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Review

Practical applications of ecosystem services in spatial planning: Lessons learned from a systematic literature review

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ABSTRACT

The integration of ecosystem service (ES) knowledge into decision-making processes is increasingly endorsed by various policies and initiatives, with spatial planning targeted as one of the most relevant fields. Learning and feeding back from existing experiences is therefore a fundamental step to ensure appropriate and useful support by ES science. This paper aims to gather and critically analyse how ES science contributes to spatial planning practices. Through a systematic review of the literature about ES use in spatial planning, we map the level of integration of ES knowledge, the scale of case studies, and the type of planning addressed; and we identify and analyse case studies of real-world applications. Studies explicitly aimed at supporting spatial planning have increased over the last decade, but are still scarce. The real-world case studies reveal advantages of integrating ES knowledge into spatial planning processes, mainly concerning practical aspects such as synthesizing complex socio-environmental information and promoting participation. Windows of opportunity offered by regulatory frameworks and innovative processes and instruments, such as marine spatial plans and strategic environmental assessments, are key factors triggering the integration. However, supportive contextual conditions are necessary, including science-policy collaborations across the entire planning process and environmental awareness among policy-makers and stakeholders.

1. Introduction

Ecosystem services (ES) have been advanced as a conceptual framework to promote awareness of socio-environmental interdependencies and interactions in decision-making (Bennett and Chaplin-Kramer, 2016; Daily et al., 2009). International bodies and agreements have endorsed the assessment of ES as a knowledge base on which to build and evaluate policies (IPBES, 2012; CBD, 2010; European Commission, 2011). In recent years, several national and local programmes have contributed to mainstream ES in different policy contexts (Beery et al., 2016; Schröter et al., 2016), and guidance documents have been published to support practitioners in conducting policy-relevant assessments (European Commission, 2019; NCC, 2018; SEPA, 2018).

The increasing commitment to contribute to transformative changes in society has been accompanied by a growing reflection on the roles of scientific knowledge (Clark et al., 2016; Kirchhoff et al., 2013) and the ways in which it can influence decisions (Posner et al., 2016; van Oudenhoven et al., 2018). In this context, learning from existing experiences and feeding-back into science is a fundamental step to ensure the relevance of scientific findings and their usability into decision-making processes (Clark et al., 2016; Dick et al., 2018; Mckenzie et al., 2014). However, in-depth explorations of cases of ES integration looking at the whole decision-making process, as opposed to content analyses of policy documents, are only few and linked to specific projects (e.g., Geneletti et al., 2020, 2018; Jax et al., 2018; Ruckelshaus et al., 2015) or topics, e.g. participatory planning (Spyra et al., 2019). Systematic collections of practical applications of ES in decision-making processes are still lacking.

Spatial planning is one of the most relevant decision-making fields affecting ES (Cortinovis and Geneletti, 2019; Rozas-Vásquez et al., 2018), and one towards which many efforts have been directed (Scott et al., 2018). Spatial plans – including urban plans (Cortinovis and Geneletti, 2018), landscape plans (Albert et al., 2014a), conservation plans (García-Llorente et al., 2018), and related environmental assessments (Geneletti, 2011) – are key policy instruments to coordinate human activities and minimise their negative impacts on natural and

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land systems (Albert et al., 2020). Specific challenges for ES integration into spatial planning processes include strong regulatory frameworks, highly codified procedures with established outputs and instruments, and consolidated professional norms that often limit cross-sectoral dialogue (Saarikoski et al., 2018). At the same time, approaches for ES integration into spatial planning have many opportunities to be replicated and upscaled, because of the widespread use of such planning around the world (Ruckelshaus et al., 2015).

Researchers have monitored the uptake and integration of ES knowledge into spatial planning processes mainly by analysing the content of plans (Geneletti and Zardo, 2016; Jaligot and Chenal, 2019; Nordin et al., 2017) or eliciting the opinions of stakeholders and decision-makers involved (Albert et al., 2014b; Mascarenhas et al., 2014; Rall et al., 2015). However, specific studies on how ES knowledge has been integrated into practical spatial planning experiences revealed that enabling factors and constraints can be captured only by tracking the co-development and use of ES knowledge along the whole decision-making process (Di Marino et al., 2019; Mckenzie et al., 2014). Factors like the presence of policy windows or active involvement of social and intellectual capital promoting ES integration (Rosenthal et al., 2015; Saarikoski et al., 2018) are unlikely to emerge without an in-depth analysis of the whole process (Geneletti et al., 2020). Most of all, the relevance and perceived legitimacy of ES knowledge, two key factors affecting its usability (Clark et al., 2016), depend on the establishment of an effective science-policy interface during the process (Adem Esmail et al., 2017; Rosenthal et al., 2015). Therefore, an in-depth analysis of spatial planning processes successfully integrating ES knowledge is needed to understand what support ES science can offer to decision-making.

The objectives of this paper are:

I to map scientific publications addressing the use of ES in spatial planning, thus providing an overview of how ES science is contributing to spatial planning practices in terms of level of integration of ES knowledge, scale of case studies, and type of planning addressed;
II to analyse case studies described in the scientific literature where ES knowledge has been integrated into real-life spatial planning processes and instruments, thus revealing advantages, enabling factors, and constraints.

Accordingly, the research combines two methods: a systematic mapping of the scientific literature and a subsequent in-depth analysis of published real-life case studies. We focus on case studies where the explicit use of the ES concept and related knowledge contributed to a formal output, i.e. (part of) a policy instrument. The selected cases allow tracking the co-development, integration, and use of ES knowledge across the whole planning process, thus revealing both the outcomes generated and the procedures adopted.

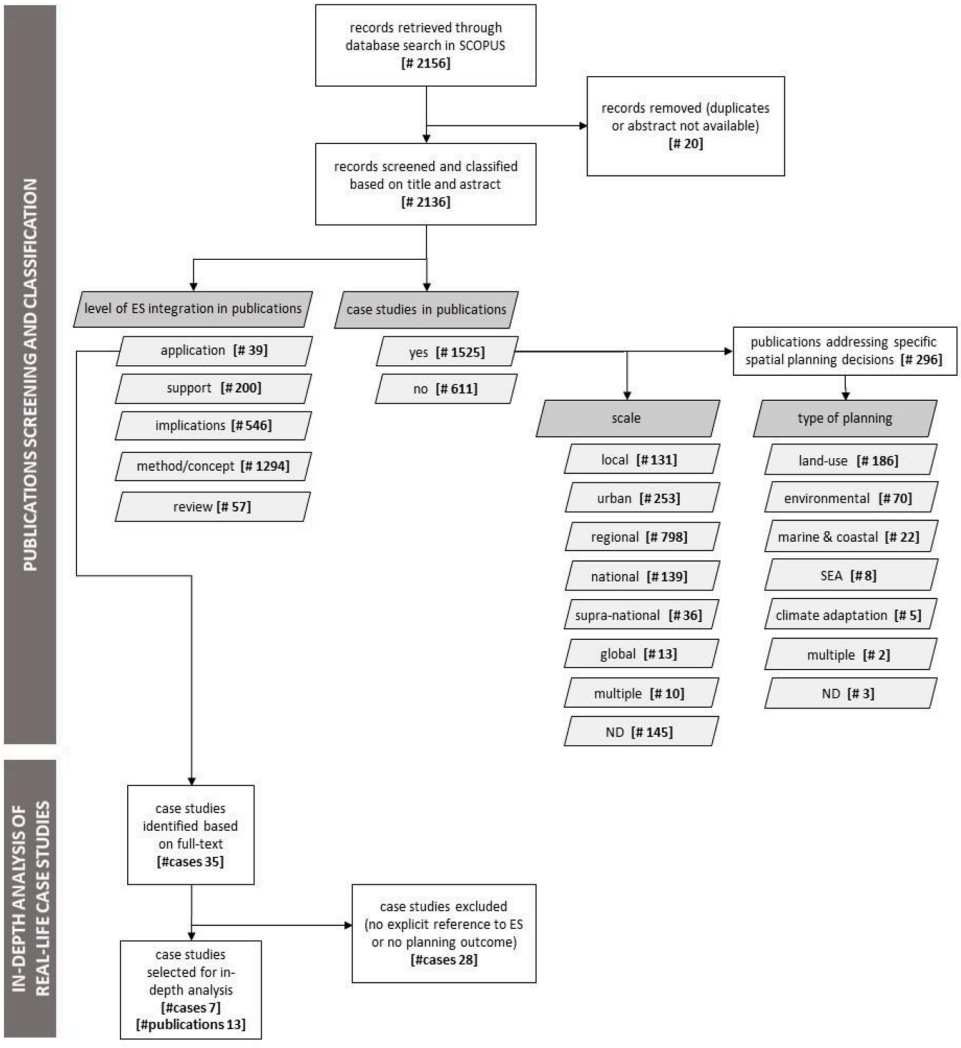

Fig. 1. Flow diagram illustrating the stages of the literature review and the classifications of scientific publications. ND: Not Determined.

2. Materials and methods

The systematic review followed two main analytical steps corresponding to the research objectives (Fig. 1). In the first step, we screened relevant peer-reviewed publications to map the level of integration of ES knowledge, the type of planning addressed, and the scale of case studies described therein. In the second step, we focused on a sub-sample of case studies providing evidence of ES integration into a spatial planning process and instrument, and analysed them in detail by applying a review framework.

