lakes, rivers, forest, grassland, street greenery, parks, gardens, cultivated land, and rooftops (a detailed definition of each structure is given in supplementary material D). Finally, in the third step, the ecological structure classification scheme was applied to each case study.

2.3.2. Classification of ecosystem services operationalization

We used the 'ecosystem services cascade' (Haines-Young and Potschin, 2010; Potschin and Haines-Young, 2011) to classify which aspects of the urban ecosystem services concept were operationalized in a given study (Fig. 1). The cascade model was introduced "with the intention [...] to highlight the essential elements that have to be considered in any full analysis of an ecosystem service and the kinds of relationships that exist between them" (Haines-Young and Potschin, 2011, p. 579). The cascade model outlines the different components of ecosystem services 'production', by differentiating between (i) ecological structures, (ii) the ecological processes and functions arising from those structures (iii) the services humans appropriate from these structures and functions as well as the benefits that flow from this appropriation (Fig. 1). We recorded which component(s) of the ecosystem service cascade were considered in each study. We did not explicitly differentiate between the appropriation of ecosystem structures and functions (e.g. services) and the ascription of values to that appropriation (benefits) because a clear distinction between appropriation and value ascription was often not made in the reviewed case studies. Nevertheless, we did record when explicit monetary or non-monetary valuations of the benefits associated with urban ecosystem services were conducted within a given case study. Here we note that there is also an additional component within the ecosystem services cascade that relates the benefits received from the appropriation of ecosystem services to the subsequent management of the ecological structures from which these services flow. This 'management' feedback loop, while crucial, was not explicitly addressed or studied in the identified case studies and therefore not included in this review.

2.3.3. Classification of the research perspectives

One key question of this review is from which perspective research has been undertaken. In order to assign case studies to a research perspective, we used the following six classifications of perspectives:

2.3.3.1. Ecology. Articles undertaken from an environmental science perspective. Examples include studies of: specific ecosystem components, ecosystem services or types of interactions between urban and other ecosystems, pressures on ecosystem services related to urbanization, urban ecosystem health and soil quality, and restoration ecology (see for example: Acar et al., 2007; Baumgardner et al., 2012; Wolter, 2010).

2.3.3.2. Governance. Articles that refer to the governance or management of ecosystems, such as institutional and organizational structures, policy instruments and that are relevant in the context of urban ecosystem services. The major focus of such articles is on explaining how decisions are made and what tools or mechanisms might enhance decision-making processes (see for example: Fotos et al., 2007; Hearne et al., 2008; Sarker et al., 2008).

2.3.3.3. Methods/Tools/Guidelines. Articles focus on the development or specification of methods, tools or instruments in relation to urban ecosystem services, including those that can be used to model (or manage) urban ecosystem services related issues as well as analysis and modeling tools (e.g. spatial models or urban assessment frameworks) (see for example: Beck et al., 2010; O'Farrell et al., 2012; Strohbach et al., 2012).

2.3.3.4. Economics. Articles that focus on economic assessments. This category mostly consists of valuation studies, complemented

by cost–benefit analyses and other assessments of the economic consequences of certain activities (see for example: Chen and Jim, 2012; Donovan and Butry, 2011; Hougner et al., 2006).

2.3.3.5. Social. Articles that deal with social behavior, perceptions and norms, discussed from a sociological, health, anthropological or philosophical perspective. Some of these suggest how to include social science considerations into urban planning (see for example: Burger, 2003; Fraser and Kenney, 2000; Tzoulas and James, 2010).

2.3.3.6. Planning. Articles that focus on urban form and related planning issues. These studies mostly follow an architectural perspective to analyze and plan urban areas (see for example: Hunter and Brown, 2012; Li et al., 2008; Yli-Pelkonen et al., 2006).

Hubacek and Kronenberg (2013) followed a similar approach, dividing scientific articles in their review of ecosystem services into five categories which support urban planning: modeling studies, governance, social, economics and tools. We acknowledge that some of the reviewed case studies spanned more than one of these research perspectives, however, most research, even that which calls for engagement in multiple perspectives had a single dominant perspective that drove the research narrative. A case study was therefore assigned to only one of the above-mentioned perspectives. Interdisciplinary papers were classified based on the dominant perspective. While such a classification is somewhat subjective it allows for useful general overview of the relative emphasis on different research perspectives within the applied urban ecosystem services literature.

3. Results

The 201 urban ecosystem services case studies identified and analyzed cover the time period 1999–2012, with a relatively smooth, exponential growth in studies through time (from one study in 1999 to 56 in 2012, see Fig. 3). Results are generally given as a percent of the 201 case studies, followed by the absolute number of case studies in parentheses.

3.1. Geographical distribution

Our results show that urban ecosystem service studies were spatially clustered (Fig. 2). Out of the 201 reviewed studies, 50% were conducted in the USA and China alone (49 and 53 respectively). Most of the remaining studies focused on European countries, with 18% of the total number of studies coming from Sweden (14), the UK (13) and Germany (9). With regard to individual cities, the highest number of studies was conducted in Stockholm (13 out of 14 conducted in Sweden), followed by Beijing (11).

The majority of case studies, 88% (177), were conducted in the country in which the first author held their primary research position. While authors primarily associated with Chinese research institutions only studied Chinese urban areas, authors from American and European research institutes also studied urban ecosystem services in Asia (5), Africa (2) and Latin America (9). In total peer-reviewed urban ecosystem services case studies were only found in 37 countries (19% of the total number of United Nations member states). However, we should note that the restriction of the analysis to English language publications may provide some bias in this analysis.

