Grunewald, K.; Bastian, O.; Louda, J.; Arcidiacono, A.; Brzoska, P.; Bue, M.; Cetin, N.I.; Dworczyk, C.; Dubova, L.; Fitch, A.; Jones, L.; La Rosa, D.; Mascarenhas, A.; Ronchi, S.; Schlaepfer, M.A.; Sikorska, D.; Tezer, A.. 2021. **Lessons learned from implementing the ecosystem services concept in urban planning.**

The definitive version was published in *Ecosystem Services*, 49, 101273.
https://doi.org/10.1016/j.ecoser.2021.101273

Grunewald, K., Bastian, O., Louda, J., Arcidiacono, A., Brzoska, P., Bue, M., Cetin, N.I., Dworczyk, C., Dubova, L., Fitch, A., Jones, L., La Rosa, D., Mascarenhas, A., Ronchi, S., Schlaepfer, M.A., Sikorska, D., Tezer, A. 2021. Lessons learned from implementing the ecosystem services concept in urban planning. Ecosystem Services, 49, p.101273.

This is a post-print version of the article. The original can be found at:

https://www.sciencedirect.com/science/article/pii/S2212041621000310

Lessons learned from implementing the ecosystem services concept in urban planning

Abstract:

This paper presents a summary of lessons learned from implementing the ecosystem services (ES) approach into urban planning practice in different European urban settings. We summarise a survey co-created with, and presented to, researchers and end-users in city administrations from ten European case study cities. To complement the expert analysis, 14 semi-structured interviews were conducted among stakeholders to assess the use of ES in practice in urban settings. There was strong agreement between scientists and practitioners on both the opportunities and the barriers to uptake the ES concept in urban planning practice. Key agreements were that the ES concept supports decision-making as well as spatial planning, it is most useful as a communication tool, and monetarisation and public pressure can be considered as promoting factors. Barriers are lack of evidence including case studies, standardised methods and criteria to evaluate nature and its benefits, lack of legislations/reform, limited capacity and reluctance to apply ES in planning practice, and limited public involvement. On individual aspects, such as the monetarisation of ES, views differed both among the scientists and the practitioners. Derived from our investigations we summarize in which circumstances the ES concept is most relevant and useful for urban planners and decision-makers.

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1 Introduction

Urban nature provides various ecosystem services (ES) that are a basic prerequisite for the quality of life in cities (e.g., Gómez-Baggethun et al. 2013; Kabisch et al. 2015; Artmann et al. 2017; Grunewald and Bastian 2017; Orta Ortiz and Geneletti 2018; Scott et al. 2018; Breuste et al. 2020; Palliwoda et al. 2020). Urban nature refers here to urban green and blue spaces (GBS) ranging from the remnants of natural ecosystems, human-designed nature typically found in urban public spaces, such as parks or allotment gardens, and informal green spaces such as wildflower meadows, vacant lots or roadside vegetation (Kowarik 2005; Sikorska et al. 2020). Blue spaces refer to waters and their surroundings including more or less artificial ones such as channels or ponds. In this context, GBS can be regarded as natural capital – stocks yielding flows of ES, from which people derive benefits (Bateman and Mace, 2020).

ES can be derived by humans both directly and indirectly from GBS, and an increasing number of studies indicate a link between ES provisioning and health and well-being of residents (Bertram and Rehdanz 2015; Jones et al. 2016; Twohig-Bennet and Jones 2018; Myers 2020). All kinds of GBS and the ES they provide are a common good for society that all citizens should equally benefit from (UN 2015). In practice, there are winners and losers and the ES generated involve trade-offs according to desired outcomes (Martín-López et al., 2014; Turkelboom et al., 2018). Thus, a key challenge for strategic planning (being it spatial, landscape or urban planning) is to ensure that the urban environment can sustain a stable flow of ES, while promoting equal access to GBS and the goods and services they provide (Scott et al. 2018; Hersperger et al. 2020; Wende et al. 2020).

Urban socio-ecological systems are highly complex and embrace multiple interactions between economic, social and ecological processes (Alberti 2005; Beichler et al. 2017). Production and consumption, demand and supply of ES interact in the urban environment, where their reciprocal linkages are not only spatiotemporally explicit but also non-linear, determined by the large existence of built and social capital. Such complex interactions make the future of urban areas mostly unpredictable, therefore challenging scientific approaches to anticipate future trends (Xiang 2013; Kaczorowska et al. 2016; Batty 2018). In addition, options and challenges for ensuring the flow of ES depend on scales of responsibility and policy actions (Grunewald and Bastian 2015). A crucial question is how to use the ES concept to improve urban planning, and to steer and manage urban development processes in order to provide favourable living conditions and minimize or avoid negative socio-economic and environmental impacts (Bateman et al. 2013; Paudyal et al. 2016). Another question is whether the ES concept can make a contribution in terms of a comprehensive socio-ecological transformation (Abson et al. 2014; Wolfram et al. 2019; Avelino et al. 2020).

Despite a recent explosion of scientific interest in urban socio-ecological systems (Andersson et al. 2019) and increasing evidence of GBS potential to provide benefits to rising city populations, the range of opportunities, barriers, and needs remains largely unexplored. There is a growing body of literature attempting to integrate ES into landscape and urban planning, management and decision-making (see for example de Groot et al. 2010; Scott et al. 2013; Haase et al. 2014; Grêt-Regamey et al. 2017; Hegetschweiler et al. 2017; Brzoska and Spāģe 2020; Geneletti et al. 2020; Macháč et al. 2020; von Haaren et al. 2020). However, few studies (as Scott et al. 2018) contrast the theoretical approach with the degree of implementation from the practitioners' point of view. Although practitioners generally agree on the potential of the ES concept to improve urban planning, they struggle with several complexities and operational limitations inherent to implementing the ES approach. Gaps might exist between practitioners' perceptions and actual implementation (Albert et al. 2014; Mascarenhas et al. 2014; Rall et al. 2015). Also, the empirical data across different urban planning contexts suggests the need to identify common lessons learned from real-world examples and hence support theoretical advancement (e.g., Ruckelshaus et al. 2015).

Against this background, the aim of this article is to assess the practical implementation of the ES concept in current urban planning and decision-making. It aims to answer three main questions:

1. In which cases is the ES concept most relevant or useful to urban planners?
2. To what extent is the ES concept already integrated into urban planning?
3. What are the barriers, opportunities, and needs for uptake of the ES concept?

The assessment combines two components, exploring the perspective of both scientists working on ES in an urban setting, and practitioners responsible for landscape and urban planning and decision-making. We gathered scientific experts' views in a dedicated session at the regional Ecosystem Services Partnership (ESP) Conference in San Sebastian, Spain, in 2018, which we supplemented by follow up discussions and joint work over an extended period; the practitioners' views we gathered through semi-structured interviews in ten cities/city-regions of seven European countries, which acted as case studies for this research.

We then integrated the views from scientific experts with the opinions and needs of practitioners and provided recommendations for an improved implementation of the ES concept in urban planning, structured to cover different categories. We are convinced that sharing experiences and good practices with other cities/city regions can improve the credibility and usability of the ES approach.

2 Methodological approach

To assess the practical implementation of the ES concept in urban planning and decision-making, we developed the methodological approach shown in Figure 1 and further detailed in the following sections.

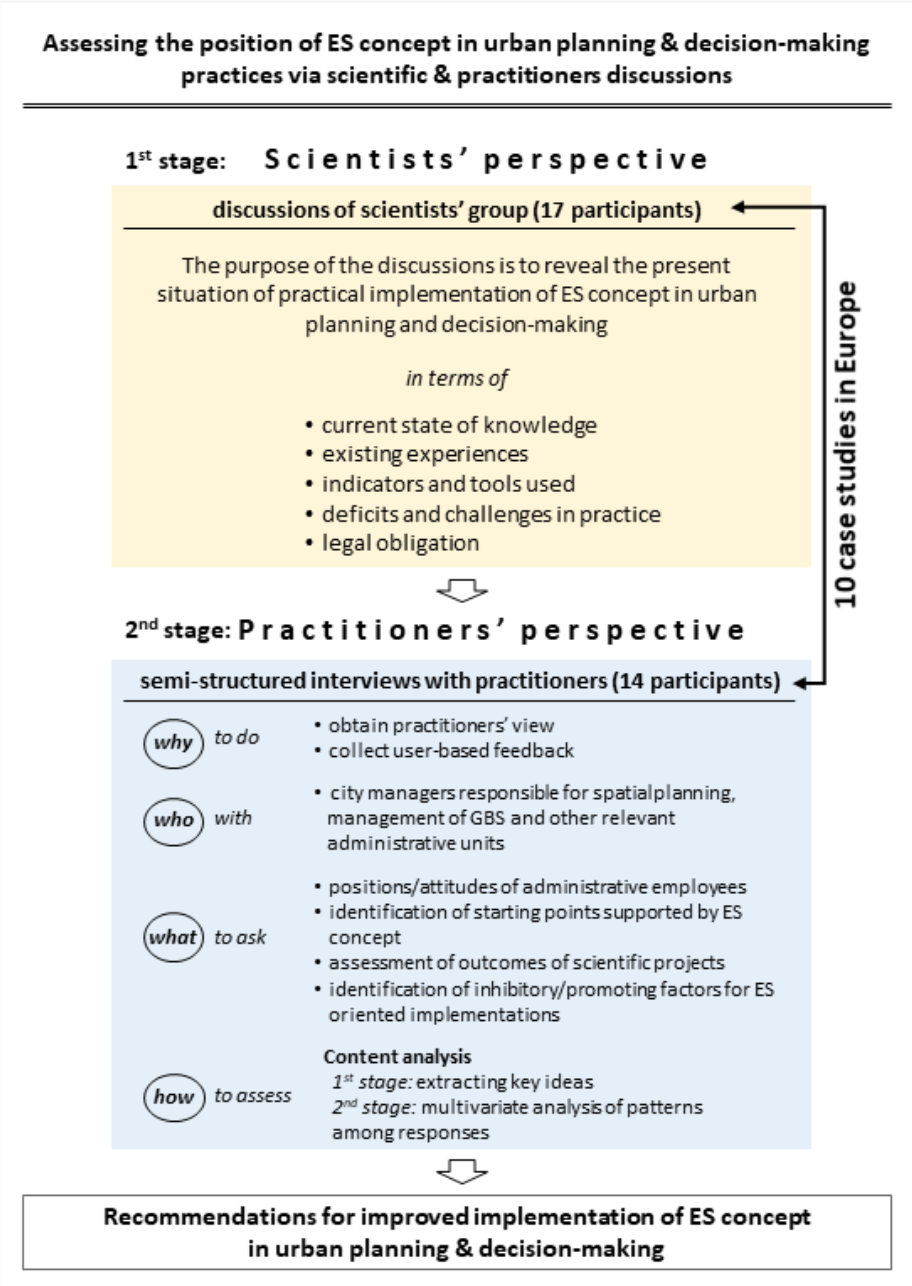

Figure 1. Research design & methodology

2.1 Scientific experts' perspective

We investigated the views of researchers, considered to be the scientific experts in ecosystem services studies during the ESP conference session entitled "Implementation of the ecosystem services concept for urban planning and development". The session was devoted to current state, knowledge, experiences, indicators, and tools but also deficits and challenges in terms of the ES concept and its practical application in urban planning and spatial decision-making. The views from seventeen scientific experts, mainly from European countries, were presented. We asked these participants to provide case study examples exploring the degree to which the application of the ES concept had been helpful for specific ecological urban planning issues in cooperation with administrations and decision-makers. The session collated the perspectives of the diverse set of urban scientists on the key questions of the study. From this exercise, key aspects related to the

application of the ES concept were bundled (concepts, spatial and temporal approaches, dimensions such as planning, economy, education).