2.1. Publications screening and classification

We searched for relevant scientific publications in Scopus. After testing different combinations, we adopted a final query composed of three sets of keywords related to i) ecosystem services, ii) spatial planning typologies, and iii) knowledge integration (see Table A.1 in the Appendix).

The search was performed on February 21, 2019 on the title, abstract, and keywords fields and limited to all types of publications in English. It resulted in 2156 publications, from which we removed duplicates and studies without abstract (20).

Based on the title and abstract, we classified the selected publications into five levels of integration of ES knowledge, namely *application*, *support*, *implications*, *method/concept*, and *review*. A detailed description of the classes is provided in the Appendix, Section 1. Furthermore, for each publication describing a case study, we recorded information about location and scale of analysis (Fig. 1).

All the publications in the classes *application*, *support*, and *review*, i.e. those including case studies addressing specific spatial planning decisions, were further sorted into six categories describing the type of spatial planning addressed (Fig.1). More details on the classification and the screening process are provided in the Appendix, Section 1.

2.2. In-depth analysis of case studies

Publications falling in the class *application* were further analysed to select the final sample of case studies for in-depth investigation. We analysed single case studies within each publication and grouped publications describing the same case study, hence the numbers of selected publications and case studies do not correspond (Fig. 1). Based on the content of the full texts, we assessed if the case studies met two eligibility criteria:

- explicit use of the term "ecosystem service*" during the planning process;
- evidence of integration and use of ES knowledge in a planning process (i.e., interaction with stakeholders and/or decision-makers) resulting in a formal planning instrument (e.g., planning or policy documents such as spatial plans, Strategic Environmental Assessment (SEA) reports, etc.).

To collect relevant information and allow comparison across case studies, we designed a review framework (Table 1). All the authors analysed the publications independently and then agreed upon the final version of the results.

The description of the categorisations used in the review framework is reported in the Appendix, Section 2.

Table 1
The review framework for in-depth analysis of case studies.

GENERAL INFORMATION	
Reference publication(s)	
Case study	
Type and scale of planning	
Temporal horizon of the planning instrument	
Duration of the planning process	
KEY ASPECTS OF ES INTEGRATION INTO THE PLANNING PROCESS AND INSTRUMENT	
WHY	Policy question/planning issue addressed
	Specific reason(s) for using ES concept, as stated in the paper
WHEN/ WHERE	Phase(s) of the planning process: 1. Identifying problems 2. Analysing the context 3. Defining goals and objectives 4. Developing and assessing alternatives 5. Defining actions 6. Monitoring the implementation and following-up on decisions
	Institution that initiated the planning process
	ES champion(s)
WHO	(Type of) Actors involved: • policy/decision-makers • experts and consultants • academics and researchers • economic sectors representatives • civil society representatives • individual citizens
	Degree of participation: a) Inform b) Consult c) Involve d) Collaborate/Partnership e) Empower
WHAT	Number and type of ES considered, with reasons for their selection
	Methods and indicators used for ES mapping and assessment
	ES-based outputs produced
HOW	Procedures and methods for integrating ES knowledge into the planning instrument
CRITICAL ASPECTS OF ES INTEGRATION (AS REPORTED IN THE PUBLICATION)	
Advantages	
External and internal constraints	
Enabling factors	

3. Results

3.1. Level of integration of ES knowledge, scale of case studies, and type of planning

After removing duplicates and studies without abstract, the search resulted in 2136 eligible records. Section 3 in the Appendix presents some overall statistics of the sample.

Of the 2136 publications, around 60% are methodological or conceptual studies that do not draw any context-specific implication for spatial planning (Fig. 2). Another 25% are case studies in which the developed ES knowledge is claimed to have potential implications for spatial planning. Only 200 publications explicitly aim to support spatial planning decisions, while case studies where ES knowledge was developed and used as part of a spatial planning process are less than 2%. However, over the last 10 years, the share of conceptual/methodological studies has progressively decreased, while studies aimed at planning-support or with potential implications have substantially increased (Fig. 2).

Among the 1525 publications describing case studies (Fig. 3a), the scale most frequently addressed is the regional one (52.3%), followed by urban (16.6%), and national (9.1%). In the subset of publications addressing specific spatial planning decisions (Fig. 3b), the most common type of planning is land-use (61.8%), followed by environmental (23.6%). We found reviews covering all planning types, but no publications specifically aimed at supporting climate adaptation planning.

3.2. In-depth analysis of selected case studies

In the 39 publications classified as *application* and screened based on the full text, we identified 35 single case studies, 7 of which were finally selected for in-depth analysis (Tables 2 and 3).

Table 2 presents the outcomes of the in-depth analysis of case

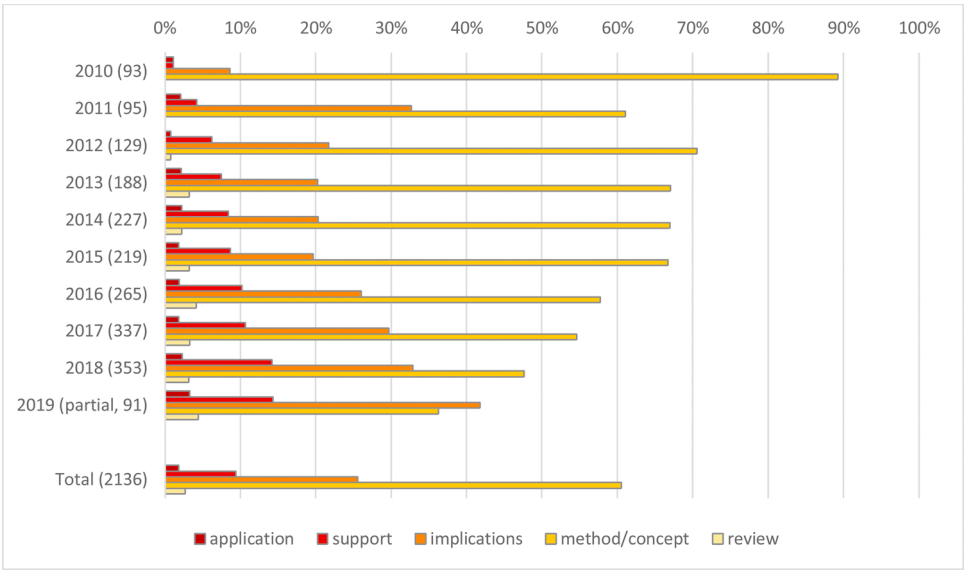

Fig. 2. Percentage of publications per level of integration of ES knowledge into spatial planning: yearly results over the last 10 years and results for the overall sample. In brackets: number of publications.

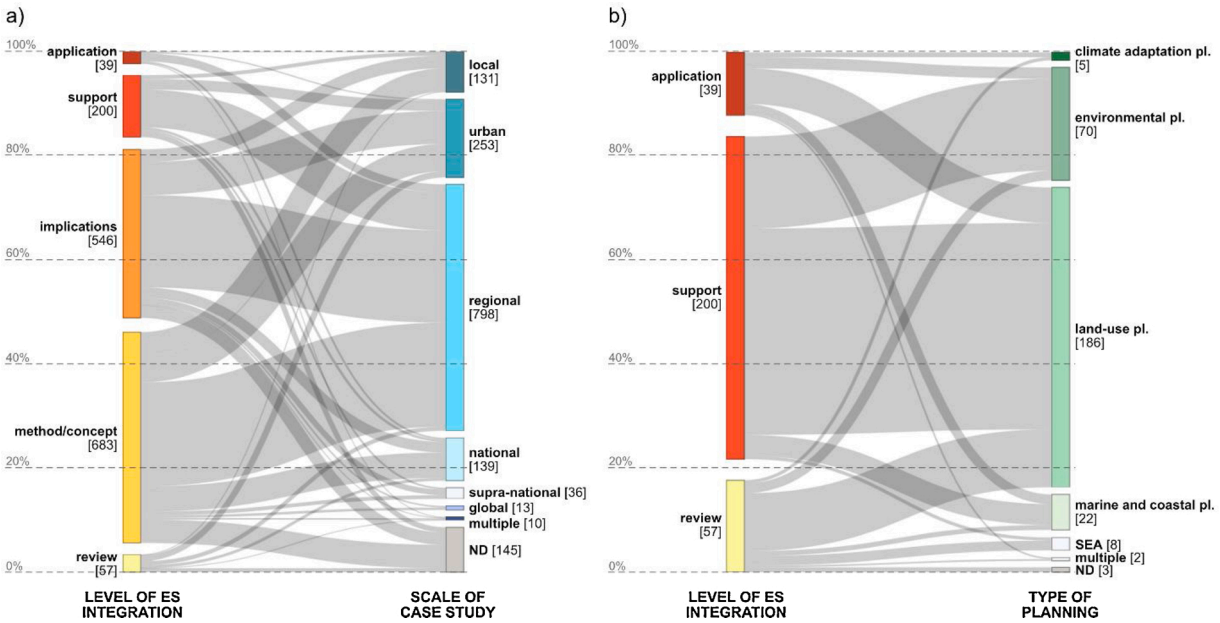

Fig. 3. Frequency of the combinations of (a) level of ES integration and scale of case study, among publications including a case study; and (b) level of ES integration and type of planning, among publications addressing a specific spatial planning decision. ND: Not Determined.

studies. A general objective common to most cases is to assess the impacts of and guide spatial planning decisions about land use and management (Table 2, row *Why*). Three cases address ES integration solely in the first stages of the planning process, to analyse the planning context, to identify problems, and/or to establish objectives. The remaining ones additionally assess the impacts on ES of alternative spatial planning decisions and synthesize assessment results to define optimal spatial solutions (*When/where)*. In all but one case, ES integration stemmed from a collaboration between public institutions in charge of spatial planning and scientists/researchers or non-government organizations. The actors involved in these planning processes included a wide variety of stakeholders and the level of participation was higher than the mere consultation (*Who*). In all but one case, selecting key ES by stakeholders and/or experts was preferred against covering a large number of ES. All the cases considering more than two ES included at least one for each category of provisioning, regulating, and cultural. Three common types of methods (Vihervaara et al., 2018) were adopted, sometimes combined, namely spatial proxy data (e.g., land use land cover maps), modelling tools for biophysical and economic assessment (e.g., InVEST), and scoring matrices based on expert/stakeholder judgments (*What*). Finally, the main ES outputs observed in all cases are maps showing the spatial distribution and, in some cases, levels of ES supply. The maps are either directly included among the plan documents, or used as a basis to produce the formal zoning scheme (*How*).