At detailed analysis of the urban area extents, population sizes and population densities was not possible due to the lack contextual information provided in the reviewed case studies. For example, 36% (72) of the studies did not provide information on the size of the study area, or the population of the study area. Similarly, other crucial contextual information – such as economic context, demographics, population growth rates, biome descriptions etc – were often not detailed in the studies.

3.2. Research perspectives in urban ecosystem service research

The results show that between 1999 and 2012, the perspectives from which research was conducted are highly variable (Fig. 3). Research published between 2010 and 2012 encompassed each of the six mentioned research perspectives (ecology, governance, methods, economics, social, planning–see Methods section). Nevertheless, studies with an ecological perspective still dominated and showed a steep and continuous increase between 2008 and 2012. Overall, the ecology perspective received the most attention with 35% of all case studies, followed by the planning perspective with 20%. The least common perspective was governance with a share of 8% of the 201 case studies.

3.3. The operationalization of urban ecosystem service research

The ecosystem services cascade is used to distinguish between the components of ecosystem services 'production' (Fig. 1). Almost 10% (19) of the studies did not assess any component of the cascade in depth (Fig. 4). These case studies focused mainly on ecosystem management, without specifically emphasizing any aspect of the ecosystem service cascade model or any ecosystem service in particular (e.g. Reynolds et al., 2010; Vollmer, 2009). A further 31% (63) of the studies considered only a single, isolated, component within the cascade (i.e. they only consider structure, function or services/benefits) with the majority of these studies focusing on urban ecosystem structures. Of the 45% of studies (91) that considered the linkages between two of the cascade components, the majority focused on the ecosystem structure-function linkage, 28% (56), and only 3% (7) consider the link between functions and services/benefits (Fig. 4).

Only 14% (28) of studies considered all three cascade components (Fig. 4). For example Manes et al. (2012) covered the entire cascade by examining the diversity of urban forest (structure) in Rome, Italy and its physiological effect on ozone concentrations in the atmosphere (function). The benefits derived from the removal of hazardous ozone by urban forests are estimated in both monetary and non-monetary terms (services/benefits). The most frequently examined cascade component was structure, with 76% (152), and the least considered component was services/benefits with 39% (78).

3.3.1. Ecological structures and ecosystem services

Out of the 201 case studies in the dataset, 48% (96) focused on a single ecological structure, four did not mention any specific ecological structure, and the rest investigated multiple structures, ranging from two structures (22) up to a maximum of eight structures (2). The most frequently mentioned ecological structures were forests with 42%, rivers/streams (34%), and cultivated land (26%). The ecological structures that were mentioned the least often are rooftops (2%) and coastal areas (6%).

All of the four MEA categories of ecosystem services were mentioned in relation to each type of ecological structure present in the dataset except rooftops (4 case studies) (Fig. 5). Case studies looking at forests (84), rivers (69) and/or cultivated land (53) studied the highest number of ecosystem services. Supporting services were the least studied services in relation to specific ecological structures.

Ecological structures were also related to the different research perspectives (Fig. 6). For example 50% of the case studies looking at street greenery and rooftops were conducted from a planning