2.2 Case studies

To explore these issues in more detail we selected ten case studies, representing a wide range of spatial scales, size of population, and geographic and climatic conditions across Europe (Table 1, Figure 2). Contextual information for each local case study supporting this research was systematically collected (Table 2).

Table 1: Overview of case study urban areas

Code	City/City-region (Country)	Spatial scale*	Size of studied area	Population (in 2019)
CS1	Istanbul (Turkey)	Very large metropolitan area	5,461 km^2	15.52 million
CS2	Lisbon (Portugal)	Large metropolitan area	3,015 km^2	2.8 million**
CS3	Munich (Germany)	Large metropolitan area	1,550 km^2	over 1.9 million**
CS4	Łódź (Poland)	Metropolitan area	293 km^2	700,000
CS5	Dresden (Germany)	Metropolitan area	404 km^2	560,000
CS6	Geneva (Switzerland)	Metropolitan area	282 km^2	501,750
CS7	Rostock (Germany)	Medium-sized urban area	670 km^2	275,000**
CS8	Liberec (Czech Rep.)	Small-sized urban area	106 km^2	104,000
CS9	Rescaldina (Italy)	Very small urban area	8 km^2	14,200
CS10	Ragalna (Italy)	Very small urban area	40 km^2	9,000

* after classification of OECD (https://data.oecd.org/popregion/urban-population-by-city-size.htm)

** Referring to year 2018

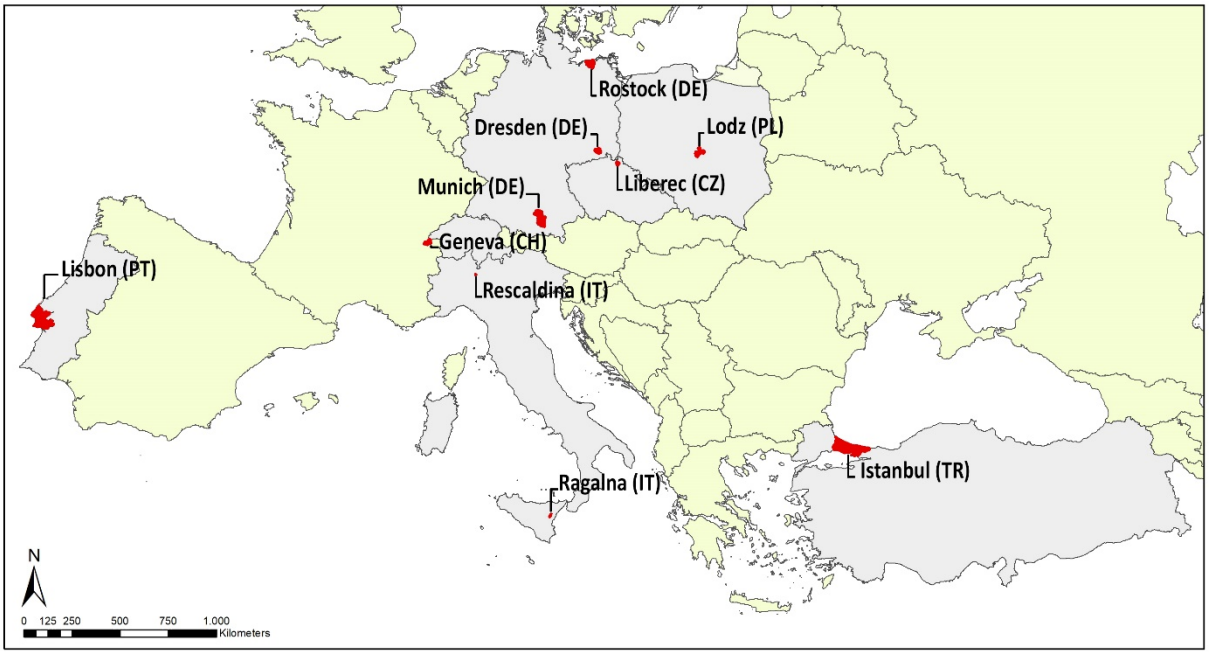

Figure 2: Locations of the case study areas

Table 2: Formal code sheet for the description of case studies.

Aspects
City name, country and administrative character (region, administrative city, district)
Responsible person, main contact person (name, e-mail); involved partners, institutions
Focus of the study/application: (a) objective, keywords, (b) ES term/concept explicitly used? (c) investigated ecosystem types and the ES categories/classes, (d) sponsors of the study
Analytical approach: (a) qualitative description and evaluation of ES (non-numeric/ordinal scaled statements) or/and (b) physical quantitative description and evaluation of ES or/and (c) monetary valuation of ES
Main results, products
Success factors, limitations

Additionally, a brief overview of the state of implementation of the ES concept, including the legally binding character, was prepared by the authors from/for the countries where the case studies and interviews (see next section) were conducted and thus these experiences could be incorporated (Supplementary material B).

2.3 Practitioners' perspective

A survey of practitioners' views was conducted by the case study investigators to obtain the perspective of those likely to be using and implementing ES approaches, which may be a very different perspective from that of the scientists. The survey targeted practitioners working in environmental management and planning authorities, covering different departments and responsibilities. Views on the implementation of the ES concept by practitioners were collected through semi-structured interviews in the case cities. The interview protocol was structured around issues such as ascertaining the level of awareness and knowledge of the integrative ES concept and the perceived level of current integration in urban planning documents or environmental assessments (cf. Mascarenhas et al. 2014). It is important to understand areas with plan led systems as opposed to development led systems, as this significantly affects how the ES concept might be used in decision-making. Plan led systems, such as those in Germany (Wende et al. 2020), means that the ES concept - if embedded - will be a statutory requirement. In development led systems, for instance those in UK, the ES concept is a material consideration only (Scott et al. 2013, 2018).

In each case study, we identified and contacted individuals responsible or involved in the urban planning process, the management of green spaces and related aspects, and where an ES approach could be implemented. In most cities it was possible to select decision-makers, managers or other practitioners from different sectors such as Environmental Agencies, Regional Planning Authorities, City Planning Offices, and Offices for Green Space, as well as Mayor/Municipal Environmental Politicians who agreed to participate in the survey. This was useful for providing recommendations on different aspects of urban planning.

The main objectives (O) / questions (Q) used in the survey were as follows:

A) O: Working out of positions/attitudes of administrative employees towards the ES concept (Q1: What do you think about the ES concept in general? Is it necessary or useful for political/administrative actors of the city administration in the implementation or decision-making processes?)

B) O: Identification of starting points/structures of daily work, which can be enriched/supported by the ES concept (Q2: What requirements/requests do you have with regard to ES/biodiversity (nature in the city)? In which concrete instruments do you see possible applications?)

C) O: Assessment of the outcome of scientific case studies/projects (Q3: To what extent are the outcomes/results of ES-assessments relevant (added value) for environmental agencies/authorities and other sectors?)

D) O: Identification of inhibitory/promoting factors for the implementation of the ES concept at municipal administration level (Q4a: Which inhibitory/promoting factors do you see? Q4b: What suggestions do you have regarding fields of application?)

We transcribed the interviews and performed the content analysis (Adams 2015), following with the extraction and summary of the key points from the interview responses using an unbiased, common language. In order to avoid bias by having a single person conducting the analysis, multiple assessors were involved in the process. The first synthesis of the interviews was conducted by the interviewers themselves who extracted large sections of text around each question, which contained key elements of the interview response. The extraction of key themes from this text was then conducted in parallel by two independent assessors. The two assessors then met together to harmonize their assessments to a common set of phrases. This produced an initial list of 115 phrases across the four questions, with some themes emerging across questions and phrased the same. The list of 115 phrases was then sent back to the original interviewer for a third check on correct interpretation of the interview content. The phrases were subsequently grouped into a maximum of eleven higher-level themes per question, prior to analysis using multivariate approaches to determine commonalities and differences in the responses across the interviews (Supplementary material A, table 6).

Each of the four questions was analysed separately, with question 4 also split into two parts, each analysed separately. For questions 1 to 3, each higher-level theme was quantitised (process of transforming coded qualitative data into quantitative data, Tashakkori and Teddlie 1998) by assigning a score of “1” if the participant provided a response that was categorised under that theme with negative views, a score of “2” if the participant had not answered or provided a response with mixed opinions and a score of “3” if the participant provided a response that was categorised under that theme with positive views. For questions 4a and 4b a score of “2” was assigned if the participant provided a response that was categorised under that theme and a score of “1” otherwise.

To derive the key points made by practitioners on the implementation of the ES concept and take into account the discrete nature of the data (Kolenikov and Angeles 2004), a principal component analysis (PCA) based on a polychoric (or tetrachoric if binary data e.g. questions 4a and b) correlation matrix was conducted for each question. Both the eigenvalue-one criterion (Kaiser 1960) and scree test (Cattell 1966) were used to determine the number of components selected for PCA interpretation (Supplementary material A). For clarity, only the first two components (PC1 and PC2) were presented and illustrated for each question. Statistical analysis was performed using R 3.5.0 (Team R Core 2018) and the psych packages (V1.9.12; Revelle 2019).

3 Results

3.1 Five statements regarding the ES integration in urban planning as a result of the ESP session

Analysis of the statements of the session contributors showed that there was high heterogeneity in the understanding and actual use of the ES concept, which is in line with the literature (e.g., Albert et al., 2014; Mascarenhas et al. 2014; Hansen et al. 2015; Lam and Conway 2018).

(1) Scientists and practitioners acknowledge ES as an innovative concept to deliver urban planning solutions

ES help to provide arguments for urban planning decisions aimed at environmental conservation (i.e. green space protection and design; limit of soil sealing; biodiversity protection and increase), and better planning/design of new urban areas or rehabilitation of urban ecosystems. A crucial issue to be addressed in contemporary urban contexts is the dichotomy between the pursuit for urban compactness (to limit further urban sprawling) and the demand for new greenery or increased access to it.

These arguments are often based on multiple benefits derived from nature that can be quantified via ES (e)valuation. Improved information on benefits and costs (including opportunity costs – or benefits foregone) can increase the consensus on planning decisions aimed at the protection or increase of the urban ecosystem services. Participatory planning approaches tend to be more successful (i.e. with citizen participation for issues such as identification of preferred equipment/services in parks), and ES can help to communicate the importance of GBS and raise awareness of a wide range of benefits derived by urban ecosystems (see also Mascarenhas et al. 2016).