We additionally searched for critical aspects of ES integration - i.e. advantages, constraints, and enabling factors - as reported by the authors. Most of the reviewed publications had a prevalent descriptive character, with critical reflections presented and discussed unsystematically. However, several recurring points emerged, as summarized in Table 3. Section 4.2 discusses these findings in the light of the other key

Table 2
General information about the analysed case studies and key aspects of ES integration into the planning process and instrument. * (P) = Provisioning service, (R) = Regulating service, (C) = Cultural service.

Case study		City masterplan, Lathi (Finland)	Integrated Coastal Zone Management Plan, Belize	Sustainable Development Plan, Andros Island (Bahamas)	ES framework to support spatial planning, South-East Queensland (Australia)	Marine Spatial Plan, Latvia	Collaborative landscape planning, Krummhörn region (Germany)	Protected area, Blanco River basin (Argentina)
Reference publication(s)		(Brunet et al., 2018)	(Arkema et al., 2015; Arkema and Ruckelshaus, 2017; Loomis, 2015; Verutes et al., 2017)	(Arkema and Ruckelshaus, 2017)	(Maynard et al., 2015, 2011, 2010; Petter et al., 2013)	(Veidemane et al., 2017)	(Karrasch et al., 2017, 2014)	(Rubio et al., 2017)
Type and scale of planning		Land use planning, urban scale	Marine and coastal planning, national scale	Land use planning, regional scale	Planning-support tool for land use planning, regional scale	Marine and coastal planning, national scale	Climate adaptation planning, regional scale	Environmental planning, regional scale
Temporal horizon of the plan		4 years	4 years	25 years	Various temporal horizons	n.d.	n.d.	n.d.
Duration of the planning process		n.d.	6 years	n.d.	4 years	16 months	4 years	3 years
Reference to plan material (available online)		https://www.lahti.fi/en/housing-and-environment/planning-of-urban-environment/city-planning/	https://www.openchannels.org/sites/default/files/literature/Belize%20Integrated%20Coastal%20Zone%20Management%20Plan%202016.pdf	https://www.vision2040bahamas.org/media/uploads/andros_master_plan.pdf	http://www.seqcatchments.org/programs/planning-amp-innovation-seq-es-framework http://www.seqcatchments.org/_literature_70157/A_Guide_to_Incorporating_the_Ecosystem_Services_Framework	https://juraspla nojums.net/english/	https://www.heidekreis.de/home/bauen-planen/regional-und-bauleitplanung/regionales-raumordnungsprogramm/regionales-raumordnungsprogramm-entwurf-2015.aspx	n.d.
WHY	**Policy question/ planning issue addressed**	How to incorporate the ES concept in urban planning of the city?	Where coastal and ocean uses should be sited to reduce risk to marine ecosystems and enhance the benefits they provide to people?	What and where public and private investments should be made to enhance food and water security, coastal resilience, transportation and connectivity, livelihoods and income inequality, and education and capacity building?	How to identify areas to be considered as valuable natural assets of the region, deserving appropriate protection measures or significant offsets if they are diminished or degraded in any way?	How to address conflicts and organise human activities in order to avoid negative impacts on marine health, functions and services?	Which land management alternatives might be suitable for a sustainable future of low-lying coastal landscapes?	How to delineate a protected area to safeguard the provision of ES in the wetlands, specifically the quality and quantity of water resources and the scenic beauty of the basin's landscape?
	Specific reason (s) for using ES concept, as stated in the paper	i) To introduce a new, more anthropogenic viewpoint on urban nature. ii) To provide a synthesizing perspective to the impact assessment of the plan.	i) To measure the impacts of human activities in terms of flow of benefits. ii) To be used as a dialogue tool for stakeholders.	i) To understand how climate and the management decisions made today would affect the future of the island.	i) To direct conservation policies, environmental offsets and enhancement programmes to the right areas.	i) To assess possible impacts of different sea use scenarios. ii) To raise stakeholder awareness concerning the importance of ecosystems in the provision of societal benefits.	i) To enrich the "social-ecological systems" framework with an ecological component.	i) To design a conservation strategy that incorporates the community's perception of natural resources and ES.
WHEN/ WHERE		1. Identifying problems			2. Analysing the context			

(*continued on next page*)

Table 2 (*continued*)

Case study		City masterplan, Lathi (Finland)	Integrated Coastal Zone Management Plan, Belize	Sustainable Development Plan, Andros Island (Bahamas)	ES framework to support spatial planning, South-East Queensland (Australia)	Marine Spatial Plan, Latvia	Collaborative landscape planning, Krummhörn region (Germany)	Protected area, Blanco River basin (Argentina)
WHO	**Phase(s) of the planning process**		2. Analysing the context 3. Defining goals and objectives 4. Developing and assessing alternatives 5. Defining actions	2. Analysing the context 3. Defining goals and objectives 4. Developing and assessing alternatives		2. Analysing the context 3. Defining goals and objectives 4. Developing and assessing alternatives 5. Defining actions	4. Developing and assessing alternatives	1. Identifying problems 2. Analysing the context 3. Defining goals and objectives
	Institution that initiated the planning process	Municipality of Lathi	Government of Belize who designated the Belizean Coastal Zone Management Authority and Institute (CZMAI)	Office of the Prime Minister, with the support from the Inter-American Development Bank	South East Queensland Catchments (SEQC), a regional non-government community-based not-for profit business established by the Federal Government	Ministry of the Environmental Protection and Regional Development of Latvia	Researchers involved in the collaborative research project "Sustainable coastal land management: Trade-offs in ecosystem services" (COMTESS)	Municipality of Luján de Cuyo accompanied by the Ministry of Land, Environment and Natural Resources of the Government of Mendoza
	ES champion(s)	City planners	Scientists from the Natural Capital Project in collaboration with the CZMAI	Scientists from the Natural Capital Project in collaboration with the Office of Prime Minister	The SEQC, acting as an interface between the government and the community	The Baltic Environmental Forum – Latvia	Researchers of the project COMTESS	Researchers who led the stage related to the identification, assessment and mapping of ES
	(Type of) Actors involved	· policy and decision makers · experts and consultants · individual citizens	· policy and decision makers · academics and researchers · civil society representatives · economic sector representatives · individual citizens	· policy and decision makers · academics and researchers · economic sector representatives · civil society representatives	· policy and decision makers · academics and researchers · civil society representatives	· policy and decision makers ·academics and researchers · economic sector representatives · civil society representatives	· policy and decision makers · economic sector representatives	· policy and decision makers · academics and researchers · economic sector representatives · civil society representatives · individual citizens
	Degree of participation	a) inform b) consult	a) inform b) consult c) involve d) collaborate/ partnership	a) inform b) consult c) involve d) collaborate/ partnership	a) inform b) consult c) involve	a) inform b) consult c) involve d) collaborate/ partnership	a) inform b) consult c) involve d) collaborate/ partnership	a) inform b) consult c) involve
WHAT	**Number and type* of ES considered, with reasons for their selection**	2 ES: preservation of groundwater quality (R) and recreation (C).	3 ES: fisheries provision (P), coastal protection (R), and tourism recreation (C).	3 ES: fisheries provision (P), coastal protection (R), and tourism recreation(C).	28 ES (including provisioning, regulating, and cultural).	7 ES: wild animals and their outputs (P), wild plants, algae and their outputs (P), bioremediation by micro-organisms, algae, plants, and animals (R), filtration by animals (R), maintaining of nursery population (R), global climate regulation (R),	9 ES: food production (P), forage production (P), freshwater provision (P), biomass for energy (P), hazard regulation by water retention (R), prevention of saltwater intrusion (R), reduction of greenhouse gases (R), recreation and tourism (C), and community identification (C).	6 ES: water for agriculture, human consumption, and industrial use (P), erosion regulation (R), regulation of the water cycle (R), regulation of the biotic environment (R), aesthetic, spiritual and non-use representations (C), and recreation and ecotourism (C).