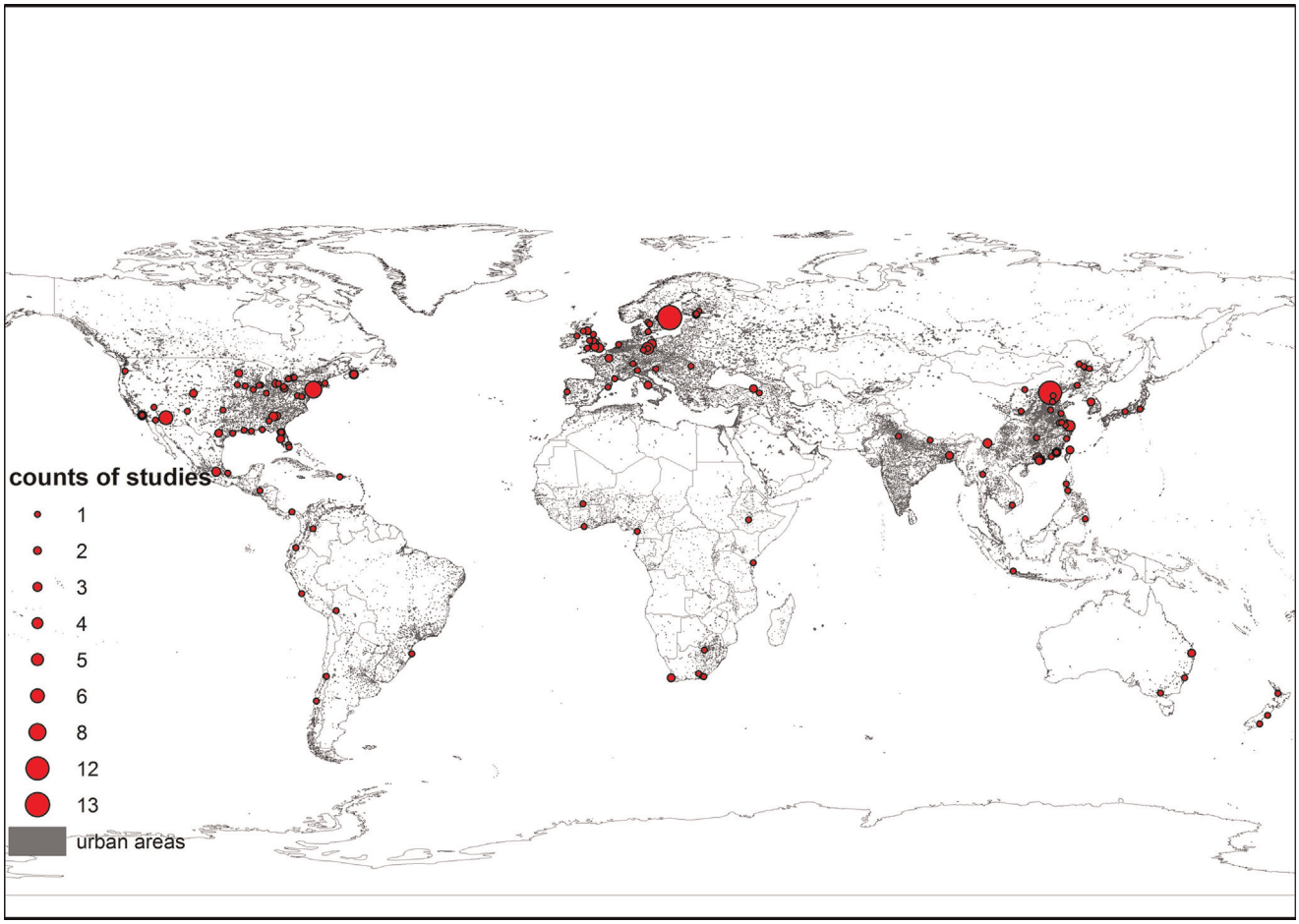

Fig. 2. Global distribution of studies on ecosystem services conducted in urban areas covered in the review.

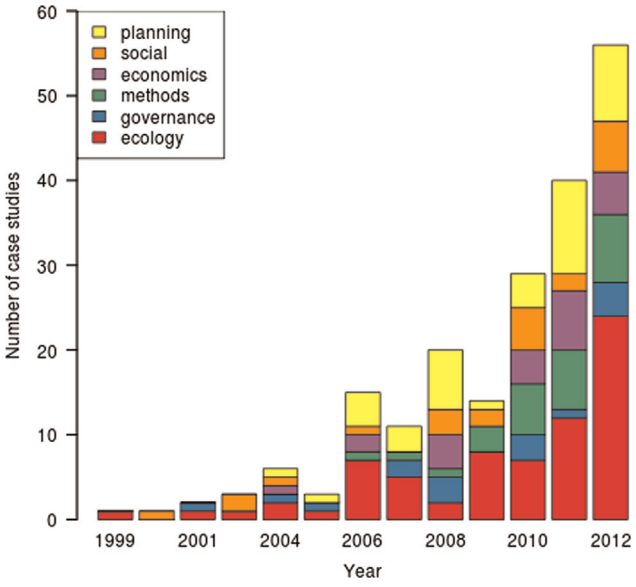

Fig. 3. Distribution of case studies and their main perspective over time.

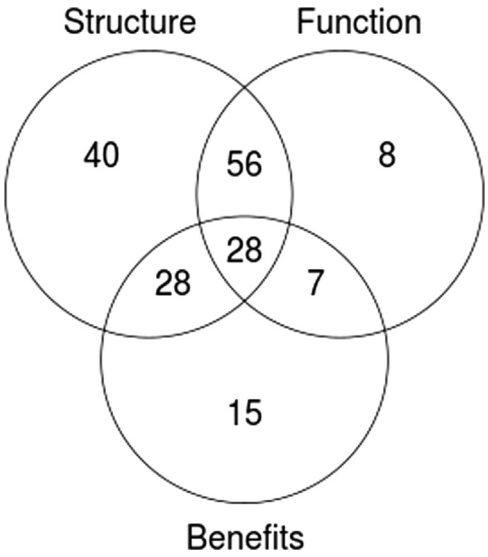

Fig. 4. Distribution of the number of case study papers analyzing different components of the ecosystem service cascade model, 19 studies did not consider any of the cascade components in detail.

perspective. Approximately 40% of studies that considered gardens did so form an ecological perspective. Ecology papers usually made up around 20–30% of the papers that mentioned a specific structure, which was more equally distributed than any other perspective. With the exception of street greenery and rooftops all ecological structures were analyzed from all research perspectives.

3.3.2. *Mentioned and examined ecosystem services*

Ecosystem services that were mentioned (Fig. 7(a)) were compared with those that were actually studied (Fig. 7(b)). The analysis also took into consideration the MEA category to which the services belong and the research perspective.

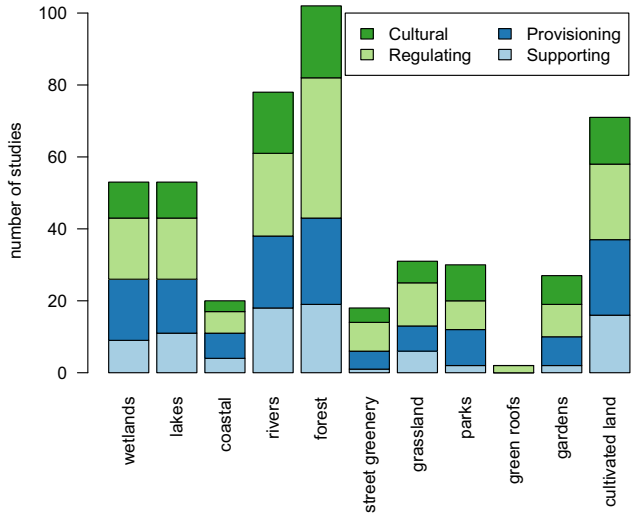

Fig. 5. Number of ecosystem services examined in relation to ecological structures (a single study may examine multiple services and ecological structures).