(2) ES concept and related terminology are still far from reaching a common consensus

Many terms (i.e. ecosystem services, natural capital, green-blue infrastructure, nature-based solutions, well-being, nature's contributions to people, ecological functions and benefits, landscape functions) are often used in an inter-exchangeable and unclear way. This is particularly evident for practitioners or other technical individuals involved in urban decision-making (planners, municipality politicians, officials or technicians), who are not very familiar with the concept of ES, or have never heard of it. Some administrations are characterised by having a lack of experts, inadequate personnel, and a lack of economic resources or appropriate data for the assessment. There is a frequent resistance and inertia in innovating "established" structures and processes, as administrators or technicians might prefer a consolidated approach in urban planning ("continue-as-before"), especially if they are also sceptical towards the added value or novelty of ES (an old idea in new words).

(3) The use of ES in spatial planning and practices at different scales is limited but increasing

The practical use of ES in spatial planning is increasing and involves planning processes at different scales, ranging from urban regions, municipalities of different size to neighborhoods (as residential gardens, street greenery), therefore including different ecosystems or ecological spatial units (e.g. hydrological basins, parks, coastal areas, urban-rural interface, peri-urban landscapes), see also Ronchi et al. (2019, 2020) and Tezer et al. (2020).

Previous policy efforts at European, national and regional scales aimed at the promotion of ES in policy-making have increased the use of ES in planning processes (Keenan et al. 2019). However, similar to previous findings by Mascarenhas et al. (2015), a direct and explicit reference to ES in planning processes and related documentation is still rare, and in the majority of the cases ES were a simplistic label to encapsulate or reiterate general environmental/ecological objectives or strategies. Furthermore, the added value of the integration of ES is not always explicitly reported or transparently communicated to all stakeholders involved in the planning processes.

(4) Diverse challenges in the ES assessment phases are major factors influencing the degree of ES integration in spatial planning

Quantitative approaches to ES assessment such as monetarisation (especially for regulating and cultural services) depend on so many uncertain factors that it is very complicated if not impossible to evaluate them in a sound and replicable way, or no precise economic relation between the

ecosystem and the provided services can be found, or valuation rules are missing. Lack of appropriate and systematic data for ES assessment is also a critical issue, especially when assessment scale decreases and fine resolution data become needed (c.f. Davidson 2013; La Rosa et al. 2016). Furthermore, reliability of assessments changes with the single ES considered (see also Hamel and Bryant 2017). The highest reliability referring to monetary valuation is attributed to provisioning services (as their calculation is based on market products), while the lowest is attributed to cultural ES (especially those which cannot be connected to tourism). Regulating ES also require complex modelling approaches and are heavily dependent on the assumptions made. Differences in results derived from assessments can be a result of the assessment design and application.
Another crucial dimension of uncertainty is the difficult interpretation of the outputs from ES assessments for decision-makers and local politicians, and their translation in a more direct and understandable way. This point is related to the gap between theory (science generated knowledge) and practice (the application of that knowledge) when policies informed by scientific knowledge do not generate collective benefits (c.f. Walker et al. 2001). An important side-effect of the persistency of this gap is the potential loss of trust in the policy-making process by citizens.

(5) Binding legal frameworks are essential to ease the ES integration

The overall legal dimension of ES can cover a wide range of laws, regulations, norms, constraints in the use of the land (i.e. protected areas/habitats/elements) but it is not yet a legal approach nor an official instrument. The lack of integration is also strongly due to the relation between urban planning and national/regional planning systems, which shape the scope and content of each spatial plan, as each country/region has its own planning framework and rules for the design of spatial plans. A normative reform can offer a possible path towards the mainstreaming of this concept to local practitioners and planning administrations, embedding ES through new forms of regulations and planning standards, at least in countries with plan led development systems.

3.2 Implementation of ES in urban planning - case studies from Europe

Ten case studies (Table 1) show examples where the application of the ES concept was helpful for specific ecological urban planning issues in cooperation/acceptance of administrations and politicians/decision-makers. The ES term and ES concept were explicitly used in all studies. Most studies had assessed ES qualitatively and quantitatively, while not all had conducted monetary valuations. According to the different objectives and tasks in the case studies, the products to be developed were also different (Table 3).

Even though the concept of ES has been used by scientists for almost two decades, its practical use in urban planning and decision-making process varies from country to country and from city to city. The respective national and local-regional context is important. Amongst others, a clear distinction between existing concepts and the ES approach is desired by practitioners. As a rule, in a planning context of a country or region, it is decisive whether the ES concept is seen as an "add-on" solution or whether ES is already integrated in the planning process.

For the case studies, we tried to interpret possible impacts of current practices depending on the main outcomes (Table 3). Our basic starting point of this interpretation was to answer the questions of “What could the impacts of the outcome of X in the planning scale of Y be and/or how could it be useful for further processes of planning?” This interpretation supports the tangible explanation of current level of ES and urban planning integration at different spatial scales. Thus, it is clear from Table 3 that current ES practices are mostly at the upper-scale planning level such as regional or metropolitan by mainly aiming to steer or guide subscale planning tools like master plans or development plans. This guiding process is basically carried out by determining blue and green

infrastructure networks, ES indicators, zoning, critical ES provision areas, etc. that can directly create tangible impacts on planning applications. On the other side, small scale (local/neighborhood level) practices are still in the process of raising awareness of stakeholders, therefore, it is difficult to mention ES based urban planning practices in municipalities of small-sized cities or districts.

There are examples in some cities, particularly in Central and Eastern Europe, where the integration of ES in urban planning has recently started; as reported for cases CS8 (Liberec) and CS4 (Łódź, Table 3, 4). Many of these cities have experienced a socio-economic transition from a centrally-planned to a market economy, and a management shift from entirely top-down to participatory (Skaruba et al. 2017). For emerging economies, the situation is more challenging. Actors of the market economy often have close relationships with policy-makers and central authorities, which can foster urban projects (i.e. spatial development projects) and therefore hamper the use of ES approaches for sustainable planning of cities (CS1, Istanbul).

In several case studies the scientists and practitioners highlighted the interesting discrepancy between the (scientific) criticism of the monetarisation of ES (critical of the reduction of the highly diverse human-nature-relationship into specific or pre-defined economic categories; see for example Schröter et al. (2014) for a synthesis) and the wishes of practitioners and policy makers to rely on monetarisation of ES, as a powerful tool in the discussion with the public on the benefits that some ecosystems can have for people.

The success factors in the implementation of ecosystem services in urban planning listed in Table 4 show that good contacts, trusting cooperation between scientists, practitioners, planners and administration are essential. Limitations concern the data situation but also political and planning related contexts.

The short overview of the implementation of the ES concept in the case study countries (see Supplementary material B) showed that in Portugal and Switzerland, the ES concept is already explicitly implemented in some of the national, regional and/or municipal strategic policy documents and it is integrated in urban planning activities. In most of the studied countries (Turkey, Germany, Italy and Czech Republic) integration of ES in practical planning processes is on a good trajectory but still underdeveloped, the general reason being there is no legal obligation to implement the ES concept into urban planning. In these countries, the ES concept is usually proposed by spatial planners and other stakeholders (on a voluntary basis) as a decision support tool or as an information base for setting strategies (e.g. municipal climate adaptation strategies). In Poland, planners and decision-makers still do not work with the ES concept in a direct way.

Table 3: Results/output of case study applications and integration of results in urban planning/decision-making

Case study (CS), City (see Tab. 1)	**Addressed/related planning scale**	**Main results, products, outcomes**	**Output integrated in planning process/ decision-making**	**Potential direct/indirect impacts of outputs on other planning instruments (spatial plans, policies and actions)**
CS1 Istanbul	Greater Municipality Environmental Master Plan	Determination of critical ES potential areas, which will guide spatial land-use and land-management strategies in the environmental master plan.	Yes	- Developing land-use and land management strategies by considering ES - Guiding regulatory tool for subscale (lower level) spatial plans such as masterplans and local level development plans
CS2 Lisbon	Metropolitan area	Qualitative analysis of ES integration.	No	- Not applicable, as the study was on the integration of ES itself.
CS3 Munich CS7* Rostock	Urban and Regional Plan	(i) Analysing formal and informal planning documents as well as participatory processes relating to ES (ii) Determining ES integration potential in planning instruments (iii) Assessing appropriate indicators for urban ES, which can then be used in urban and regional planning (iv) Brochures for planning practitioners, administrators, decision-makers and the public; information event and exhibition (about ES and biodiversity)	Yes	- Identifying connecting points for linking the ES approach to regional and urban planning - Increasing awareness and knowledge of planners, decision-makers/local politicians and public about ES
CS4 Łódź	City of Łódź	(i) Implementing “Blue-Green-Network” concept into city’s Integrated Development Strategy (coherent network of urban and metropolitan green	Partially, terms “functions and benefits” are used, as ES concept is poorly recognized by the public	- Increasing awareness of public about ES via recreational services of green infrastructure - Developing blue and green infrastructure network in masterplans and monitoring

		areas including sports facilities, public recreation, areas as well as natural areas) (ii) Setting threshold values in the masterplan for Łódź for green areas accessibility standards – minimal distance to green space for each inhabitant and area available (iii) Recreational ES from parks available for the residents in an online map database		the performances of masterplans via threshold values on urban green space accessibility
CS5 Dresden	Municipal Landscape Plan of Dresden	(i) Brochure for the public, smartphone based guided trail with information of ES for visitors (ii) Recommendations for planners/decision-makers/local politicians	Partly (primarily for the communication process)	- Increasing awareness and knowledge of planners, decision-makers/ local politicians and public about ES
CS6 Geneva	Regional (Canton)	(i) A strategic plan for future tree plantations based on optimizing key ES (ii) Green Infrastructure based on biodiversity, connectivity and ES (iii) Biodiversity Strategy for the Canton of Geneva based explicitly on ES	Yes	- Developing area action plans for tree plantations - Developing action plans for implementation of Biodiversity Strategy - Green infrastructure planning for new projects, policies and zoning laws to ensure the ES based objectives
CS8 Liberec	Municipal Master Plan of Liberec City	(i) Brochure for the public, recommendations for urban planners/decision-makers/local politicians, study on green and blue infrastructure network in the city.	Mainly for communication and raising awareness among decision-makers	- Increasing awareness and knowledge of planners, decision-makers/local politicians and public about ES (blue and green infrastructure) - Developing municipal climate adaptation strategy
CS9 Rescaldina	Municipal Plan	(i) Urban Plan based on ES assessment (The Urban Plan is now approved and in force)	Yes	Implementations of ES based spatial decisions via green infrastructure practices

		(ii) ES were functional for the deployment of a local Green Infrastructure		
CS10 Ragalna	Municipal Plan	(i) Qualitative evaluation in the report of the plan (ii) Zoning	ES considered (partially) in the final zoning of the Plan	- Increasing awareness of planners, decision-makers/politicians and public about ES in local level - Developing master plans and/or implementing development plans by considering ES potentials

* CS3/CS7 - Munich and Rostock were analyzed together

Tab. 4: Success factors and limitations in the implementation of ES in urban planning within the case studies