(*continued on next page*)

Table 2 (*continued*)

Case study		City masterplan, Lathi (Finland)	Integrated Coastal Zone Management Plan, Belize	Sustainable Development Plan, Andros Island (Bahamas)	ES framework to support spatial planning, South-East Queensland (Australia)	Marine Spatial Plan, Latvia	Collaborative landscape planning, Krummhörn region (Germany)	Protected area, Blanco River basin (Argentina)
						and experiential and physical use of land/ seascapes (C).		
		The two ES are related to the plan's objectives regarding the preservation of the city groundwater area and citizens' recreational opportunities.	Stakeholders agreed that such ES were of high economic and cultural importance.	The three ES are related to the plan's objectives regarding fisheries, tourism, and coastal resilience, the most important benefits that stakeholders want to secure in the future.	The list of ES and their categories have been adapted from De Groot et al. (2002); Millennium Ecosystem Assessment (MA) (2005).	The choice of ES was influenced by data availability and knowledge of local experts.	Those ES were considered (by experts) to be affected by land use change in the analysed scenarios.	The six ES were selected according to the ranking made by the surveyed population.
	Methods and indicators used for ES mapping and assessment	Land use/land cover classes used as proxies of ES supply.	Spatial estimates of production and economic value of ES were computed using InVEST. The models consider the extent of functional habitats and the distribution of human activities in each scenario, integrating ecological, physical, and socio-economic data. See also Arkema et al. (2014) and Arkema et al. (2019) for further details on assessment models.	Spatial estimates of production and economic value of ES were computed using InVEST. The models consider the extent of functional habitats and the distribution of human activities in each scenario, integrating ecological, physical, and socio-economic data. See also Arkema et al. (2019) for further details on assessment models.	The assessment was based on expert judgement. Experts scored the capacity of each ecosystem type to provide ecosystem functions and associated ES.	For regulating ES, experts were asked to evaluate the link between ES and ecosystem types (yes/no). For provisioning and cultural ES, ecosystem types were scored based on a combination of expert judgement and empirical data.	Land use/land cover classes used as proxies of ES supply.	Citizens were asked to identify the supply areas of the six priority ES on a land-use map. The results were used to select the most relevant land uses to be included in the protected area.
HOW	**ES-based outputs produced**	A map of forest and groundwater areas as proxies of ES, which served as a tool to facilitate discussions and promoting ES as an interpretative lens through which to view the plan and its impact assessment.	Spatially explicit maps of ES supply (biophysical and economic values) in the current condition and under three future scenarios. Stakeholders selected and improved the preferred scenario by iteratively evaluating their feedback and model results.	Spatially explicit maps of ES supply (biophysical and economic values) in the current condition and under several future scenarios.	Matrices of scores linking ecosystem categories, functions, and services, and related series of maps to be used as knowledge base for further planning processes.	ES maps representing the diversity of provisioning, regulating and cultural ES in four alternative scenarios. Optimal spatial solutions were proposed based on the results of scenarios' impact assessment and discussions with stakeholders as part of iterative assessment process.	A co-designed actor-based land use scenario synthesizing the former alternatives based on ES assessment results.	Identification of priority sites for a protected area according to the level of ES provision as perceived by the surveyed population.
	Procedures and methods for integrating ES knowledge into	A section on ES was included in the plan report's text.	The preferred scenario evolved into a science-based zoning scheme that informed the final designation of areas for	n.d.	The Framework composed of matrices of scores and related maps is now embedded in the superseding statutory	Mapping results concerning the optimal spatial solutions were integrated into	Essential elements of land use allocation developed in the actor-based scenario were implemented in	A second proposal put forth by the Municipality was ultimately selected, disregarding the

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Table 2 (*continued*)

Case study	City masterplan, Lathi (Finland)	Integrated Coastal Zone Management Plan, Belize	Sustainable Development Plan, Andros Island (Bahamas)	ES framework to support spatial planning, South-East Queensland (Australia)	Marine Spatial Plan, Latvia	Collaborative landscape planning, Krummhörn region (Germany)	Protected area, Blanco River basin (Argentina)
the planning instrument		preservation, restoration, and development uses in the plan.		regional plan and several other regional spatial policies, with the potential to be integrated into local planning schemes.	the environmental impact assessment of the plan.	the regional spatial plan.	results of the participatory process, and prioritising the protection of a larger area over the provision of assessed ES.

aspects emerging from the in-depth analysis and of the wider scientific literature.

4. Discussion

4.1. Main outcomes of the literature review

Despite the keywords selected to limit the results to publications dealing with integration and use of ES knowledge in spatial planning, conceptual and methodological studies remain the majority. The greater the level of ES integration, the smaller the number of publications. However, a fair number of ES studies (classified as *support*) are explicitly aimed at supporting spatial planning. These often involve simulations of realistic planning cases inspired by existing planning issues (e.g., Longato et al., 2019), thus potentially producing valuable and usable knowledge. The share of this type of study has steadily increased during the last 10 years.

The regional scale is the most widely targeted across all types of publications, including case study papers. This is not surprising, given that ES frameworks and assessment models, as well as ES-related decision-support tools, are primarily focused on the regional scale (Grêt-Regamey et al., 2017; Pandeya et al., 2016). Furthermore, some authors agree that the regional scale is the most suited to address certain ES in planning (Fürst et al., 2010; Mascarenhas et al., 2015). Consequently, local scale applications often suffer from poorer data availability and have to rely on coarser ES information, which may not provide reliable support to decision-making (Grêt-Regamey et al., 2014). The critical mass of human, technical, and political capacities may also play a key role in favouring ES integration in national and regional rather than in more local decision-making processes.

The analysis of spatial planning typologies reveals, beyond the most common land use and environmental plans, specific spatial planning instruments in which the integration of ES seems to be easier and more straightforward. These include Marine Spatial Planning (MSP) and SEA, where the ES concept provides a potentially useful tool to support systematic environmental assessments (Geneletti, 2011; Partidario and Gomes, 2013). This emerging role of SEA as an entry-point for integrating ES knowledge into planning processes is coherent with the findings of Mckenzie et al. (2014), who revealed that impact assessment of planning actions, including the analysis of trade-offs, is one of the main "instrumental" uses of ES knowledge in decision-making processes. MSP is a comparatively newer type of planning which addresses the co-existence and interactions of various environmental, social, and economic aspects while regulating different land and sea uses. In the EU, MSP is regulated by a legal framework (European Commission, 2008) that requires the application of an ecosystem-based approach to the management and planning of human activities, to which the ES concept is well suited. The need to balance socio-economic concerns in contexts characterised by higher environmental concerns and stricter environmental protections compared to many terrestrial ecosystems has made MSP a testing ground to experiment with ES approaches, not only in the EU (Arkema et al., 2015; Arkema and Ruckelshaus, 2017; Veidemane et al., 2017).

Finally, the small number of publications specifically dealing with climate adaptation planning might be surprising, given the emphasis on ES-based approaches to tackle climate change-related issues (Munang et al., 2013). However, climate adaptation plans are rarely developed as standalone spatial plans. More often, climate adaptation planning is either a sectoral non-spatial planning process, or is integrated in other formal spatial planning instruments, such as in the case of the regional landscape plan in the Krummhörn region, Germany (Karrasch et al., 2017, 2014).

4.2. Lessons learned from in-depth analysis of case studies

The reviewed case studies reveal three main advantages of

Table 3
Critical aspects of ES integration in the analysed case studies.