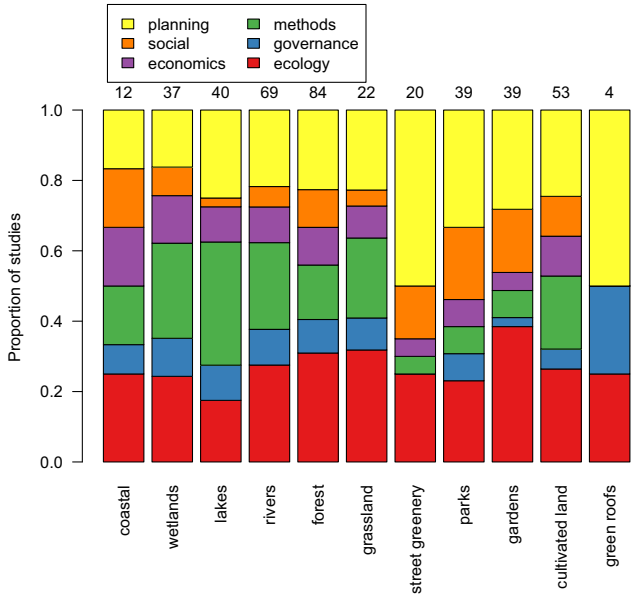

Fig. 6. Ecological structures mentioned with regard to the different research perspectives. On top of the stacks are the total numbers of case studies mentioning an ecological structure (each case study could mention more than one structure).

Case studies mentioned a lot more ecosystem services than they actually studied. Regulating services were mentioned most often, in 132 case studies, whereas provisioning services were mentioned the least often, in 79 case studies (Fig. 7(a)). Regulating services were also the most studied services, in 68 case studies, and provisioning services were the second most studied service category with 58 case studies (Fig. 7(b)). Cultural and supporting services were studied least often, both in 36 case studies.

The most services were mentioned in papers with a planning and ecology perspective. This is different for studied services, where planning case studies had a smaller share (Fig. 7(b)). In contrast, the economic perspective had a higher share for studied services than it had for mentioned services. Almost 40% of supporting and regulating services were studied by papers with an ecology perspective. Case studies from a social perspective had the highest share of studied cultural services. The governance perspective was the least dominant for both examined and mentioned services.

3.4. Stakeholder involvement

We identified 40 case studies (20%) that involved stakeholders in some way in the research process. Of these 40 case studies, only 18 examined a specific ecosystem service category. Out of these 18 case studies, we analyzed which ecosystem services are examined (note: multiple hits possible). 13 studies involved stakeholders to investigate cultural services, while fewer case studies investigated provisioning (7) or regulating services (6) and the lowest stakeholder involvement occurred in case studies that looked at supporting services (2).

4. Discussion

4.1. Geographical focus

Our results revealed that research on urban ecosystem services has a clear bias towards the northern hemisphere. Similar to patterns in ecosystem services research in general (e.g. Howe et al., 2014; Seppelt et al., 2011), our review confirms that case study research in urban areas is to a large extent dominated by China and the US. This trend would be even more significant if articles identified by our search string, but written in Chinese, had been included (e.g. the journal 'Shengtai Xuebao/Acta Ecologica Sinica' has published the second highest number of studies on urban ecosystem services e.g. Hubacek and Kronenberg, 2013). Apart from the loss of important findings that are published in languages other than English, the bias resulting from excluding articles written in Chinese might also pose serious challenges for future meta-analyses (Clavero et al., 2011; Møller and Jennions, 2001).

Our results further showed that a small number of urban areas attracted considerable research attention, with Stockholm (Sweden) and Beijing (China) being the most often studied. Considering that environmental characteristics (and thus also ecosystem service generation) are partly dependent on local environmental and historical conditions (Lehmann et al., 2014), the de facto exclusion of certain geographical areas – whether continents, large countries such as India, Mexico or Russia, or certain globally significant cities – means that urban ecosystem services research still lacks balanced knowledge generation. Moreover, the lack of carefully documented information regarding the context within which a particular study is undertaken is highly problematic for identifying other sources of contextual research bias and more importantly for transferring insights to inform planning in other urban areas. For example, few studies provided accurate geo-referenced locations, quantification of urban extent, population densities, income distributions or other important contextual information.