Code/ city	Success factors	Limitations
CS1 Istanbul	Scientists and practitioners working together from the beginning. Therefore, practitioners gain experience and knowledge from scientists about new methods and approaches related to ES.	Lack of temporal and site specific ES based quantitative data for different level spatial scales, such as zoning or development scales. Additionally, legal tools of spatial plan making do not have yet an explanatory background for ES integration into spatial plans explicitly.
CS2 Lisbon	Existing contacts with regional planning authority.	Lack of some documented information; Lack of human resources in the administration with deep knowledge/understanding of ES.
CS3 Munich CS7* Rostock	Inter- and transdisciplinary communication and cooperation: bridging the gap between science and practice by integrating actors and experts operating in local and regional planning practice (science-praxis dialogue); Identifying connecting points for linking the ES approach to regional and urban planning by analysing formal and informal planning documents analysing participatory planning processes; Enhanced consciousness on relevance and importance of ES in planning.	Since the ES concept is not yet a legal approach or an official planning input, broad involvement of regional (planning) actors is limited; ES is not recognized as a concept in the administrative process; Lack of data for appropriate and comparable quantification of supply and demand of all selected ES in both study areas.
CS4 Łódź	Cooperation of scientists, local policy makers and other practitioners. Currently a general willingness from administration to integrate ES into spatial planning (translated into some national-level planning policies). Support from the research community sought by municipal institutions.	Often changing political representation in the city which has different priorities (urban greenery is not always the main priority), lack of data (in comparison to other countries), most of the practitioners are not familiar with the ES concept and it has no support in the legal documents.
CS5 Dresden	Scientists and practitioners working together from the beginning.	Lack of data for some approaches; ES not yet a legal approach, not an official instrument; no recognised concept in the administrative process.
CS6 Geneva	Scientists and practitioners working together from the beginning. Technical positions (e.g., GIS analysts) shared between state and research institutions. Cohesive informal group creates safe space for experimentation and exchanges.	Lack of data for key ecosystem services (e.g., pollination) and lack of familiarity with concepts by partners.

CS8 Liberec	Constant engagement of the scientists in the planning process and support by the research community (trainings, workshops, sharing data and knowledge), general willingness to integrate ES into planning	Poor recognition of the term by the public, despite the policy-makers are well familiar with the concept, lack of knowledge in the private sector as a limiting factors
CS9 Rescaldina	The support of the local administration in the ES implementation for the decision-making process.	Time-consuming process (5 years), most of the decisions depended on the political stability of the administration.
CS10 Ragalna	Protection of ecosystems, which provide regulating ES, is higher.	No spatial explicit assessment; not all categories of ES included (no specific focus on cultural ES); no focus on large forest ecosystems although present in the municipality.

* CS3/CS7 - Munich and Rostock were analyzed together

3.3 Synthesis of the interviews with practitioners

Question 1. "What do you think about the ES concept in general? Is it necessary for political/administrative actors of the city administration?"

Analysis of question 1 is shown in Figure 3a. The PCA indicated that awareness of ES was closely related to planning and decision-making, for example, "*some politicians, administration officers but also residents are aware of ES*"(Participant 11), "*you have useful indicators that are valid and can be used in the planning process"* (Participant 5). In general, practitioners who were aware of the ES concept agreed that the ES concept supported decision-making as well as spatial planning: "*I can see how the ES concept can potentially help arbitrate broader societal question that relate to natural resources, especially in urban centres*" (Participant 6). Some practitioners were convinced by the benefit of using the ES concept in planning, for instance, the ES concept can be "*the key to address a series of concerns at the level of regional and municipal planning, but also national level*" (Participant 9), "*it is very useful concept for cities*" (Participant 11). Others already used the ES approach as part of upper-level planning studies (Participant 10).

It was also suggested that the ES concept was useful for decision-making and in some cases "*is already in the language of the local decision-makers*" (Participant 9). The evaluation of benefits provided by the ES concept appeared to be an important aspect for decision-making as it can " *[…] help in argumentation at all levels (officers, politics, public)*" (participant 11).

Some practitioners felt the ES concept could be useful as a communication tool to promote the benefits of nature: "*I see it as a kind of communication concept*" (Participant 1), "[the ES concept could be] *very beneficial for the city's administration, especially in communicating to the citizens how we can use nature for reducing costs of city's functioning*" (Participant 7). However, the analysis separated interviewees who thought it was useful for decision-making and planning, from those who thought it was most useful as a communication tool. As such, some practitioners saw the potential of the ES approach to "*promote activities based on nature*" (Participant 7), while others believed ES could be "*a good way to communicate some of the planning choices*" but not vital for planning processes: "*We have relied for decades on planning processes without ES*" (Participant 14). Some practitioners also referred to the ES concept as "*an idea*" but the lack of legislation in urban planning meant that the ES concept was not applied in practice (Participant 8).

Practitioners who stated the valuation of nature through monetarisation often found the public could play an important role in ES implementation (e.g. public pressure), but found the ES concept difficult to implement and appeared less likely to adopt it (e.g. willingness). For instance, *"It would be very beneficial if the benefits provided by urban nature would be systematically quantified on the city level [...] ES assessment and valuation is very complex and needs effort from wide range of experts (multidisciplinary approaches are not very common in public administration)"* (Participant 11). Only two practitioners were sceptical about monetarisation because it "*[…] is not effective in politics*" (Participant 4) and there is no "*meaningful benefit for the administration*" (Participant 1) to value nature through monetarisation.

There was no clear relationship between the opinion of practitioners towards the ES concept and the size of the city they belong to, or in relation to their associated role (Figure 3a).

Question 2. "What requirements/requests do you have with regard to ES/biodiversity (nature in the city)? In which concrete instruments do you see possible applications?)"

Figure 3b shows the groupings for question 2. As for question 1, practitioners that stated a system of monetarisation for the valuation of nature often found the ES concept challenging to implement, due for instance to the limited capacity: "*One has already noticed that the many different systems, that the enormous amount of effort required in administration, in mediation, also with the decision-makers, and even more so with the public […]. If that would succeed in bringing the ecological flank into the process via monetarisation, then that would certainly be helpful*" (Participant 5), and requires more funding: "*the […] sector should be adequately funded to meet the growing demands*" (Participant 3). Similar to question 1, there was a divergence among those who thought the concept helped with implementation and decision-making versus those who thought it most useful as a communication tool. Practitioners who were less willing to apply the ES concept often suggested the need for more evidence, such as stronger scientific arguments, standardised methods and criteria to value nature, and more case-study examples. No clear pattern was observed between the size of the city or the role of the participant and the requirement with regards to ES (Figure 3b).

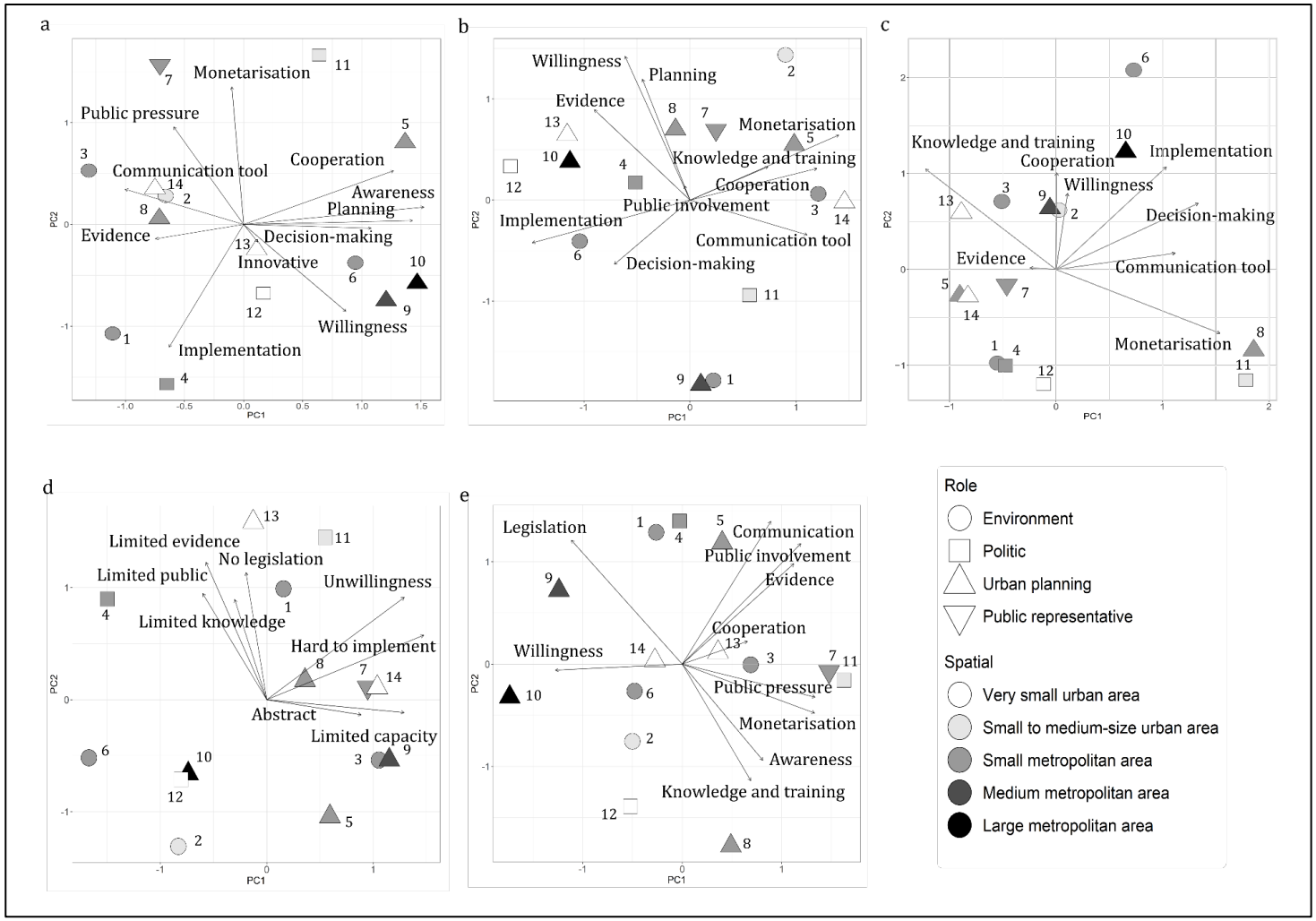

Figure 3. PCA analysis (only the first two components PC1 and PC2 are presented, see also Supplementary material A) of responses to: a) Question 1 - perceptions of the ES concept, b) Question 2 - the role of ES and biodiversity in urban planning, c) Question 3 - to what extent the outcomes/results of ES-assessments are relevant for different stakeholders, d) Question 4a - the inhibiting and e) Question 4b - the promoting factors from application of the ES concept. Role of the interviewees is indicated by symbols. Shade of grey indicates the spatial scale from small urban area to large metropolitan area (light to dark). Each category (arrow) points in the direction of the positive concept associated with it (a-c) or inhibiting/promoting factors ES application (d-e). Numbers refer to each participant.