Case study	City masterplan, Lathi (Finland)	Integrated Coastal Zone Management Plan, Belize	Sustainable Development Plan, Andros Island (Bahamas)	ES framework to support spatial planning, South-East Queensland (Australia)	Marine Spatial Plan, Latvia	Collaborative landscape planning, Krummhörn region (Germany)	Protected area, Blanco River basin (Argentina)
Advantages	i) ES acted as a synthesizing perspective to assess the plan's impacts on nature and human wellbeing. ii) ES allowed for a broader understanding of the human-nature relationships.	i) ES secured the support of the plan from a diversity of stakeholders. ii) ES facilitated the interaction between science and policy. iii) ES facilitated explicit consideration of multiple objectives that resource managers typically evaluate separately.	i) ES facilitated explicit consideration of multiple objectives that resource managers typically evaluate separately. ii) ES helped to find synergies and minimise trade-offs in management objectives and solutions.	i) ES supported optimal land use zoning and spatial allocation of urban and industrial development. ii) ES created a common language that enabled experts from a wide range of disciplines to contribute.	i) ES enriched the perspective of the SEA since covering all relevant ecosystems, cultural aspects, and economic considerations.	i) ES enriched the "social ecological system" framework by an ecological component.	i) ES helped to include citizens' values and perspectives in the identification of priority sites for conservation.
External and internal constraints	i) Multiple and overlapping scales of ES might get lost in the master plan-level maps. ii) Some aspects related to ES are not easily translatable into specific spatial units on a map. iii) Difficulties in communicating and understanding ES, especially to citizens.	i) Shadow trade-offs with unmeasured services. ii) Quality and scarcity of input data, dearth of tools, and uncertainty of models. iii) Difficulties in translating the jargon of ES into layman's terms.	i) ES-related objectives might not clearly resonate with conventional planning objectives. ii) Limited understanding of local economic aspects and issues in island nations to link ES to measures of wellbeing.	i) Insufficient time, funding, and research capacity to construct complex ecological models for the whole region. ii) Lack of organization's capacity to incorporate ES assessments into planning. iii) Difficulties in tailoring ES actions due to governance and jurisdictional complexity.	i) Budget limitations, data scarcity, and high levels of uncertainty in ES mapping and assessment. ii) Difficulties in communicating ES as a justification for preventing human uses.	n.d.	i) Other approaches to nature conservation can conflict with prioritising areas for ES provision.
Enabling factors	i) One of the city officials had a background in ES research. ii) Planning legislation requires that the impact on nature and people of plans are assessed. iii) ES were selected as one of the main focal points to work on during the previous planning round.	i) The government passed legislation in 1998 calling for cross-sector, ecosystem-based management of coastal and marine ecosystems. ii) Long-term institutional commitment and flexible resources from engaged donors. iii) Partnership with The Natural Capital Project. iv) Maps and quantitative data were some of the main reasons stakeholders were continuing to participate in the process.	i) Funding opportunities from a multilateral development bank interested in connecting the development plan with subsequent loans for implementation. ii) Growing societal demand for information about ways ecosystems support economic development and human well-being.	i) The involvement of local experts that provided credibility of results and garnered public and professional support. ii) The previous statutory regional planning document and natural resource management plan both identified the need for an ES assessment. iii) Growing interest in the use of ES for planning purposes by the SEQC and key stakeholders. iv) High value that the community of SEQ attach to environment.	i) The Marine Strategy Framework Directive (European Commission, 2008) that requires the application of an ecosystem-based approach to the management of human activities. ii) The presence of a (mandatory) Strategic Environmental Assessment of the Plan, suited for incorporating ES assessments.	i) Partnership with a research project as an occasion to develop the informal planning process.	i) An initiative of permanent and temporary residents, who submitted a claim to the municipal authorities for the negative impacts on the provision of ES in wetland areas. ii) Institutional support of the Municipality of Luján de Cuyo that formed the Integrative Committee for the creation of the protected area.

integrating ES into spatial planning processes. The first advantage concerns the capacity of the ES concept to broaden the scope of the planning process and enlarge the perspective on relevant issues to address. Two aspects (comprehensiveness and broadness) also listed by the stakeholders involved in the case studies presented by Dick et al. (2018). Karrasch and colleagues (2017) report on the use of ES as a way to enrich the social-ecological system framework by an ecological component. Veidemane et al. (2017) claim that the "*ES approach enriches the perspective of the SEA as it covers all relevant ecosystems, cultural aspects as well as economic considerations*". This shows how the ES concept provides an overall perspective to account for the social, ecological, and economic impacts of spatial planning decisions. However, it should be noted the lack of assessments of ES demand, which still is a serious challenge in ES science (Geijzendorffer and Roche, 2014).

The second advantage relates to the use of ES as a lens to synthesize and interpret multiple information. This clearly emerges in the description of the case studies in Belize and Bahamas (Arkema et al., 2015; Arkema and Ruckelshaus, 2017; Verutes et al., 2017), where the adoption of an ES approach resulting in spatially-explicit assessments led to the explicit consideration of multiple objectives, but also to the possibility of analysing the results altogether, thus helping to find synergies and minimise trade-offs through an iterative planning process. Brunet and colleagues (2018) stated that the ES approach "*was used as a means to move forward from surveying and measuring toward processing and interpreting the existing data*".

The third advantage concerns the use of ES as a boundary concept that facilitates interactions between multiple actors involved in the process (Adem Esmail and Geneletti, 2017; Dick et al., 2018; Galler et al., 2016; Spyra et al., 2019). The ES concept can help to overcome communication gaps between scientists, policy-makers, and stakeholders, as in the case of Belize (Verutes et al., 2017), as well as across sectors and disciplines, as in the ES framework for South-East Queensland (Maynard et al., 2011). Rubio et al. (2017) maintain that ES served as an entry point to include citizens' values and perspectives in the otherwise fully top-down process for the identification of conservation sites.

Regarding the barriers, some are recurring to the adoption of ES in decision-making processes, for example data availability and accuracy, and lack of resources (time, competences, and money) to produce the assessments (Beichler et al., 2017; Palomo et al., 2018; Spyra et al., 2019). Brunet et al. (2018) discuss the difficulties in capturing "the multiple and overlapping scales of ES" in a plan at the urban scale, considering also that ES knowledge is not always easily translatable into specific spatial units. Similarly, several authors (Veidemane et al., 2017; Verutes et al., 2017) comment on uncertainties, errors, and simplifying assumptions of the models for ES mapping and assessment, at times not fitting the resolution required to take specific spatial planning decisions.

Other constraints are specific to ES integration into spatial planning. Linking ES goals to the objectives of the planning process is sometimes difficult, despite planning objectives implicitly or explicitly aiming to secure and enhance human wellbeing (Arkema and Ruckelshaus, 2017). The relationship between ES provision and the wellbeing of local communities is not always as straightforward in reality as it is at the conceptual level. In this context, methods and indicators used for ES assessments play a key role (Olander et al., 2018). While many efforts of ES science have focused on developing approaches, classifications, and tools as general as possible to ensure wide applicability and comparability, the case studies reveal a need for a deep understanding of the local context as a prerequisite to provide effective planning support. In fact, site differences in management goals, ecosystem function, and human use may affect the extent of ES integration (Arkema et al., 2006).

Communication is sometimes considered as a limitation, consistently with previous findings regarding stakeholders' opinion about ES (Albert et al., 2014b). For example, difficulties in communicating and understanding the ES concept, especially by citizens, were reported by Brunet et al. (2018). Some of the participants, when interviewed by the authors, made a distinction between the ES concept, helpful and enriching, and the related ES terminology. The need for scientists to work on translating the ES jargon into laymen's terms emerged also in another case (Verutes et al., 2017).

ES approaches may sometimes conflict with established spatial planning approaches. In one case, for example, the innovative approach of identifying priority conservation areas based on their relevance for ES provision was in conflict with more traditional approaches to conservation planning (Rubio et al., 2017). Eventually, the latter were chosen, demonstrating how traditionally-established professional norms and codes of conduct may prevent the integration of ES approaches into planning practices (Saarikoski et al., 2018). On the other hand, a successful integration of ES knowledge in established planning approaches and tools, such as zoning, may help to communicate ecosystem-based strategies and actions, paving the way to innovative solutions (Arkema et al., 2006). This particularly happened in the Bahamas case study, where ES assessments helped to demonstrate the importance of mangroves and other coastal habitats for reducing coastal risk, ultimately leading to a bank loan for a nature-based coastal protection project (Silver et al., 2019).

The analysed publications also report about a number of enabling factors that boosted ES integration into the planning process. Several authors identify a specific "window of opportunity" that made it possible to initiate an extra-ordinary collaborative planning process. The law approved in 1998 by the Belizean government calling for cross-sector, ecosystem-based management of coastal and marine ecosystems and the subsequent establishment of a dedicated authority with mandate to create a spatial plan is an example (Arkema et al., 2015). Similarly, in the case of the Marine Spatial Plan of Latvia, ES integration was promoted by the ecosystem-based approach required in the Marine Strategy Framework Directive (European Commission, 2008). In South East Queensland, previous statutory plans stated the need for an ES assessment, leading the path towards the participatory development of the framework and ensuring the mainstreaming of the results (Maynard et al., 2010). These cases reveal the importance of regulatory frameworks as facilitators for triggering ES integration into spatial planning.

In some cases, a supportive social environment – a broadening of what Saarikoski et al. (2018) define as "social capital" – also played a key role as an enabling factor. Arkema and Ruckelshaus (2017) highlight that "*societal demand for information about the ways in which ecosystems support economic development and human well-being is growing*", while Maynard et al. (2011) claims that "*the impetus to develop an ecosystem services framework […] can in part be attributed to the importance the community and stakeholders attach to the environment*". Then, perhaps not surprisingly, almost all authors reflect on the importance that "people" (Rosenthal et al., 2015) had for a successful integration of ES. This refers to the "policy champions" (Saarikoski et al., 2018) who promote ES integration: sometimes researchers and scientists, sometimes the institutions responsible for the planning process, or even stakeholders, as in the case of Latvia (Veidemane et al., 2017). But it also refers to the wider "intellectual capital" (Saarikoski et al., 2018) involved in the process, including scientists, planners, and experts of different sectors. For example in Lathi, where "*one of the city officials had a background in ES research*" (Brunet et al., 2018), or in South East Queensland, where problems of data availability were overcome thanks to local knowledge, which also enhanced credibility and legitimacy of the results (Maynard et al., 2011).

Overall, the analysed case studies suggest that the involvement of a wide variety of stakeholders is linked not only to a higher degree of participation, but also to more substantial and meaningful ES-based planning outputs. This is also true for the very first step of ES integration, i.e. the selection of ES to assess. An iterative science-policy interface (Rosenthal et al., 2015) and a process of knowledge co-production (Saarikoski et al., 2018) with planning institutions, ES champions, and other stakeholders involved emerge as essential factors to initiate and successfully complete the process of ES integration into spatial planning.