4.2. Research perspectives and studies over time

In line with Hubacek and Kronenberg (2013), we found not only that the number of studies has increased but also that the ecosystem services concept has attracted a growing number of research perspectives. The ecosystem services concept was initially designed to bring together ecology and economics by employing economic language ("goods and services") and a utilitarian logic (valuation of "benefits" for humans) for conservation purposes (e.g. Daily, 1997; De Groot, 1987). Given these foundations, it is not surprising to see the consistently strong representation of the ecological perspective in the dataset, although we did not necessarily see the 'domination by ecology and economy' that is sometimes claimed (Orenstein, 2013). Many scholars have called for ecosystem services research to embrace the social sciences (Orenstein, 2013), referring to the inherently social nature of policymaking (Cohen, 2006) and the need to "*work our way*

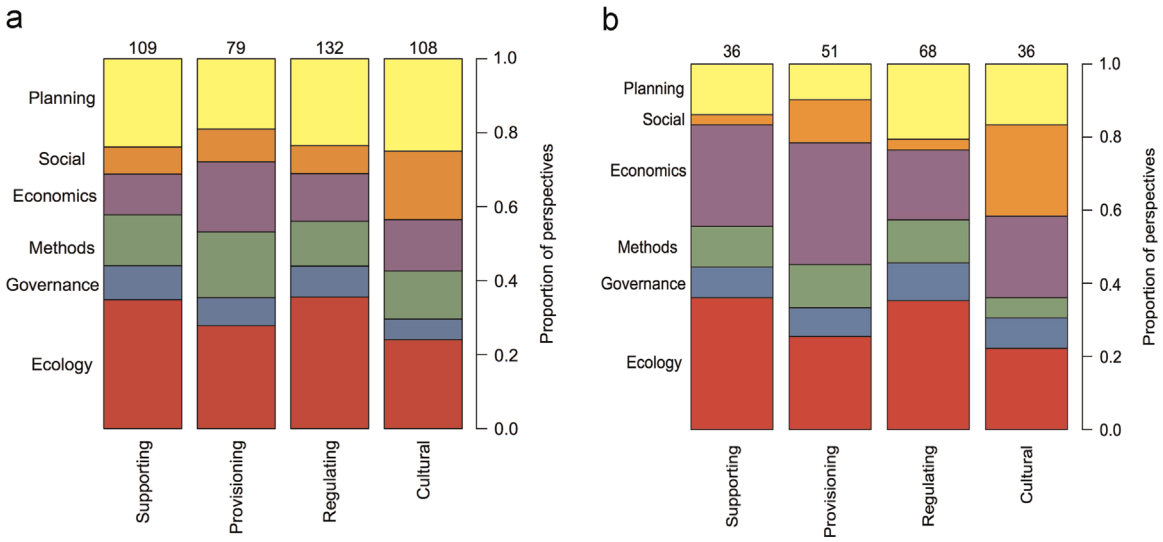

Fig. 7. Distribution of mentioned (a) and examined (b) ecosystem services throughout the research perspectives. The services were assigned to the MEA categories. On top of the stacks are the total numbers of case studies mentioning/examining a service from the four MEA categories (e.g. 108 case studies mentioned a cultural service). One case study could mention/examine several services but has only one perspective.

backwards from society and its specific needs to ecosystem processes, and not vice versa, as scientists usually do" (Jax, 2010, p. 70 original emphasis). The relatively large proportion of papers with a social perspective (11%) may also help to fill the acknowledged gap in valuation of cultural services (Chan et al., 2011; Spangenberg and Settele, 2010) in the context of urban ecosystem services research.

The ecosystem services concept has often been criticized for its narrow economic perspective (Gómez-Baggethun et al., 2010; Norgaard, 2010; Peterson et al., 2010), its use as an operational economic tool for decision-making (Jax et al., 2013), and for creating a 'technocratic approach' which selectively privileges certain types of knowledge with regard to biodiversity while ignoring others (Turnhout et al., 2013). Such critiques are not borne out from our analysis of urban ecosystem services research, which found that only 11 % of the studies apply an explicitly economic perspective and only 17% of studies undertook explicit monetary valuation of ecosystem services. Here it should be noted that some papers with a primarily non-economic perspective still undertook economic valuations (e.g. Shang et al., 2012; Tong et al. 2007; Vejre et al., 2010), often based on relatively unsophisticated benefits transfer approaches, rather than the explicit elicitation of values in the actual case studies.

Despite the importance of the governance discourse in urban ecosystem services research (e.g. Haase et al., 2014; McPhearson et al., 2015), we did not see strong trends of increasing representation of explicit governance perspectives in the case study research in this review. In past decades, there has been a rise in the terminology of governance and emphasis on the sharing of the functions formerly associated with government with the private sector and civil society actors (e.g. Driessen et al., 2012) in a bid for greater efficiency, democracy, and adaptability in addressing issues of sustainable development. Furthermore, our results showed that a planning perspective, associated with a more top-down, traditionally centralized form of governance, was still strongly represented in the dataset.

The urban ecosystem services concept has a yet unrealized potential to act as a boundary object—bringing together multiple perspectives within a common conceptual framework—for sustainable urban planning. Our findings suggest that a perhaps surprisingly diverse range of perspectives have engaged with the urban ecosystem services concept over the last 13 years. This in turn implies that the urban ecosystem services concept can bring together many concerns, approaches, and research communities (see (Jax et al., 2013); (Abson and Hanspach, 2013) and (Abson et al., 2014) for more general discussions of ecosystem services as a boundary object for fostering interdisciplinary work). However our review also suggests that the integration of the different research perspectives has not yet been realized and that the research is still largely dominated by single perspective approaches, leading to a fragmented understanding. The importance of the integration of multiple perspectives into ecosystem services research has been stated many times (Daily et al., 1996; De Groot, 1987; MEA, 2005; TEEB, 2010), although many barriers to inter- or transdisciplinary research still exist, including a variety of definitions, research approaches, and underlying paradigms (Carpenter et al., 2009; Flint et al., 2013; Nahlik, Kentula et al., 2012; Seppelt et al., 2011; Turnhout et al., 2013).