Question 3. "To what extent are the outcomes/results of ES-assessments relevant (added value) for environmental agencies/authorities and other sectors?"

Analysis of responses to question 3 are shown in Figure 3c. ES assessment appeared to be valuable for decision-making as mentioned by some practitioners: "*This helps decision-makers take such ecosystem services into consideration*" (Participant 6), "*The outcomes of scientific studies provide a directive knowledge for decision-makers like us*" (Participant 10).

Monetarisation was again an important theme with some practitioners believing that ES assessment was "*important in relating benefits from nature with monetary value*" and this exercise could help in negotiations with the public (Participant 8).

As a communication tool, some practitioners indicated having difficulties in translating scientific reports into the language of their own field as illustrated in these following statements: "*Expanding your knowledge base is always useful. There is always a problem when the scientific results are to be incorporated into concrete urban planning work. You have to give it extra thought*" (Participant 5), "*Unfortunately usability of scientific outputs very much depends on erudition of employees […] for most departments the outputs are often too much scientific*" (Participant 11), "*The ES-based approach requires a change in the traditional planning procedure with results and outputs different from the most common ones and, therefore, it is not always easy to understand the benefits in the use of ES*" (Participant 12).

Knowledge and training of the ES concept was an important driver of differences between areas of expertise. As such, practitioners from political authorities often highlighted the need for comprehensive knowledge and training of the ES concept as well as case study examples (evidence) in order to understand ES assessments: "*It would help, if the scientific outputs would be developed in close collaboration with city officers (of course if they are willing to collaborate)*" (Participant 11), "*The presence of other experiences concerning the use of ES for planning purposes could be very important for the local administrators to have practical evidence of the opportunities*" (Participant 12).

For this question, there was a clear differentiation in responses according to the role of interviewees (Figure 3c). Practitioners from environmental agencies and urban planning were mostly located in the top part of the biplot, while politicians such as mayors were positioned closer to the bottom part of the biplot. This pattern may suggest that ES assessment is more favourably received by environmental and urban planning employees than political authorities, and may raise an issue of knowledge transfer between different areas of expertise. Since we researched the relevance of ES assessment for practical urban planning and environmental management, from our point of view it did not make sense to include scientists view. Scientists who are dealing with ES assessment are convinced the assessment outputs are relevant and useful for environmental and urban planning authorities (see Sect. 3.1). There was no clear relationship between size of the city and the relevance of ES-assessments.

Question 4.

A) Which inhibitory factors do you see? What suggestions do you have regarding fields of application?

Three broad groups of categories could be distinguished from the biplot (Figure 3d). The first group included limited evidence and methods, limited knowledge and training, no legislation and limited public involvement (high on Axis 2). The second and third groups represented categories related to the implementation of ES, with difficulties to implement and unwillingness to apply ES concept

belonging to the second group (independent of the two first axes), and limited capacity and abstract concept for the third group (high on Axis 1).

Participants who highlighted the difficulties in implementation often listed the limited capacity and reluctance to apply ES concept. For instance, a practitioner with public expertise stated: "*I can say that the concept seldom finds support from the administrative bodies. In order to implement it would require extra effort from a given person and broadening their knowledge, which taking into account multiple constraints is little likely"* (Participant 7), and this is further supported by the following statement from a practitioner with urban planning expertise: "*Another possible inhibiting factor is a mismatch between the timing when the plans are developed and the funding opportunities that allow implementing some planning measures on the ground*." (Participant 9).

Most participants stated that the concept of ES was too abstract, challenging to understand the scientific output, and often highlighted the existence of a language barrier. For example, "*In terms of some topics/sub-topics, I hope the representation of ES can do some good*" (Participant 1), "*In our case study, the lack of other experiences has made the process more difficult because we did not understand what the results and outputs could be. The ES assessment was a little bit clear, but the planning application was only theoretical*" (Participant 13), "*Also availability of information mostly in English language is also an obstacle*" (Participant 7).

The lack of legislations/reform was highlighted across several practitioners from various areas of expertise, including environmental practitioners, those with a political role and those dealing with the public. For instance, "*Once the consideration of ecosystem services is enshrined in a law or other mandatory tool, architects and consultants will take them into consideration more explicitly and earlier in their thinking*" (Participant 6), "*In order to achieve the effect in a larger scale – legal implementation is necessary"* (Participant 7).

Additionally, the lack of evidence including case studies, standardised methods and criteria to evaluate nature appeared to be another important barrier to ES application as stated by several employees: "*Yes, it is fundamental to have case studies and best practices in Italy (but also in other contexts) to have clear evidence on the opportunities and positive impacts in the adoption of an ES-based approach for planning purposes*" (Participant 13).

Another possible barrier was the limited public involvement, and this was particularly highlighted by interviewees with a political role as shown with the following statement: "*It is very important to find ways how to influence the broad public – not preach to the converted. Scientific outputs are unfortunately not the best way … these outputs should be presented in an attractive way (i.e. short video with some famous actor, article by recognized journalist etc.)*" (Participant 11).

Relationships between size of the city and the potential inhibiting factors of ES implementation were weak (Figure 3d). However, there was an indication that politicians held stronger views about the lack of evidence, knowledge and the legislation to back this up.

B) Which promoting factors do you see? What suggestions do you have regarding fields of application?

Analysis is shown in Figure 3e. Monetarisation and public pressure were both cited as promoting factors. For instance by the full range of participant roles: "*Easy to apply measures or cost estimates that we could use would be needed*" (Participant 7), and by politic authority: "*Monetary valuation is a relatively simple way, how to express the benefits using one simple indicator/value […] The monetarisation is a great basis for negotiations*" (Participant 11).

Several participants suggested that ES application could be greatly enhanced by improved communication, which is supported by analysis of previous questions. Knowledge/training was stated

by politicians and urban planners as an important promoting factor for ES application. For instance, an employee of urban planning expertise mentioned: "*I believe that it is essential to organise a training course, specifically dedicated to them, to spread the knowledge on environmental protection and to learn the competencies and skills*" (Participant 13), while a politic person stated: "*My suggestion is to invest in constant and continuous training of technicians/employees of municipal offices in order to give them the instruments and knowledge for integrate ES in planning*" (Participant 12).

There was a weak relationship between the size of the city and the promoting factors for ES application stated by employees (Figure 3e). Several practitioners from all spatial scales, excluding medium and large metropolitan areas, highlighted the importance of the public in promoting the application of ES: "*There is also increasing pressure from citizens to preserve existing greenery. And this is currently on the rise and you can see the feedback from the city administration. This is not a monetary value now, but already the realisation that the city greenery must be given a different status in urban planning*" (Participant 2). No clear pattern was observed among areas of expertise.

4 Discussion

Overall, the results show multiple similarities emerging from the scientific experts' discussions (Sect. 3.1), the case study applications in the framework of ES projects with practical relevance, i.e. involving actors from the urban administration or other experts in urban planning (Sect. 3.2), and the semi-structured interviews with practitioners (Sect. 3.3). Also, we found common emerging themes (Sect. 3.2, Supplementary material B): mainstreaming of ES, increasing attention to the concept, but hardly anchored explicitly in national legislation.

Although some practitioners, and often local politicians, complain that academics do not always know what is actually necessary and helpful in decision-making practice on the ground, there were hardly any contrasting views on the usefulness of the ES concept. Only a few interview participants stated that the concept of ES would be too abstract, that it was challenging to understand the scientific output, or highlighted the existence of a language barrier. On individual aspects, such as the monetarisation of ES, views differed both among the scientists and the practitioners. In principle, almost everyone sees monetarisation as useful. But the scientists stress that it is difficult or even impossible to make "objective" monetarisation of ES (see 'challenges in the ES assessment' in Sect. 3.1 that aligns with findings by Spangenberg and Settele 2010).

We have to acknowledge the complementarity of terms/concepts (ES, GBS, green infrastructure, nature-based solutions etc.). We see greater value in seeking linkages and synergies between terms and concepts (see Kadykalo et al. 2019 for an example) than spending too much effort on "single-concept" approaches to urban planning, which might miss important aspects for a holistic approach. In fact, as our results show (see Sect. 3.2), an ES approach can be followed even if the term "ecosystem services" is not mentioned explicitly.

To promote an ES approach in urban planning processes, terms or labels that work best in a given context need to be identified. For example, green infrastructure or nature-based solutions might find better traction among stakeholders. The public might not recognize the term "ecosystem services", however frequently residents are well aware of the goods and services derived from urban green spaces (Włodarczyk-Marciniak et. al 2020), which does not prevent the possibility of application of the concept by practitioners. In the scientific literature Scott et al. (2018), for example, used the term "ecosystem science" as an umbrella term covering several terms (e.g. natural capital or ES) to capture approaches and tools located within a social-ecological systems perspective, in a spatial planning context.

As a rule, in the planning context of a country or region, it is decisive whether the ES concept is seen as an "add-on" solution or whether ES has been already integrated in the planning process. Existing literature provides some evidence supporting this observation. A study in Stockholm (Kaczorowska et al. 2016) showed that the promotion of urban ES – regardless of how beneficial it may be – will add further complexity to already strained workloads among planners, policy-makers and urban managers. Scott et al. (2018) argue that ES can be embedded into the existing work priorities and vocabularies of spatial planning practice using 'hooks' (linking ecosystem science to a key policy or legislative term, duty or priority that relate to a particular user group) and 'bridges' (linking ecosystem science to a term, concept or policy priority that is used and readily understood across multiple groups and publics).

Our studies highlighted cases in which the ES concept is most relevant and useful to urban planners and potentially for decision-makers and other stakeholders:

- The ES approach is useful to support quantified assessments of urban nature and the benefits for citizens arise from it. It supports the planning, design and development of GBS by revealing what stakeholders appreciate, identifying priorities and setting benchmarks. These can contribute to a methodological modernization of landscape and urban planning.
- As part of a broader, integrated valuation of ES, the monetary valuation of nature and landscapes could create important additional arguments for the protection and sustainable use of landscapes. Fundamental for this is that its shortcomings are acknowledged and communicated in a transparent way.
- The extension of landscape and urban planning through the ES approach can improve the analysis of conflicts as well as the derivation, communication and implementation of planning measures.
- The essential key of the ES approach lies in the communication with different planning stakeholders. By implementing the ES approach, the objectives, contents and benefits of landscape and urban planning can be better communicated.

Aligned with the notion of ES as a boundary object (Abson et al. 2014), the ES concept managed to bring a diverse group of stakeholders around a common table, as the case studies showed. This, in turn, can:

- provide additional arguments for nature conservation and/or implementation of new green infrastructure elements/nature-based solutions in cities with human health and well-being in the centre of attention;
- underline environmental aspects (e.g. role of nature-based solutions in air pollution control, climate and flood protection);
- contribute to design that considers sustainable nature-based solutions and ecological principles;
- demonstrate the social, educational and health advantages of urban nature (learning, encountering, experiencing, increasing environmental justice, economic and cultural well-being etc.);
- support the communication of nature-related topics (visualizations, changes in space and time);
- identify/quantify ES supply, demand and flows.