4.3. Limitations of the study

The keywords used in the search string, necessarily arbitrary, affected the results of the study. This is particularly true for the terms used to capture the integration between ES and spatial planning, but it also applies to the keywords related to spatial planning, mainly based on western countries' terminology and possibly overlooking definitions specific of other contexts. For example, we may have overlooked more studies dealing with MSP that did not explicitly use the term "spatial plan*" and studies dealing with water management planning. However, our search strategy was able to capture some studies in these fields that explicitly highlight the spatial dimension of planning, which is the primary focus of our analysis.

In addition, we searched publications only in Scopus, and did not consider grey literature, even though it could be a valuable source of case studies (Laurans et al., 2013). We focused our analysis on a homogeneous set of peer-reviewed publications that analyse the process of ES integration from a critical perspective, more likely to be found in scientific than in grey literature. However, this might have influenced some of the results, such as the fact that most of the ES champions found in the case studies are researchers. Furthermore, other case studies of ES integration mentioned in the literature (e.g., in publications classified as *reviews*) were excluded since providing insufficient information on the whole planning process and decisions that led to ES integration, which is the core objective of our review.

Finally, our synthesis of critical aspects is based on the information reported in the publications. The extent to which they reflect evidence produced during the planning process as opposed to the authors' perceptions and opinions is impossible to ascertain. However, the peer-review process should guarantee scientifically sound results, and we found correspondence for most of the findings in the wider scientific literature.

5. Conclusions

Our results revealed that methodological and conceptual studies are still the majority in scientific literature, while case studies with policy-relevant applications of ES are very few, confirming the mismatch between ES science and its use in practice (Lautenbach et al., 2019). Over the last few years, we observed an increase in the share of applied studies explicitly aimed at supporting spatial planning decisions, not just by providing usable tools and methods but trying to address real-world planning issues. However, such knowledge can produce a real impact only if the policy question is committed by decision-makers and if the process of knowledge (co-)production is incorporated within a planning process, eventually resulting in a formal policy instrument or programme.

The main advantages of introducing ES knowledge in spatial planning processes emerged from the case studies are: i) a broader inclusion of relevant issues to address during the planning process, ii) a synthesizing perspective to interpret multiple data and information, and iii) an effective involvement of stakeholders with higher degree of participation. Overall, this can contribute to legitimate decisions dealing with more sustainable spatial allocation of uses and management options. One of the most important factors may trigger ES integration is the "window of opportunity" offered by high-level regulatory frameworks (e.g., at national or EU level) promoting ES-based approaches, or by new planning processes and tools (e.g., SEA and MSP) more open to innovative concepts. However, also bottom-up initiatives such as informal planning processes with researchers and citizens' claims may push authorities to achieve this integration into statutory spatial planning.

The cultural background of policy-makers, stakeholders, and citizens seems to be a crucial pre-requisite for promoting ES integration into planning processes. In most of the analysed case studies, ES integration occurred because of the commitment of policy-makers and stakeholders and their high awareness of ES importance. This need for a "fertile ground" suggests limitations to the conceptual use of ES as the entry point to promote environmental awareness and pro-environmental attitudes, at least within spatial planning processes. Rather, the main advantages emerged point to practical aspects related to the instrumental use of ES knowledge, such as its usefulness in synthesizing and facilitating the understanding and use of complex socio-environmental information. However, specific contextual conditions are necessary for a successful integration, including the establishment of a science-policy collaboration across all stages of the planning process.

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CRediT authorship contribution statement

Davide Longato: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Chiara Cortinovis:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Supervision. **Christian Albert:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision. **Davide Geneletti:** Conceptualization, Methodology, Investigation, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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References

Adem Esmail, B., Geneletti, D., 2017. Design and impact assessment of watershed investments: an approach based on ecosystem services and boundary work. Environ. Impact Assess. Rev. 62, 1–13. https://doi.org/10.1016/j.eiar.2016.08.001.

Adem Esmail, B., Geneletti, D., Albert, C., 2017. Boundary work for implementing adaptive management: a water sector application. Sci. Total Environ. 593–594, 274–285. https://doi.org/10.1016/j.scitotenv.2017.03.121.

Albert, C., Aronson, J., Fürst, C., Opdam, P., 2014a. Integrating ecosystem services in landscape planning: requirements, approaches, and impacts. Landsc. Ecol. 29, 1277–1285. https://doi.org/10.1007/s10980-014-0085-0.

Albert, C., Hauck, J., Buhr, N., von Haaren, C., 2014b. What ecosystem services information do users want? Investigating interests and requirements among