4.3. The ecosystem service cascade

Urban ecosystems services research is fragmented in terms of the components of the ecosystem services concept it engages with. Only 14% of studies engaged with all components of the ecosystem services cascade (see for example, (Wang et al., 2009); (Escobedo et al., 2010)), while 35% only considered a single isolated aspect of the cascade model (i.e. structure, or function, or benefit). The generally larger focus on structure and function, than on services/benefits, may in part be explained by the high share of studies that were conducted from an ecological perspective. The cascade model was introduced "with the intention [...] to highlight the essential elements that have to be considered in any full analysis of an ecosystem service and the kinds of relationships that exist between them" (Potschin and Haines-Young, 2011, p. 579) and understanding each of the components and the relations between them is a prerequisite for a broader understanding of the links between ecological mechanisms and human well-being. Our findings suggest a lack of full engagement with all aspects of the ecosystem services "production chain", with consequential problems for generating integrated understanding of how to manage and embed the ecosystem services concept into sustainable urban planning.

Studies that did not explicitly engage in any component of the ecosystem services cascade nevertheless provided important

bridges between the urban ecosystem services concept and broader issues of urban sustainability. For example, Vollmer (2009) investigated urban challenges and how strategic planning can be employed to maintain urban ecosystems. Other studies that did not address components of the ecosystem service cascade model used the concept merely as one aspect of their argumentation, using the concept as a 'buzzword' rather than directly addressing it. A further problem is that there are (potentially many) studies that could be classified as referring to urban ecosystem services, but which do not explicitly use the term 'ecosystem services'. Evaluating whether such papers provide novel or distinct approaches not found in the self-identified urban ecosystem services literature is an interesting question, but beyond the scope of this review.

4.3.1. Ecological structures

An ongoing challenge to urban planning is the risk of 'mismatches' between spatial scales of service appropriation, the location of ecological structures and the relevant planning level. We identified eleven distinct categories of ecological structures, the majority of which provide services in all of the four MEA categories. The case studies were divided evenly between those that looked at multiple ecological structures (101), and those that examined only a single structure (96). Multiple ecological structures can provide a single service (Davies et al., 2011), and a single structure is also capable of providing multiple services (Smith et al., 2013). Urban forests, for example, which were the most frequently examined structures within the data set (20%) might be assessed for their carbon uptake (Escobedo et al., 2010) or their ability to combat the urban heat island effect (Jenerette et al., 2011). While individual trees in gardens (9%) might contribute to such services at a city-wide level, or be valued and managed preliminary for providing cultural identity (Fraser and Kenney, 2000), or increasing property value (Donovan and Butry, 2011) at the level of the individual household. In addition, a mismatch in scales exists between the potential beneficiaries of the multiple services that flow from a given ecological structure. For example, the benefits from the mitigation of the urban heat island effect by urban trees flow to urban dwellers, but the carbon sequestration benefits of those same trees are potentially shared by all of humanity. These mismatches can result from (i) administrative boundaries that do not match ecological entities, (ii) temporal dynamics of ecological processes not being considered and (iii) the interplay with adjacent systems being neglected (Bai et al., 2010; Borgström et al., 2006; Gómez-Baggethun et al., 2013; Jones et al., 2009; Ramalho and Hobbs, 2012).

Contrary to the claim that domestic gardens have been ignored in urban ecological studies (Cilliers et al., 2011), we found that, in terms of ecosystem services, they were only marginally less frequently examined than parks. Private property owners can significantly influence the ecological structures of an urban area and private gardens can be a useful instrument to increase ecosystem services, independent from central planning and trade-offs inherent in public spaces (Van Heezik et al., 2012). Although private areas and the associated property rights such as access, resource use and withdrawal or management provide challenges to research, it is positive to note that private areas are being considered in ecosystem services research. Several studies did, however, mention difficulties in obtaining permission for research in private areas (e.g. Davies et al., 2011; Knapp et al., 2012; Strohbach and Haase, 2012).

4.3.2. Ecosystem services (mentioned vs. examined)

In accordance with Martínez-Harmsa and Balvanera (2012) more general review of ecosystem services, we found that regulating and provisioning services were the most commonly examined urban ecosystem service types. A potential explanation for this is the fact that the application of external primary and secondary data to evaluate these services in a given case is more straightforward than for other service types (Martínez-Harms and Balvanera, 2012). Supporting services were examined the least often, as they tended to be considered primarily in relation to their contribution to the generation of other types of services.

Ecosystem services from all categories have both been mentioned and examined in all of the perspectives, showing that this concept is deployed by researchers from different disciplines. The results indicate that a large number of case studies mentioned ecosystem services, but a much smaller proportion of these actually examined services. This indicates that the practical application of the ecosystem services concept may still be problematic (Kandziora et al., 2013), limiting how effectively the urban ecosystem services concept can contribute to sustainable urban planning. Within the ecological and planning perspectives in particular, many studies referred to large numbers of services that they did not further examine.

4.4. Stakeholder involvement

The relatively small number of case studies that involved stakeholders (20%) is potentially problematic for the use of the urban ecosystem services in relation to sustainable urban planning for a number of reasons.

Studies that involved ecosystem benefits, along with those that combined structures and benefits, were more likely to involve stakeholders, whereas studies concerning functions were much less likely to do so. In relation to the ecosystem service cascade model, while ecosystem functions are biophysical and cannot be influenced by opinion, ecosystem benefits are contextual and largely subjectively attained (Abson and Termansen, 2011). Even though this reasoning is reflected in our results with studies focusing on benefits having the highest rate of stakeholder involvement, the number is still low considering that the benefits from ecosystem services are contextual.