A greater understanding of the many benefits provided by GBS is clearly shown within an ES framework. This provides an opportunity to regard urban nature in new ways, improving urban planning and design to achieve multiple outcomes through integrated planning in order to make cities more livable for people. At the same time, this brings challenges and potential barriers to implementing an ES approach in decision-making and planning. These include its complexity, relative novelty as a concept compared to established thinking, guidelines on urban planning which have

been evolving over many decades, and the need to take a holistic approach which considers many different sectors. There may be a need for scientific studies to provide further experimental evidence on the benefits of GBS, to provide evidence synthesis for easy communication to policy and decision-makers (see for example Raymond et al. 2017), and to help answer questions held by city managers and officials, which have not been previously considered.

GBS and ES play a particularly important role in times of crisis, such as during the COVID-19 pandemic when many people were expected to spend large parts of their day in their own homes, when journeys to distant destinations were not possible and even trips to the wider surroundings were only permitted to a limited extent. This makes it all the more important for people to be able to find and visit urban green spaces in their immediate living environment. The Coronavirus crisis has made it clear that urban planning is well advised to ensure that the greenery in residential areas is well-designed (Kleinschroth and Kowarik 2020; Venter et al. 2020).

Finally, based on our results we provide recommendations for implementing the ES approach in urban planning. Target groups for the application of the ES concept in practice are local politicians, urban planners and decision-makers, and other stakeholders as well as citizens.

There is a need for long-term perspectives in ecological planning (spatial, urban, environmental, nature conservation planning) supported by new tools and methods for valuing ES (see also Kaczorowska et al. 2016). Further on, it is necessary to

- modernise the methodological framework of urban planning (include the ES concept/framework);
- provide new arguments for spatially based decision-making, which could positively influence the well-being of city residents;
- establish method sets, standards and guidelines as well as provide supplementary databases for the application of new methods as a major requirement for successful integration of ES in urban planning;
- communicate the relationship between societal well-being and the structure and functioning of ecosystems and the services they provide to the broader public as well as to stakeholders and decision-makers;
- embed ES through new regulations and planning standards;
- promote professional training on ES-based quantitative methods, planning of measures and participatory methods.

In the process of planning and implementing physical measures on the ground (construction measures, restructuring of running waters, maintenance and upgrading of parks, gardens and green spaces, etc.), practice should be supported by science in implementing ES-related approaches. The following points should be noted by those responsible for such measures:

- Consult partners/relevant stakeholders very early in the process of ‘high profile’ projects and create a shared conceptual framework (around ES) (= a conceptual bridge between state, NGOs and research institutions). Involve stakeholders in the co-design and co-creation of implementation projects (= scientific bridge between state, NGOs and research institutions). This echoes recommendations by Mauser et al. (2013) or Frantzeskaki and Kabisch (2016).
- Allow research institutions – viewed as more impartial – to coordinate the co-creation processes (as recommended by Cowling et al. 2008). Provide time for co-creation and be patient, as there is a long time-lag before results are seen. Communicate results through various means.
- Recognise the importance of stability and continuity of key positions (coordinators, project leaders, political appointees).
- Identify key ES through participatory processes (see for example Mascarenhas et al. 2016). Use simple, spatially-explicit indicators for key ES (as recommended by Ruckelshaus et al. 2015), and ideally relevant to local context. Make it plausible; which ES are provided and which actors are

involved in their provision or even impairment and to what extent. Then goals and measures could be defined more purposefully and successfully than in many cases so far, and could be communicated within the framework of participation and find support (Spyra et al. 2018).

- Integrate all forms of nature into urban development for people's nature experiences and benefits (Grunewald et al. 2018; Bastian et al. 2020). Use synergies in the implementation of ES approaches, in particular with biodiversity strategies, with climate mitigation and adaptation plans.
- Create/use new opportunities for public actions (e.g. competitions) in favour of nature in the city (such as nature-based solutions). In their implementation the aesthetics and recreation, despite their primary role for the public, should not play a too dominant role. Rather, the focus should be on multifuncionality of areas, in which designs that promote cultural ES are complemented by structures essential for regulating ES and biodiversity (cf. Sikorska et al. 2017; Brzoska et al. 2021).

5 Conclusions

Urban growth and densification as well as climate change adaptation and urban biodiversity strategies promote the interest in planning with ES as a vital parameter for urban qualities. The concept of urban ecosystem services makes it possible to demonstrate the many ways in which nature - in all its facets - contributes to people's prosperity and well-being, especially in cities. It helps to better explain and clarify the value of nature's services in the city to decision-makers and non-specialists. Although there are already numerous laws and instruments in place to protect nature in the city, the ES approach offers the opportunity to focus more on the impact on, and benefits for, residents, e.g. health. Also, the demand perspective, which can be included e.g. by surveys, as well as the possibility of economic evaluations are special features of this concept.

We conclude that landscape and urban planning practices should be more open to the ES concept and its integration, and that it should be integrated in the form of supplementary contributions. This would not necessarily require an adaptation of the legal framework conditions. ES indicators for the local and regional level need to be adapted and developed by research/science in order to be able to use them in planning practice. The modernisation/further development of the methodological approaches of landscape and urban planning can be intensified by an assessment of nature and landscape performance, which is as quantifiable as possible. Quantifying ES in landscape and urban planning also enables the success of planning objectives to be monitored. In the context of integration, basic definitions of the ES concept need to be introduced in planning practice; however, the terms used should be kept as simple as possible. For public discourse and recognition of the concept in practice a targeted transfer of expertise is necessary.

The integration of ecosystem services into spatial decision-making processes is often associated with changes towards greater sustainability and protection of natural resources. We are convinced that the ES concept can also make a contribution in the sense of a comprehensive socio-ecological transformation, in which existing institutions and practices are tested, changed and/or replaced, thus breaking path dependencies.

Further integration is needed for the inclusion of ES in more strategic spatial planning. This is particularly important in the context of larger urban areas where ecosystems are a part of even larger metropolitan surroundings, requiring cross-administrative attention and strategic governance. According to our findings we can state that the ES tools suitable for practical implementation in urban planning should be co-developed by scientific experts and practitioners. The role of scholar-practitioners (scientists involved in planning processes) in proposing procedural and technical innovation of existing planning procedures, standards, norms and regulations could be crucial to integrate scholarly knowledge into daily technical and administrative domains. This approach would

help to include the novel scientific findings as well as the needs of urban and environmental planners, politicians and other stakeholders.

Acknowledgements

Lenka Dubova's research was supported by project BIDELIN "The values of ecosystem services, biodiversity and green-blue infrastructure in cities using the examples of Dresden, Liberec and Decin" (Grant No. 100282320), financed by European fund for regional development (Interreg V-A 2014-2020 Saxony–Czech Republic). The work of Olaf Bastian, Patrycia Brzoska and Karsten Grunewald was also supported by the BIDELIN project (http://bidelin.ioer.eu/en/project/).

Claudia Dworczyk´s research was supported by research project ÖSKKIP (Ecosystem Services of Urban Regions – Mapping, Communicating and Integrating into Planning to conserve biodiversity during a changing climate) funded by the German Ministry of Education and Research (BMBF) under the funding code FKZ 16LC1604B.

Laurence Jones was supported by the EU Horizon 2020-project REGREEN (Grant Agreement No. 821016).

Jiri Louda's research was supported by project "Smart City – Smart Region – Smart Community" financed by the Operational Programme Research, Development and Education of the Czech Republic – Grant no. CZ.02.1.01/0.0/0.0/17_048/0007435 and project "Economic and Institutional Aspects of Planning and Implementation Nature Based Adaptation Solutions" (UJEP-IGA-JR-2021-45-008-2).

Daria Sikorska's research was supported as part of the project ENABLE, funded through the 2015–2016 BiodivERsA COFUND call for research proposals, with the national funders The Swedish Research Council for Environment, Agricultural Sciences, and Spatial Planning, Swedish Environmental Protection Agency, German aeronautics and space research centre, National Science Centre (Poland), The Research Council of Norway and the Spanish Ministry of Economy and Competitiveness.

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Supplementary Material A for Grunewald et al.

Thematic analysis of stakeholder interviews

Question 1. "What do you think about the ES concept in general? Is it necessary for political/administrative actors of the city administration?"

The four components revealed by PCA (eigenvalue > 1) accounted for 80% of the total variance in practitioner's perception/attitude of the ES concept. The first component PC1 (explaining 36% of the total variance) was characterised by a high positive loading with three main categories: awareness of ES concepts, planning and cooperation (Table 1). These categories were positively correlated to the axis PC1. Other categories including decision-making/legislation, communication tool and willingness to use ES concept also contributed to a lesser extent to the first component with communication tool (negative loading) located at the opposite end of the axis. The second component PC2 (explaining 19% of the total variance) was characterised by monetarisation (positively correlated to PC2) and implementation (negative loading) followed by public pressure and willingness (negative loading) located in the opposite direction (Table 1).

Table 1. Results from the principal component analysis (PCA) showing the four principal components. Associations between categories were analysed across the 14 interviews. Categories with factor loadings below a cut-off value of −0.50 and above a value of 0.50 are shown in bold and further referred to as components of the PCs.

	PC1	PC2	PC3	PC4
Monetarisation	-0.06171	**0.838625**	-0.27277	0.260492
Communication tool	**-0.62232**	0.214788	-0.29251	0.465713
Planning	**0.886667**	0.023514	-0.22929	-0.12049
Decision-making	**0.669362**	-0.02298	0.461759	-0.07388
Cooperation	**0.78656**	0.327528	-0.12468	-0.11552
Implementation	-0.39078	**-0.74786**	-0.26287	0.182931
Public pressure	-0.36635	**0.594476**	0.564397	0.135854
Evidence	-0.46295	-0.08784	0.481614	-0.59788
Willingness	**0.537284**	**-0.53045**	0.138899	0.417626
Innovative	0.074389	-0.1075	0.628871	0.637419
Awareness	**0.946393**	0.105881	-0.00104	0.132834

Question 2. What requirements/requests do you have with regard to ES/biodiversity (nature in the city)? In which concrete instruments do you see possible applications?)

The four components revealed by PCA (eigenvalue > 1) accounted for 79% of the total variance in the data that characterised the identification of starting points/structures of daily work, which can be enriched/supported by the ES concept. The first component PCA (explaining 31% of the total variance) was characterised by two main categories monetarisation and implementation which are located opposite from each other (Table 2). Cooperation, communication tool and evidence were also contributing to a lesser extent to the horizontal axis PC1.The second component PC2 (explaining 19% of the total variance) was characterised by willingness to use ES concept and to a lesser extent by the categories planning and evidence (positive loadings) (Table 2).

Table 2. Results from the principal component analysis (PCA) showing the four principal components. Associations between categories were analysed across the 14 interviews. Categories with factor loadings below a cut-off value of −0.50 and above a value of 0.50 are shown in bold and further referred to as components of the PCs.