landscape and regional planners in Germany. Landsc. Ecol. 29, 1301–1313. https://doi.org/10.1007/s10980-014-9990-5.
Albert, C., Fürst, C., Ring, I., Sandström, C., 2020. Research note: spatial planning in Europe and Central Asia – enhancing the consideration of biodiversity and ecosystem services. Landsc. Urban Plan. 196, 103741 https://doi.org/10.1016/j.landurbplan.2019.103741.
Arkema, K.K., Ruckelshaus, M., 2017. Transdisciplinary Research for Conservation and Sustainable Development Planning in the Caribbean, Conservation for the Anthropocene Ocean: Interdisciplinary Science in Support of Nature and People. Elsevier Inc. https://doi.org/10.1016/B978-0-12-805375-1.00016-7
Arkema, K.K., Abramson, S.C., Dewsbury, B.M., 2006. Marine ecosystem-based management: from characterization to implementation. Front. Ecol. Environ. 4, 525–532. https://doi.org/10.1890/1540-9295(2006)4[525:MEMFCT]2.0.CO;2.
Arkema, K.K., Verutes, G., Bernhardt, J.R., Clarke, C., Rosado, S., Canto, M., Wood, S.A., Ruckelshaus, M., Rosenthal, A., McField, M., De Zegher, J., 2014. Assessing habitat risk from human activities to inform coastal and marine spatial planning: a demonstration in Belize. Environ. Res. Lett. 9 https://doi.org/10.1088/1748-9326/9/11/114016.
Arkema, K.K., Verutes, G.M., Wood, S.A., Clarke-Samuels, C., Rosado, S., Canto, M., Rosenthal, A., Ruckelshaus, M., Guannel, G., Toft, J., Faries, J., Silver, J.M., Griffin, R., Guerry, A.D., 2015. Embedding ecosystem services in coastal planning leads to better outcomes for people and nature. Proc. Natl. Acad. Sci. USA 112, 7390–7395. https://doi.org/10.1073/pnas.1406483112.
Arkema, K.K., Rogers, L.A., Toft, J., Mesher, A., Wyatt, K.H., Albury-Smith, S., Moultrie, S., Ruckelshaus, M.H., Samhouri, J., 2019. Integrating fisheries management into sustainable development planning. Ecol. Soc. 24 https://doi.org/10.5751/ES-10630-240201.
Beery, T., Stålhammar, S., Jönsson, K.I., Wamsler, C., Bramryd, T., Brink, E., Ekelund, N., Johansson, M., Palo, T., Schubert, P., 2016. Perceptions of the ecosystem services concept: opportunities and challenges in the Swedish municipal context. Ecosyst. Serv. 17, 123–130. https://doi.org/10.1016/j.ecoser.2015.12.002.
Beichler, S.A., Bastian, O., Haase, D., Heiland, S., Kabisch, N., Müller, F., 2017. Does the ecosystem service concept reach its limits in Urban environments? Landsc. Online 50, 1–21. https://doi.org/10.3097/LO.201751.
Bennett, E.M., Chaplin-Kramer, R., 2016. Science for the sustainable use of ecosystem services. F1000Research 5, 2622. https://doi.org/10.12688/f1000research.9470.1.
Brunet, L., Tuomisaari, J., Lavorel, S., Crouzat, E., Bierry, A., Peltola, T., Arpin, I., 2018. Actionable knowledge for land use planning: making ecosystem services operational. Land Use Policy 72, 27–34. https://doi.org/10.1016/j.landusepol.2017.12.036.
CBD, 2010. Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at Its Tenth Meeting. Strategic Plan for Biodiversity 2011–2020, Including Aichi Biodiversity Targets. Montreal.
Clark, W.C., van Kerkhoff, L., Lebel, L., Gallopin, G.C., 2016. Crafting usable knowledge for sustainable development. Proc. Natl. Acad. Sci. 113, 4570–4578. https://doi.org/10.1073/pnas.1601266113.
Cortinovis, C., Geneletti, D., 2018. Ecosystem services in urban plans: what is there, and what is still needed for better decisions. Land Use Policy 70, 298–312. https://doi.org/10.1016/j.landusepol.2017.10.017.
Cortinovis, C., Geneletti, D., 2019. A framework to explore the effects of urban planning decisions on regulating ecosystem services in cities. Ecosyst. Serv. 38, 100946 https://doi.org/10.1016/j.ecoser.2019.100946.
Daily, G.C., Polasky, S., Goldstein, J., Kareiva, P.M., Mooney, H.A., Pejchar, L., Ricketts, T.H., Salzman, J., Shallenberger, R., 2009. Ecosystem services in decision making: time to deliver. Front. Ecol. Environ. 7, 21–28. https://doi.org/10.1890/080025.
De Groot, R.S., Wilson, M.A., Boumans, R.M.J., 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. Ecol. Econ. 41, 393–408. https://doi.org/10.1016/S0921-8009(02)00089-7.
Di Marino, M., Tiitu, M., Lapintie, K., Viinikka, A., Kopperoinen, L., 2019. Integrating green infrastructure and ecosystem services in land use planning. Results from two Finnish case studies. Land Use Policy 82, 643–656. https://doi.org/10.1016/j.landusepol.2019.01.007.
Dick, J., Turkelboom, F., Woods, H., Iniesta-Arandia, I., Primmer, E., Saarela, S.R., Bezák, P., Mederly, P., Leone, M., Verheyden, W., Kelemen, E., Hauck, J., Andrews, C., Antunes, P., Aszalós, R., Baró, F., Barton, D.N., Berry, P., Bugter, R., Carvalho, L., Czúcz, B., Dunford, R., Garcia Blanco, G., Geamănă, N., Giucă, R., Grizzetti, B., Izakovičová, Z., Kertész, M., Kopperoinen, L., Langemeyer, J., Montenegro Lapola, D., Liquete, C., Luque, S., Martínez Pastur, G., Martin-Lopez, B., Mukhopadhyay, R., Niemela, J., Odee, D., Peri, P.L., Pinho, P., Patrício-Roberto, G. B., Preda, E., Priess, J., Röckmann, C., Santos, R., Silaghi, D., Smith, R., Vădineanu, A., van der Wal, J.T., Arany, I., Badea, O., Bela, G., Boros, E., Bucur, M., Blumentrath, S., Calvache, M., Carmen, E., Clemente, P., Fernandes, J., Ferraz, D., Fongar, C., García-Llorente, M., Gómez-Baggethun, E., Gundersen, V., Haavardsholm, O., Kalóczkai, Á., Khalalwe, T., Kiss, G., Köhler, B., Lazányi, O., Lellei-Kovács, E., Lichungu, R., Lindhjem, H., Magare, C., Mustajoki, J., Ndege, C., Nowell, M., Nuss Girona, S., Ochieng, J., Often, A., Palomo, I., Pataki, G., Reinvang, R., Rusch, G., Saarikoski, H., Smith, A., Soy Massoni, E., Stange, E., Vågnes Traaholt, N., Vári, Á., Verweij, P., Vikström, S., Yli-Pelkonen, V., Zulian, G., 2018. Stakeholders' perspectives on the operationalisation of the ecosystem service concept: results from 27 case studies. Ecosyst. Serv. 29, 552–565. https://doi.org/10.1016/j.ecoser.2017.09.015.
European Commission, 2008. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). OJ L. 164, 19–40.
European Commission, 2011. Our Life Insurance, Our Natural Capital: an EU Biodiversity Strategy to 2020 (COM/2011/0244 Final). Brussels.
European Commission, 2019. EU Guidance on Integrating Ecosystems and Their Services Into Decision-making. SWD(2019) 305 Final.
Fürst, C., Volk, M., Pietzsch, K., Makeschin, F., 2010. Pimp your landscape: a tool for qualitative evaluation of the effects of regional planning measures on ecosystem services. Environ. Manag. 46, 953–968. https://doi.org/10.1007/s00267-010-9570-7.
Galler, C., Albert, C., von Haaren, C., 2016. From regional environmental planning to implementation: paths and challenges of integrating ecosystem services. Ecosyst. Serv. 18, 118–129. https://doi.org/10.1016/j.ecoser.2016.02.031.
García-Llorente, M., Harrison, P.A., Berry, P., Palomo, I., Gómez-Baggethun, E., Iniesta-Arandia, I., Montes, C., García del Amo, D., Martín-López, B., 2018. What can conservation strategies learn from the ecosystem services approach? Insights from ecosystem assessments in two Spanish protected areas. Biodivers. Conserv. 27, 1575–1597. https://doi.org/10.1007/s10531-016-1152-4.
Geijzendorffer, I.R., Roche, P.K., 2014. The relevant scales of ecosystem services demand. Ecosyst. Serv. 10, 49–51. https://doi.org/10.1016/j.ecoser.2014.09.002.
Geneletti, D., 2011. Reasons and options for integrating ecosystem services in strategic environmental assessment of spatial planning. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 7, 143–149. https://doi.org/10.1080/21513732.2011.617711.
Geneletti, D., Adem Esmail, B., Cortinovis, C., 2018. Identifying representative case studies for ecosystem services mapping and assessment across Europe. One Ecosyst. 3, e25382 https://doi.org/10.3897/oneeco.3.e25382.
Geneletti, D., Esmail, B.A., Cortinovis, C., Arany, I., Balzan, M., Van, P., Bicking, S., Borges, P.A.V., Borisova, B., Broekx, S., Gil, A., Inghe, O., Kopperoinen, L., Kruse, M., Liekens, I., Mizgajski, A., Mulder, S., Nedkov, S., Ostergard, H., Picanço, A., Ruskule, A., Santos-martín, F., Sieber, I.M., Svensson, J., Va, D., Veidemane, K., Kiel, C.A.U., 2020. Ecosystem services mapping and assessment for policy- and decision-making : lessons learned from a comparative analysis of European case studies. One Ecosyst. 5, e53111 https://doi.org/10.3897/oneeco.5.e53111.
Geneletti, D., Zardo, L., 2016. Ecosystem-based adaptation in cities: an analysis of European urban climate adaptation plans. Land Use Policy 50, 38–47. https://doi.org/10.1016/j.landusepol.2015.09.003.
Grêt-Regamey, A., Weibel, B., Bagstad, K.J., Ferrari, M., Geneletti, D., Klug, H., Schirpke, U., Tappeiner, U., 2014. On the effects of scale for ecosystem services mapping. PLoS One 9, 1–26. https://doi.org/10.1371/journal.pone.0112601.
Grêt-Regamey, A., Sirén, E., Brunner, S.H., Weibel, B., 2017. Review of decision support tools to operationalize the ecosystem services concept. Ecosyst. Serv. 26, 306–315. https://doi.org/10.1016/j.ecoser.2016.10.012.
IPBES, 2012. Resolution on the Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services Adopted by the Second Session of the Plenary Meeting to Determine the Modalities and Institutional Arrangements for IPBES. Panama City.
Jaligot, R., Chenal, J., 2019. Integration of ecosystem services in regional spatial plans in Western Switzerland. Sustainability 11. https://doi.org/10.3390/su11020313.
Jax, K., Furman, E., Saarikoski, H., Barton, D.N., Delbaere, B., Dick, J., Duke, G., Görg, C., Gómez-Baggethun, E., Harrison, P.A., Maes, J., Pérez-Soba, M., Saarela, S.-R., Turkelboom, F., van Dijk, J., Watt, A.D., 2018. Handling a messy world: lessons learned when trying to make the ecosystem services concept operational. Ecosyst. Serv. 29, 415–427. https://doi.org/10.1016/j.ecoser.2017.08.001.
Karrasch, L., Klenke, T., Woltjer, J., 2014. Land Use Policy linking the ecosystem services approach to social preferences and needs in integrated coastal land use management – a planning approach. Land Use Policy 38, 522–532. https://doi.org/10.1016/j.landusepol.2013.12.010.
Karrasch, L., Maier, M., Klenke, T., Kleyer, M., 2017. Collaborative landscape planning: co-design of ecosystem-based land management scenarios. Sustainability 9, 1–15. https://doi.org/10.3390/su9091668.
Kirchhoff, C.J., Carmen Lemos, M., Dessai, S., 2013. Actionable knowledge for environmental decision making: broadening the usability of climate science. Annu. Rev. Environ. Resour. 38, 393–414. https://doi.org/10.1146/annurev-environ-022112-112828.
Laurans, Y., Rankovic, A., Billé, R., Pirard, R., Mermet, L., 2013. Use of ecosystem services economic valuation for decision making: questioning a literature blindspot. J. Environ. Manag. 119, 208–219. https://doi.org/10.1016/j.jenvman.2013.01.008.
Lautenbach, S., Mupepele, A.C., Dormann, C.F., Lee, H., Schmidt, S., Scholte, S.S.K., Seppelt, R., van Teeffelen, A.J.A., Verhagen, W., Volk, M., 2019. Blind spots in ecosystem services research and challenges for implementation. Reg. Environ. Change 19, 2151–2172. https://doi.org/10.1007/s10113-018-1457-9.
Longato, D., Gaglio, M., Boschetti, M., Gissi, E., 2019. Bioenergy and ecosystem services trade-offs and synergies in marginal agricultural lands: a remote-sensing-based assessment method. J. Clean. Prod. 237 https://doi.org/10.1016/j.jclepro.2019.117672.
Loomis, I., 2015. A 'Blue economy' for Belize. Planning 81, 28–32.
Mascarenhas, A., Ramos, T.B., Haase, D., Santos, R., 2014. Integration of ecosystem services in spatial planning: a survey on regional planners' views. Landsc. Ecol. 29, 1287–1300. https://doi.org/10.1007/s10980-014-0012-4.
Mascarenhas, A., Ramos, T.B., Haase, D., Santos, R., 2015. Ecosystem services in spatial planning and strategic environmental assessment-A European and Portuguese profile. Land Use Policy 48, 158–169. https://doi.org/10.1016/j.landusepol.2015.05.012.

Maynard, S., James, D., Davidson, A., 2010. The development of an ecosystem services framework for South East Queensland. Environ. Manag. 45, 881–895. https://doi.org/10.1007/s00267-010-9428-z.