Secondly, involving stakeholders in management or research can be approached in many ways such as through co-management, surveys, interviews, or observations (Reed, 2008) to assess perceptions and valuation regarding urban planning objectives. A more integrated approach of incorporating stakeholders in discussion and decision making reflects core methodologies embedded in sustainability science research (Kerkhoff, 2013; Miller et al., 2014), particularly integrating actors from different sectors outside academia (Kates et al., 2001; Lang et al., 2012). Evidence from 60 plan-making processes in Florida and Washington States indicates that with greater stakeholder involvement, comprehensive plans are stronger, and proposals made in plans are more likely to be implemented (Burby, 2003).

Thirdly, stakeholder engagement is likely to be particularly important in managing urban cultural ecosystem services. Cultural services have been considered as 'difficult' to measure because of their abstract nature, inherent subjectivity, and often intangible benefits (Chan et al., 2012). However, the involvement of stakeholders could be one way to tackle this difficulty. Whereas other less tangible ecosystem services types (e.g. supporting and regulating services) are seen in many contexts as part of the responsibility of urban area authorities and experts (Wamsler and Brink, 2014), cultural ecosystems are much more a part of citizens' everyday knowledge and sphere of activity. This knowledge needs to be seriously considered with aims to avoid marginalizing or disempowering through the engagement process (Reed, 2008).

Finally, while our research did not specifically focus on management aspects, links to a common understanding of management functionality are apparent when incorporating stakeholders

into the ecosystem service cascade model. The cascade model provides a framework for operationalizing objective services that can be subjectively perceived or experienced by local stakeholders, and should therefore be adjusted accordingly for planning purposes in urban areas. Accounting for feedback and adjustments between the components within the cascade model, for example between benefits and structures through local stakeholder engagement, can be seen as the management component. Whereas stakeholders were more frequently involved in benefit-oriented studies, these benefits originate from how we utilize and implement structures and their corresponding functions. Further integration of stakeholders in ecological structure management implementation processes, either directly or through third-party organizations, could bridge the gap and allow for further bottom-up governance into typically top-down oriented decision making (Folke et al., 2005). These relationships indicate the necessity for research aimed at management aspects that not only focus on individual cascade components, but also on their linkages, in which stakeholder involvement can play a key role.

4.5. Six key challenges for future urban ecosystem services research

The ecosystem services concept is transitioning from a heuristic model for understanding human–environmental interactions to an explicit management tool (Bateman et al., 2013; Daily et al., 2009). This stresses the need to reassess how urban ecosystem services research is undertaken and linked to practice. In this context our review has highlighted six key challenges for urban ecosystem services research: (i) comprehensive spatial and contextual coverage of research, (ii) clarification of definitions, (iii) limited transferability of data, (iv) stakeholder engagement; (v) integrated research efforts; and (vi) closing the feedback loop between benefits and subsequent management of urban ecosystem services in the context of sustainable urban planning agendas.

4.5.1. (i) Comprehensive spatial and contextual coverage of research

Based on our finding that a significant emphasis of ecosystem services research is on the northern hemisphere, and that research is concentrated in a small minority of the world's large urban areas (Fig. 1), we see the need for an exploration of the concept's potential for urban areas in other parts of the world. Ecosystem services research is highly context specific and transferability between contexts is limited (Hubacek and Kronenberg, 2013), especially between urban areas with varying climatic and socio-economic conditions. While studying these different contexts, there is thus a need for clarity regarding (a) the boundaries of the systems under study, (b) the location of ecological structures that are considered to be part of the research and (c) the structures and services that are studied. For example, 36% of the studies did not provide information on the geographical or population size of the study area making it difficult to know to what extent the existing literature is representative of the range of cities sizes over which urban ecosystem services need to be managed.

4.5.2. (ii) Clarification of definitions

The identification of case studies of urban ecosystem services is dependent, to a large extent, on how the term 'urban' is defined (Section 2.2). In the process of reviewing the case studies, we found that the term was frequently used without explicit definition or a comprehensive case description from which a definition could be inferred. We consider this to be a barrier for systematic cross-case analysis. In addition, it makes the identification of urban ecosystem services and their beneficiaries difficult, since the definition of a service as urban or not also depends on whether a 'producer' or 'consumer' approach is being applied (Bennett et al., 2015). Ambiguities are found in both approaches as neither production nor appropriation of services is clearly attributable to one single ecosystem, one specific geographic location or one individual beneficiary. Future urban ecosystem services research needs to pay considerably more attention to providing clear and unambiguous descriptions of the socio-economic and environmental context within which the research was conducted. This includes clear descriptions of urban extent that consider population sizes and densities, socio-cultural environments, economic and political conditions, as well as key environmental variables that influence the ecological structures and functions providing urban ecosystem services.