	PC1	PC2	PC3	PC4
Monetarisation	**0.810643**	0.372198	0.024273	-0.3787
Communication tool	**0.63844**	-0.19915	-0.14677	-0.09509
Planning	-0.25952	**0.691929**	-0.03074	-0.58402
Decision-making	-0.41237	-0.36775	0.38541	-0.29631
Cooperation	**0.692178**	0.180992	**0.538981**	0.36922
Implementation	**-0.85989**	-0.24475	-0.0031	0.273158
Public involvement	-0.03025	0.081257	**0.870659**	-0.19145
Evidence	**-0.5218**	**0.517244**	0.458914	0.288577
Knowledge and training	0.425081	0.191051	-0.0123	**0.670372**
Willingness	-0.35413	**0.822451**	-0.33963	0.18894

Question 3 To what extent are the outcomes/results of ES-assessments relevant (added value) for environmental agencies/authorities and other sectors?

The four components revealed by PCA (eigenvalue > 1) accounted for 89% of the total variance in the data that characterised the relevance of the outcome of scientific case studies/projects. The first component PC1 (explaining 26% of the total variance) was characterised by communication tool, implementation and monetarisation (positive loadings).The second component PC2 (explaining 22% of the total variance) was predominantly characterised by the category knowledge and training (positive loading). Evidence (positive loading) to a lesser extent also contributed to PC2 (Table 3).

Table 3. Results from the principal component analysis (PCA) showing the four principal components. Associations between categories were analysed across the 14 interviews. Categories with factor loadings below a cut-off value of −0.50 and above a value of 0.50 are shown in bold and further referred to as components of the PCs.

	PC1	PC2	PC3	PC4
Monetarisation	**0.865023**	-0.3734	0.034216	-0.07925
Communication tool	**0.629563**	0.095846	0.208482	**0.637653**
Cooperation	0.003967	**0.566542**	-**0.56169**	0.019998
Implementation	**0.581507**	**0.60032**	0.295521	0.075371
Evidence	-0.1374	0.010048	**0.842501**	0.143188
Knowledge and training	-**0.689**	**0.589067**	0.071215	0.368875
Willingness	0.061164	0.446087	0.407317	-0.75466
Decision making	**0.750659**	0.388033	-0.25386	-0.07569

Question 4:

C) Which inhibitory factors do you see? What suggestions do you have regarding fields of application?

The three components revealed by PCA (eigenvalue > 1) accounted for 77% of the total variance in the data that characterised the inhibitory factors of ES. The first component PC1 (explaining 34% of the total variance) was characterised by the difficulties to implement, limited capacity and unwillingness to apply ES concept (all positive loadings). Abstract concept also contributed slightly to the PC1.The second component PC2 (explaining 27% of the total variance) was characterised by limited evidence/standardised methods, the lack of legislation and to a lesser extent limited public involvement, unwillingness to apply ES concept and limited knowledge (all positive loadings) (Table 4).

Table 4. Results from the principal component analysis (PCA) showing the three principal components. Associations between categories were analysed across the 14 interviews. Categories with factor loadings below a cut-off value of −0.50 and above a value of 0.50 are shown in bold and further referred to as components of the PCs.

	PC1	PC2	PC3
No legislation	-0.12049	**0.702782**	-0.48808
Hard to implement	**0.912594**	0.356454	-3.18E-05
Limited public	-0.37247	**0.587552**	**0.51434**
Limited evidence	-0.35402	**0.759679**	-0.25373
Limited knowledge	-0.1863	**0.553947**	0.483028
Unwillingness	**0.800064**	**0.565874**	-0.05791
Limited capacity	**0.79936**	-0.07085	**0.516579**
Abstract	**0.549555**	-0.08321	-0.42515

A) Which promoting factors do you see? What suggestions do you have regarding fields of application?

The three components revealed by PCA (eigenvalue > 1) accounted for 71% of the total variance in the data that characterised the inhibitory factors of ES. The first component PC1 (explaining 31% of the total variance) was characterised by public pressure, monetarisation and willingness to implement ES. Public involvement, case studies (and standardised methods) and legislation also contributed to a lesser extend to the axis PC1. The second component PCA2 (explaining 23% of the total variance) was characterised by communication and to a lesser extent legislation, public involvement, knowledge and training, and case studies (Table 5).

Table 5. Results from the principal component analysis (PCA) showing the three principal components. Associations between categories were analysed across the 14 interviews. Categories with factor loadings below a cut-off value of −0.50 and above a value of 0.50 are shown in bold and further referred to as components of the PCs.

	PC1	PC2	PC3

Knowledge and training	0.359424	**-0.59372**	**-0.53898**
Case studies and standardised methods	**0.583818**	0.510741	-0.01342
Legislation, regulation, reform	-0.58046	**0.630142**	-0.18856
Monetarisation	**0.692646**	-0.24899	0.291875
Communication	0.463912	**0.725922**	0.372823
Cooperation	0.341464	0.115836	**-0.74943**
Public involvement	**0.620506**	**0.612945**	0.039491
Public pressure	**0.695217**	-0.16808	-0.04415
Willingness	**-0.66383**	-0.0309	0.451636
Awareness	0.422511	-0.48958	**0.66007**

Table 6. Higher-level themes for each question. The 115 phrases across the four questions were grouped under higher-level themes.

Question	Higher-level themes	Phrases
1	Communication tool (help in valuation and inter-connectedness of nature)	Complex and abstract Too theoretical, need examples/ evidence of physical benefits ES concept not widely used / known ES useful as communication tool High potential if emphasise in physical benefits Nature is valuable for people/ enriching (benefits for public) Valuation of ES useful and important e.g. wellbeing ES = useful in valuation of nature
	Cooperation	ES facilitates cooperation across different actors ES concept links nature to other sectors ES concept is applicable/ can be used at multi levels (municipal, regional and national) ES has international support ES = useful for political/administrative actors of the city administration ES = important / essential / crucial

	Decision-making and legislation	Lack/outdated of ES concept in official planning document ES not incorporated into legislation Es concept not central to decision making ES helps in justification for decision making ES approach leads to even/equalise the demand-supply region (e.g. rural v. city)
	Planning	ES concept supports planning High potential of using ES for urban planning authorities Applicable/ ES concept has a role in planning
	Awareness	ES concept has been previously applied/ implemented ES concept, some people are aware of it
	ES implementation	Limitation/ valuation and practices not transferable Awareness of how to implement ES is low/ uncertain on how to implement ES ES concept not working Enlightened politician/community leader is important for implementation of ES into planning
	Evidence and methods	Standardised methods and criteria to value nature needed
	Innovative concept	Not a new concept ES concept used but not named (vague) ES = Innovative, novel concept ES= New better approach to assess natural environment
	Monetarisation	Sceptical about monetarisation of nature Monetarisation of nature has some accessory benefit but not the driving force for policy or administration Nature cannot be exchanged Valuation of ES useful and/or important e.g. monetarisation
	Public pressure	Strength of public pressure to consider ES (existence of public awareness of nature value) Weight of public opinion in politics matters
	Willingness to adopt ES	Using ES when it suits the individual/ opportunistic Unwillingness to adopt ES Willingness to implement ES concept

2	Communication tool (help in valuation and inter-connectedness of nature)	Terminology issues e.g. language barrier Terminology issues e.g. need standardise clarification as too abstract/ complex, vague, no legal terms) ES useful as communication tool ES concept improves communication Promote various usage of nature/ multi-functionality High potential if emphasise in physical benefits exists
	Decision-making and legislation	Valuable for negotiating/ discussion Change the way actors think ES helps in Justification for decision making ES central to policies Integration of ES into legislation needed Reform planning needed ES Implementation across all levels needed Inforce legislation Government needs to "buy-in" into the ES concept/ inforce Targets for resources conservation needed
	Planning	Need to Prioritise eco-sensitive land use policies (Green infrastructure / nature based solution) ES helps understand urban planning Inclusion of ES into spatial planning High potential of using ES for urban planning authorities
	ES implementation	Co-funding by key economic players can help to implement ES Challenge to fund new ES project Limited capacity (lack of resources, time and high cost) New ES approach can be challenging to use (hard to change plans) Progress v. preservation (competing interests)
	Knowledge/training of ES	Need to increase understanding/ knowledge/ training of ES

	Evidence and methods	Stronger scientific arguments / evidenced needed Standardised methods and criteria to value nature needed Case study - example (proof of concept) needed Baseline data, information needed
	Cooperation	Need for Cooperation across different actors Collaboration between scientists and non-scientists needed Need to link nature to other sectors
	Public involvement	More citizen involvement needed Reaching new audiences needed (public outreach) Strong opportunities for citizen involvement Citizen involvement is a strength
	Monetarisation	Need to value ES e.g. monetary Valuation of ES useful and/or important e.g. monetarisation
	Willingness to adopt ES	Using ES when it suits the individual/ opportunistic
3	Communication tool	Output of scientific case studies useful for communication Hard to understand scientific output
	Cooperation	Strength of collaborative projects (share workload, expand knowledge) ES project links nature to other sectors
	Decision-making	Output of scientific case studies useful for decision-making
	ES implementation	Gap between science research and real world implementation (e.g. administration, consultancy) Limited capacity (lack of resources, time and high cost) Difficult to implement scientific study New ES approach can be challenging to use (hard to change plans)
	Knowledge/training of ES	More ES education needed Importance of prior knowledge to understand scientific case study

	Evidence and methods	Case study - example (proof of concept) are important/needed More capability in tools to transfer ES concept across sectors Reputation of the source (e.g. scientific) can affect the influence of the study Outcomes of scientific project useful/ applicable Output of scientific case studies generate evidence and knowledge
	Monetarisation	Valuation of ES useful and/or important e.g. monetarisation
	Willingness to adopt ES	Sceptical about the outputs of public opinion survey Mixed feelings on the added value of scientific project
4a	Abstract	Terminology issues e.g. language barrier Terminology issues e.g. need standardise clarification as too abstract/ complex, vague, no legal terms) Gap between science research and real world implementation (e.g. administration, consultancy) Challenging to relate benefits/services of nature to individual level Lack of direct measure of nature Hard to understand scientific output ES concept is complex and abstract Research output not enough to reach public, need for attractive and effective ways to disseminate ES message
	No legislation	ES not incorporated into legislation Lack/outdated of ES concept in official planning document
	Limited capacity	Profit-driven decision, not long term Limited capacity (lack of resources, time and high cost) Challenge to fund new ES project Mismatch between timing of plan development and funding opportunities

	Hard to implement ES	Difficult to decided when contrasting aspects in planning Challenge to focus on more than one system (required multi) Lack of evaluation of impacts of decision-making (lack of case studies) New ES approach can be challenging to use (hard to change plans) Timing mismatch with ES assessment (research output) given after planning stage Difficult to implement ES concept Change in financial-economic mechanism of planning, how can ES be translated into city revenue opportunity
	Limited knowledge/training of ES	Lack of knowledge/training/ experience
	Limited evidence	Lack of standardised methods and criteria to value nature
	Limited public involvement	Reaching new audiences can be challenging (public outreach) More citizen involvement needed Research output not enough to reach public, need for attractive and effective ways to disseminate ES message Require public pressure/interest
	Unwillingness	Unwillingness to adopt ES Sceptical about the outputs of public opinion survey Buy-in of ES concept/effectiveness of ES depends on individual perceptions Resistance to change Using ES when it suits the individual/ opportunistic
4b	Communication tool (help in valuation and inter-connectedness of nature)	Improve communication Nature/greenness = Popular topic -> help ES implementation Promote various usage of nature/ multi-functionality
	Legislation	Reform planning Integrate ES into legislation Inforce legislation from top-down If ES based-argument are well-evidenced, increase opportunity to influence decision-making/court ruling/planning

	Cooperation	Cooperation across different actors/ sectors help for ES implementation International support (Multi-actors meeting/ agreement) for ES concept Inspiration from other countries that use ES
	Awareness	Incorporation of ES informally into planning (ES concept already in use)
	Knowledge/training of ES needed	more understanding/ knowledge/ training about ES concept needed
	Evidence and methods	Case study - example (proof of concept) are important/needed Standardised method and criteria to value nature is important/needed (e.g. model)
	Monetarisation	Valuation of ES is useful and/or important e.g. monetarisation
	Public involvement	Citizen are more positive toward conservation => use this for pushing ES concept forward Strong opportunities for citizen involvement Citizen involvement is a strength
	Public pressure	Public pressure to consider ES (existence of public awareness of nature value) Weight of public opinion in politics matters (move toward conservation and nature)
	Willingness to adopt ES	Willingness to implement ES concept

Supplement Material B for Grunewald et al.