Maynard, S., James, D., Davidson, A., 2011. An adaptive participatory approach for developing an ecosystem services framework for South East Queensland. Australia. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 7, 182–189. https://doi.org/10.1080/21513732.2011.652176.

Maynard, S., James, D., Hoverman, S., Davidson, A., Mooney, S., 2015. An ecosystem services-based approach to integrated regional catchment management: the South East Queensland experience. In: Martin-Ortega, J., Ferrier, R.C., Gordon, I.J., Khan, S. (Eds.), Water Ecosystem Services. Cambridge University Press, Cambridge, pp. 90–98. https://doi.org/10.1017/CBO9781316178904.012.

Mckenzie, E., Posner, S., Tillmann, P., Bernhardt, J.R., Howard, K., Rosenthal, A., 2014. Understanding the use of ecosystem service knowledge in decision making: lessons from international experiences of spatial planning. Environ. Plan. C Gov. Policy 32, 320–340. https://doi.org/10.1068/c12292j.

Millennium Ecosystem Assessment (MA), 2005. Ecosystems and Human Well-being: a Framework for Assessment, Ecosystems. Island Press, Washington DC.

Munang, R., Thiaw, I., Alverson, K., Liu, J., Han, Z., 2013. The role of ecosystem services in climate change adaptation and disaster risk reduction. Curr. Opin. Environ. Sustain. 5, 47–52. https://doi.org/10.1016/j.cosust.2013.02.002.

NCC, 2018. How to Do It: a Natural Capital Workbook.

Nordin, A.C., Hanson, H.I., Alkan Olsson, J., 2017. Integration of the ecosystem services concept in planning documents from six municipalities in southwestern Sweden. Ecol. Soc. 22 https://doi.org/10.5751/ES-09420-220326.

Olander, L.P., Johnston, R.J., Tallis, H., Kagan, J., Maguire, L.A., Polasky, S., Urban, D., Boyd, J., Wainger, L., Palmer, M., 2018. Benefit relevant indicators: ecosystem services measures that link ecological and social outcomes. Ecol. Indic. 85, 1262–1272. https://doi.org/10.1016/j.ecolind.2017.12.001.

Palomo, I., Willemen, L., Drakou, E.G., Burkhard, B., Crossman, N., Bellamy, C., Burkhard, K., Campagne, C.S., Dangol, A., Franke, J., Kulczyk, S., Le Clec'h, S., Abdul Malak, D., Muñoz, L., Narusevicius, V., Ottoy, S., Roelens, J., Sing, L., Thomas, A., Van Meerbeek, K., Verweij, P., 2018. Practical solutions for bottlenecks in ecosystem services mapping. One Ecosyst. 3, e20713 https://doi.org/10.3897/oneeco.3.e20713.

Pandeya, B., Buytaert, W., Zulkafli, Z., Karpouzoglou, T., Mao, F., Hannah, D.M., 2016. A comparative analysis of ecosystem services valuation approaches for application at the local scale and in data scarce regions. Ecosyst. Serv. 22, 250–259. https://doi.org/10.1016/j.ecoser.2016.10.015.

Partidario, M.R., Gomes, R.C., 2013. Ecosystem services inclusive strategic environmental assessment. Environ. Impact Assess. Rev. 40, 36–46. https://doi.org/10.1016/j.eiar.2013.01.001.

Petter, M., Mooney, S., Maynard, S.M., Davidson, A., Cox, M., Horosak, I., 2013. A methodology to map ecosystem functions to support ecosystem services assessments. Ecol. Soc. 18 https://doi.org/10.5751/ES-05260-180131.

Posner, S., McKenzie, E., Ricketts, T.H., 2016. Policy impacts of ecosystem services knowledge. Proc. Natl. Acad. Sci. 113, 1760–1765. https://doi.org/10.1073/pnas.1502452113.

Rall, E.L., Kabisch, N., Hansen, R., 2015. A comparative exploration of uptake and potential application of ecosystem services in urban planning. Ecosyst. Serv. 16, 230–242. https://doi.org/10.1016/j.ecoser.2015.10.005.

Rosenthal, A., Verutes, G., McKenzie, E., Arkema, K.K., Bhagabati, N., Bremer, L.L., Olwero, N., Vogl, A.L., 2015. Process matters: a framework for conducting decision-relevant assessments of ecosystem services. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 11, 190–204. https://doi.org/10.1080/21513732.2014.966149.

Rozas-Vásquez, D., Fürst, C., Geneletti, D., Almendra, O., 2018. Integration of ecosystem services in strategic environmental assessment across spatial planning scales. Land Use Policy 71, 303–310. https://doi.org/10.1016/j.landusepol.2017.12.015.

Rubio, M.C., Rubio, C., Abraham, E., Salomón, M.A., 2017. Conservation of ecosystem services in high-altitude Andean wetlands: social participation in the creation of a natural protected area. Ecol. Austral 27, 177–192. https://doi.org/10.25260/EA.17.27.1.1.271.

Ruckelshaus, M., McKenzie, E., Tallis, H., Guerry, A., Daily, G., Kareiva, P., Polasky, S., Ricketts, T., Bhagabati, N., Wood, S.A., Bernhardt, J., 2015. Notes from the field: lessons learned from using ecosystem service approaches to inform real-world decisions. Ecol. Econ. 115, 11–21. https://doi.org/10.1016/j.ecolecon.2013.07.009.

Saarikoski, H., Primmer, E., Saarela, S.R., Antunes, P., Aszalós, R., Baró, F., Berry, P., Blanko, G.G., Goméz-Baggethun, E., Carvalho, L., Dick, J., Dunford, R., Hanzu, M., Harrison, P.A., Izakovicova, Z., Kertész, M., Kopperoinen, L., Köhler, B., Langemeyer, J., Lapola, D., Liquete, C., Luque, S., Mederly, P., Niemelä, J., Palomo, I., Pastur, G.M., Peri, P.L., Preda, E., Priess, J.A., Santos, R., Schleyer, C., Turkelboom, F., Vadineanu, A., Verheyden, W., Vikström, S., Young, J., 2018. Institutional challenges in putting ecosystem service knowledge in practice. Ecosyst. Serv. 29, 579–598. https://doi.org/10.1016/j.ecoser.2017.07.019.

Schröter, M., Albert, C., Marques, A., Tobon, W., Lavorel, S., Maes, J., Brown, C., Klotz, S., Bonn, A., 2016. National ecosystem assessments in Europe: a review. Bioscience 66, 813–828. https://doi.org/10.1093/biosci/biw101.

Scott, A., Carter, C., Hardman, M., Grayson, N., Slaney, T., 2018. Mainstreaming ecosystem science in spatial planning practice: exploiting a hybrid opportunity space. Land Use Policy 70, 232–246. https://doi.org/10.1016/j.landusepol.2017.10.002.

SEPA, 2018. Guide to Valuing Ecosystem Services (No. 6854).

Silver, J.M., Arkema, K.K., Griffin, R.M., Lashley, B., Lemay, M., Maldonado, S., Moultrie, S.H., Ruckelshaus, M., Schill, S., Thomas, A., Wyatt, K., Verutes, G., 2019. Advancing coastal risk reduction science and implementation by accounting for climate, ecosystems, and people. Front. Mar. Sci. 6, 1–19. https://doi.org/10.3389/fmars.2019.00556.

Spyra, M., Kleemann, J., Cetin, N.I., Vázquez Navarrete, C.J., Albert, C., Palacios-Agundez, I., Ametzaga-Arregi, I., La Rosa, D., Rozas-Vásquez, D., Adem Esmail, B., Picchi, P., Geneletti, D., König, H.J., Koo, H., Kopperoinen, L., Fürst, C., 2019. The ecosystem services concept: a new Esperanto to facilitate participatory planning processes? Landsc. Ecol. 34, 1715–1735. https://doi.org/10.1007/s10980-018-0745-6.

van Oudenhoven, A.P.E., Schröter, M., Drakou, E.G., Geijzendorffer, I.R., Jacobs, S., van Bodegom, P.M., Chazee, L., Czúcz, B., Grunewald, K., Lillebø, A.I., Mononen, L., Nogueira, A.J.A., Pacheco-Romero, M., Perennou, C., Remme, R.P., Rova, S., Syrbe, R.U., Tratalos, J.A., Vallejos, M., Albert, C., 2018. Key criteria for developing ecosystem service indicators to inform decision making. Ecol. Indic. 95, 417–426. https://doi.org/10.1016/j.ecolind.2018.06.020.

Veidemane, K., Ruskule, A., Strake, S., Purina, I., Aigars, J., Sprukta, S., Ustups, D., Putnis, I., Klepers, A., 2017. Application of the marine ecosystem services approach in the development of the maritime spatial plan of Latvia. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 13, 398–411. https://doi.org/10.1080/21513732.2017.1398185.

Verutes, G.M., Arkema, K.K., Clarke-Samuels, C., Wood, S.A., Rosenthal, A., Rosado, S., Canto, M., Bood, N., Ruckelshaus, M., 2017. Integrated planning that safeguards ecosystems and balances multiple objectives in coastal Belize. Int. J. Biodivers. Sci. Ecosyst. Serv. Manag. 13, 1–17. https://doi.org/10.1080/21513732.2017.1345979.

Vihervaara, P., Mononen, L., Nedkov, S., Viinikka, A., 2018. Biophysical Mapping and Assessment Methods for Ecosystem Services.