4.5.3. (iii) Limited transferability of data

Although calls for clear and shared definitions of "key concepts and typologies (of services, benefits, values)" (De Groot et al., 2010, p. 271) and a context specific approach to ecosystem services have been made (Hauck et al., 2013) the extent to which findings can be compared and transferred still remains in doubt. We encountered several case studies that transfer valuations between contrasting contexts or from the global to the local level, such as by applying data from (Costanza et al., 1997) to regional settings. Although services provided by certain structures and functions may, from an objective viewpoint, be the same, benefits or well-being gains received from them are dependent on local stakeholder perceptions (Ernstson, 2013; Martín-López et al., 2012). Thus, it is neither helpful nor representative to transfer case study results for benefits as secondary data to other case studies while assuming the same benefits without including context specific empirical data from the local conditions or stakeholders. Moreover, applying such benefit transfer approaches to valuing urban ecosystem service provision requires that sufficient contextual information is provided in the initial valuation to ensure that it can appropriately be transferred to the new case study. Our research suggests that this often was not the case, with limited or no contextual information (e.g. city size, population density, growth rates, poverty levels etc.) provided in many of the studies reviewed.

4.5.4. (iv) Stakeholder engagement

Only a 20% of the reviewed studies involved stakeholders. If the ecosystem services approach is not to become a technocratic process (Turnhout et al., 2013) there is a pressing need to ensure that urban stakeholders are actively involved in urban ecosystem services research. Services appropriated from ecological structures and processes are not fixed, and values ascribed to the appropriated ecosystem services are dependent on those who do the appropriation. If the urban ecosystem services concept is to be a useful tool for sustainable urban planning, stakeholders' perceptions of urban ecosystem services should be considered more carefully in research. Involving stakeholders throughout the research process should be recognized for its potential to enhance the identification, valuation, and management of urban ecosystem services. Doing so will help provide meaningful and crucially context specific descriptions of the role of urban ecosystem services for improving human well-being and urban sustainability.

4.5.5. (v) Integrated research efforts

Our review has highlighted that urban ecosystem services research has drawn on a wide range of research perspectives, with particular focus on specific ecological structures providing ecosystem services and the operationalization of specific aspects of the ecosystem services cascade. In order for urban ecosystem services research to fully contribute to sustainable urban planning agendas, there is a need to better integrate these diverse and somewhat fragmented approaches. This requires greater emphasis on operationalizing the entire ecosystem services "production chain" from quantifying urban ecological structures, through

assessing the related processes and quantifying the actual appropriated services and related benefits. Moreover, future research needs to comprehensively investigate the implications of the spatial extent of planning approaches and address the mismatches of urban policies and legislation with regard to the origin and appropriation of urban ecosystem services (Bai et al., 2010; Gómez-Baggethun et al., 2013; Scarlett and Boyd, 2015). This, in part, requires a greater focus on studying multiple ecological structures within urban extents and understanding the spatial and temporal interdependencies between those structures and the services appropriated from them. Finally, the insights from the various research perspectives (ecological, governance, methods, social, economic, and planning) need to be synthesized to ensure that the full range of urban ecosystem services are considered and that research results comprehensively capture the complex relations between urban ecosystem services and human well-being. Only an "interdisciplinary and even transdisciplinary undertaking" (Potschin and Haines-Young, 2011) can truly capture all the elements of the cascade and draw holistic conclusions for the planning and management of urban ecosystem services.

4.5.6. (vi) Closing the feedback loop between urban ecosystem service appropriation and the management of urban ecological structures

In order for the ecosystem services concept to be of relevance in practice, research on urban ecosystem services need to translate scientific findings into actionable knowledge and feed information back into the planning and management of urban ecosystems (Daily et al., 2009; Potschin and Haines-Young, 2011). Our findings suggest that this 'feedback loop' between the assessment of the benefits of urban ecosystem services and the subsequent management of ecological structure and functions is lacking in the literature, with only 28 of the case studies considering ecosystem structures, functions and the benefits for the resulting ecosystem services (Fig., 4). Operationalizing the ecosystem services cascade model (Fig. 1) requires a management component that would link benefits back to structures translating scientific knowledge into practice. An understanding of received benefits would allow urban planners to better account for and manage the structures that provide them. Therefore, an essential challenge for research is to address these missing links between research and practice and to explicitly link urban ecosystem service provision and use to urban planning and management. Only then can urban ecosystem services research meaningfully contribute to urban sustainability.

5. Conclusions

This study has given an overview of the emerging trends and gaps in the existing research field on urban ecosystem services and highlighted six key challenges for future research. We examined how ecosystem services have been conceptualized and operationalized by applying a systematic review protocol to a set of 201 peer-reviewed case studies and providing a quantitative analysis of key trends and research paths that emerged. We found that while gaining momentum, the urban ecosystem services field has increasingly attracted case study research from a variety of disciplinary perspectives, which place emphasis on different conceptual elements according to their area of interest or the case study focus. Considerable discrepancies of focus are evident in the field, with few signs of convergence under leading perspectives or models.

As a result of our analysis, we want to highlight the following recommendations for further ecosystem services research in urban environments:

1. The contextual coverage of the research field should increase to provide more robust knowledge generation of how the concept can be useful for urban planning in different contextual settings.
2. To strengthen the potential of the ecosystem service concept to function as a shared concept between different fields, further research needs to explicitly address differences in the use of key terminology, while making sure that the main underlying normative assumptions are transparent.
3. While in-depth research on specific components is valuable, the aim for the research field as a whole should be to holistically cover all stages of the production of ecosystem services, including the causal links between ecological structures, their performance, and their value to humans.
4. Further research should both stress the importance of stakeholder involvement in context-specific identification of benefits, and consider ways in which stakeholder involvement can be strengthened in other stages of the ecosystem services production process, such as structuring and managing providing ecosystems.

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Appendix A. Supplementary information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.ecoser.2015.05.001.

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