Brief overview of the status of implementation of the ecosystem services concept in the seven countries studied

The status-quo in the seven countries examined is characterized by the authors of the paper on the basis of their experience, especially from the case study work, as follows:

In the Czech Republic exist several (by the Ministry of Environment) officially certified methodologies for assessment and (monetary) valuation of ecosystem services which were developed by well-known research teams as a support tool for implementation the ES concept into strategic and spatial planning processes (e.g. Macháč et al. 2019). These methodologies are often focused on urban environment. However, in general the practical integration of ES concept into strategy planning processes is still underdeveloped. In the Czech Republic does not exist any legal instrument which would force the spatial and urban planners or decision makers to explicitly take the ecosystem services into account, and more over the awareness of stakeholder toward ES concept is still very low. The implementation of ES concept into policy strategic documents is mostly mentioned only in connection with climate adaptation strategies (on local as well as on national level) or in connection with biodiversity. According to Czech National Climate Adaptation Strategy (MoE 2015) designing new adaptation measures should include thoughtful spatial planning with a long-term perspective of landscape ecosystem management and emphasis on the biodiversity protection and provision of key ecosystem services. One of the particular policy goal of the National Biodiversity Strategy (MoE 2016) is to integrate ES valuation in strategic planning by 2022. On the other hand, in recent years is slowly growing the number of municipalities adopting local climate adaptation strategies (e.g. cities of Praha, Brno, Chrudim, Plzeň etc.), which use the ES concept as an argument to support implementation of nature-based adaptation measures (green and blue infrastructure). This could be seen as first steps for future broader implementation of ES into planning processes.

For Germany, studies have shown that a comprehensive integration of ES in the landscape planning instrument is only possible to a limited extent due to a lack of data, tools and methods on the one hand and rules for the application of the ES concept on the other. An "add-on" solution, as a supplement to the established scope of landscape planning work, is therefore advocated by both science and planning practice (Heiland et al. 2016; Artmann et al. 2017; Szücs et al. 2019). The ES approach is not yet explicitly embedded in formal planning tools (such as in land use or regional plans), nor has there been any agreement on an overarching methodology to guide how the ES approach should be integrated into planning processes. Various ideas and instruments have been developed in different projects, but their practical application needs be examined further. ES researchers and practitioners emphasise that the interdisciplinary ES approach could have an integrative effect by bringing together different planning levels and decision-making processes, however, there needs to be more clarity as to where this integrative effect should take place and what it can actually achieve (Lezuo et al. 2020).

In Italy, the adoption of ES concept in spatial planning is still voluntary and not included in planning laws at any administrative level (national or regional). Therefore, ES operationalization in planning practice is still far from being in place (Cortinovis and Geneletti 2018; La Rosa 2019). Considering the Italian spatial planning system, the Urban Plan (called General Regulatory Plan) directly affect in the quality and/or quantity of ES by forecasting land transformation options that include land use/land cover changes and soil sealing (La Rosa 2019). Few urban plans have used ES mapping and assessments to derive actual planning decisions. From one hand, some recent experiences have considered ES as an information base for setting strategies or for the deployment of a local Green and Blue Infrastructure Strategy. In these cases, ES were considered mainly in the strategic vision of the plans

and not in the prescriptive framework that could ensure their operability. On the other hand, others Urban Plans (Pelorosso et al. 2017; Ronchi et al. 2020) started to experiment a performance-based approach with interesting results in Planning regulations using ES as a proxy for setting new planning standard based on ecosystem functions and provision. In the last years, at the national level, different proposals for a new national planning framework were designed but none so far adopted. Differently, some considerations on Natural capital and ES provision have been included in different planning instruments, such as the Regional Plan and the Landscape Plan. The lack of a unique and comprehensive national framework on ES and spatial planning has resulted in several interpretations of ES concept and different application of ES for planning practices.

In Poland, the application of ES concept is very restrained. The analysis of documents for Lodz revealed that the ES only appear indirectly in the documents (e.g., recreation) rather than functions (e.g., flood protection) especially at the city level. At the national level the ES approach appears in Polish legal acts and strategic documents only in an indirect form as well (Stępniewska et al. 2017)

In Portugal, the revised (in 2019) national spatial planning policy (which provides the overarching framework for regional and local/urban planning) increased the coverage of the ES concept, in relation to the previous version. The ES concept is now explicitly mentioned several times, as is the recognition that healthy ecosystems provide people with several benefits. Due to the novelty of the new national policy, it is still too early to assess how that increased integration will translate into lower governance levels (regional and local/urban). A previous analysis of existing spatial plans for the regional level (the level applicable to the LMA as a whole) has found a general low level of explicit integration of the ES concept, but several instances of notions associated with ES (implicit integration). Differences were also found in the degree of ES integration between different regions, depending on the profile of the technical teams that developed the plans (Mascarenhas et al. 2015). As pointed out in the interview with LMA's planning practitioners, at municipal level (the level with more direct influence on urban planning) there are examples where the concept was integrated, more or less explicitly. For example, in Lisbon this has been done more on an informal basis. The municipality has been doing a lot of efforts under the label of green infrastructure, with several specific projects (e.g. urban farming). One strategy they used was to engage big economic players (e.g. an oil company or the national electricity company) to (co-)fund several of those projects. They were also one of the first municipalities to change their planning regulations following the coming into force of a new spatial planning law in 2014, which determined that municipalities should create a municipal fund for environmental and urban sustainability. The new master plan of Setúbal municipality is the first one that started to use the ES concept explicitly, they made an attempt to map the municipality's natural capital and they have developed some payments for ecosystem services (PES)-like mechanisms when operationalizing the National Ecological Network[1]. There was another municipality that tried something similar, but it didn't work, because the overall approach was not consolidated enough (several issues raised with the practical implementation). Another municipality (Almada) has been promoting a flagship project on urban farming for a specific area of the municipality, linking it to a nutrition discourse. They promote the use of that area through urban farming also as a way of controlling/avoiding illegal activities that had been taking place there. The municipality of Sobral de Monte Agraço has also been using the fact that it supplies Lisbon with several food products as a discourse in its territorial marketing. In sum, a trend towards increasing integration of the ES concept is observed at national and municipal planning levels, which suggest that a similar trend should be expected for future new plans at regional level.

Switzerland: The ES concept has made a few important in-roads into policy making in Switzerland in general, and in the canton of Geneva in particular. The ES concept is a core component of the federal

[1] The principles/general regulations of which are set at national level, but has to be operationalized / mapped in detail at municipal level by the local authorities.

Action Plan for the Swiss Biodiversity Strategy (Conseil Fédéral 2017). As a result, the concept is being implemented and tested at various level of governance (federal, cantons, cities), including in cantonal biodiversity action plans (Etat de Genève 2020). Although not legally binding, such strategic documents shape how ongoing programs are implemented. For example, a 3-year project called NOS-ARBRES ("Our trees", in English) based explicitly on the ES concept analysed the status and opportunities related to trees and forests within the canton of Geneva. The project proposed the ES concept as a guiding framework, and as a result project methods, priorities, analyses and main conclusion were co-constructed through a participatory process. Elected officials financed the project, signed off the summary for policy makers (Schlaepfer et al. 2018) and implementation of key recommendations such as an increase in tree canopy cover from 21-23% to 25-30% has begun. In a similar vein, the Swiss Federal Government and canton of Geneva co-financed a study on how to integrate the ES method into strategic planning of a future Green Infrastructure (Honeck et al. 2020). On-going studies are also investigating how to integrate the ES method into Strategic Environmental Evaluations and urban planning priorities within the canton of Geneva. No comprehensive overview has been conducted on how the ES method is being implemented throughout Switzerland and it is likely that many more similar initiatives are on-going.

In Turkey, the adoption of ES concept in spatial planning is under development process by increasing collaborations of scientific community and planning practitioners. Herein, research-based ES integration, which expands and diversifies from rural, urban, regional and national scales as a decision support mechanism for planning, are the pioneer efforts to guide and initiate practical implementations in Turkey. Initial researches are related with watershed management (Albayrak 2012; Tezer et al. 2012; Tezer et al. 2015), ES for climate adaptation (Onur and Tezer 2015), rural tourism (Muhacır and Tazebay 2017), role of ES in urban planning, urban agriculture - urban ecosystems interrelation with ES provision and climate change (Çoban and Yücel 2018; Demircan 2018; Karaşah and Sarı 2019), urban green infrastructure (Tülek and Mirici 2019) and ecosystem-specific ES provision and spatial decision making (Muhacır and Özalp 2015). Additionally, using ES as a decision support tool for measuring the ecological sustainability performance of spatial plans at the regional level (Menteşe et al. 2019) and ES integrated urban watershed management models (Tezer et al. 2020) are the latest examples of ES integrated planning background that encourage planning practitioners to adopt ES concept into various spatial planning practices. Therefore, on the practice side, there are three legal planning tools which have been experienced for the integration of ES, namely national spatial strategic plan (NSSP), environmental master plan (EMP) which are linked with the "Regulation on Spatial Plan Making" and the determination of special provision in water basins (SPWB) which is linked with the "Regulation on the Protection of Drinking-Irrigation Water Basins". Although these two legal tools do not explicitly necessitate the integration of ES with spatial plans; either related ministries or local level governmental institutions were supported the idea of ES integration into spatial decision making. Presently, ES integrated NSSP is under progress and not completed yet. Review of EMP of Istanbul has been interrupted as the local government has been changed. And lastly, SPWB applied into two water basins and the approval process has been continuing. As a summary, it can be stated that although increasing ES based practices in Turkey includes several deficiencies in data and method issues, these practices are crucial not only ensure to integrate ES concept in actual spatial planning process by gaining legal framework, but also support to explain multi-dimensional benefits of ecosystems to stakeholders in a tangible way.

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