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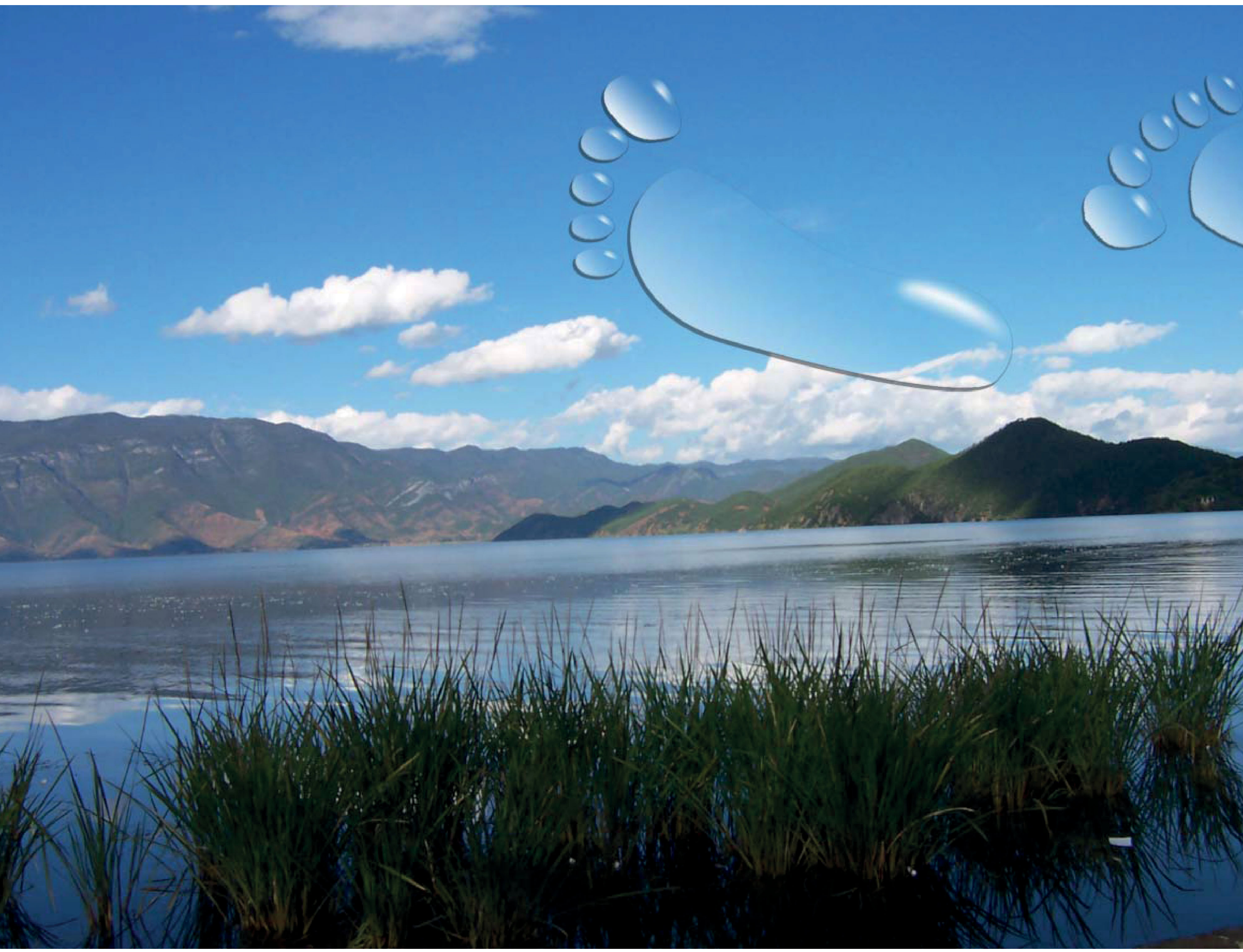

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Review

Ecosystem Service Mapping and Assessment as a Support for Policy and Decision Making

The aim of this paper is to investigate the potential of ecosystem services (ES) research to support policy and decision-making. As the ES concept is a multitier framework, there is no ideal entry point for conducting useful ES analysis. The entry point depends on the particular empirical or policy question being researched. The information on ES potential can contribute to the management of ecosystems, which provides services, including identification of priority conservation and restoration areas. Understanding the ES flows helps to protect paths needed to transmit the services to users. The demand for ES determines society's ambitions for sustainable management and ensuring a continuous supply of desired services. In turn, budget analyses allow identification of supply–demand mismatches across landscapes, and point out the appropriate institutional scale for environmental decision-making. The benefit of trade-offs analysis is weighing the improvements in one ES against the decrease of another. Finally, the specific configuration of rivalry and excludability of particular services enables the arrangement of an appropriate scheme of payments for ES. The complex recognition of the range of possible ES mapping and assessment products can help to match the ES analysis with policy goals. Once we identify a good entry point for examining a specific policy question, we can adequately embed the planned study within the ES framework.

Keywords: Assessment; Ecosystem services; Mapping; Policy; Practice

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1 Introduction

Ecosystem services, seen as "the contributions that ecosystems make to human well-being" [1], have become a very popular and prominent conceptual frame for numerous research projects. In recent years, many ES mapping and assessment approaches have been developed and applied at different spatial scales ranging from the global (*e.g.*, [2–9]) to the national (*e.g.*, [10–15]) and local (*e.g.*, [16–23]). Despite a wide range of studies, the application of ES concept to biodiversity conservation, spatial planning and natural resource management is inhibited. On the one hand, ES approach is already being integrated in different policy contexts (in the European Union, *e.g.*, [24–26]). However, while scientific and political interests in ES information increase, the actual implementation in concrete decision-making still remains limited [13, 27, 28]. According to Braat and de Groot [29], recognition of the ES value is a considerable achievement in itself, but to transform this recognition into concrete planning and management practice that leads to improved ecosystems quality and sustained levels of service delivery is an even more formidable challenge. Operationalization of knowledge on ES requires a practical reflection. The aim of this paper is to investigate the potential of ES information to support policy and decision making. Section 2 shortly reviews the scope of ecosystem services mapping and assessment (MAES). Section 3 discusses opportunities and challenges of integration ES information into policy and decision-making. Novelty of the paper is a critical review of importance of the particular ES information types for different policy goals. The MAES have many possible purposes and uses, and not one type of MAES analysis is right for the entire range of uses. The usefulness of the MAES study can best be judged by its ability to help solving the navigational question faced.

This study contributes towards the enhancement of the practical application of the ES approach through a review and a discussion of studies that examine its operational potential and shortcomings. The analyzed literature is not limited to studies published during a fixed period. However, as the ES concept is currently used in a range of studies with widely differing aims, the review is based on selected journals indexed in Scopus, which focus on creating the interface between ES science and practice. In doing so, the author omitted studies published outside arbitrarily chosen set of journals. Nevertheless, in the author's opinion the source material makes it possible to draw representative conclusions on the main issues of operationalizing the ES concept. The search was performed in July 2015 and resulted in 97 policy oriented ES studies, derived from 23 different journals.

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Abbreviations: ES, ecosystem service; **MAES**, ecosystem services mapping and assessment; **PES**, payments for ecosystem services; **SBA**, service benefiting area; **SCA**, service connecting area; **SPH**, service provision hotspot; **SPU**, service providing unit.

2 Scope of ecosystem service mapping and assessment

Figure 1 shows a possible scope of MAES, outlined on the basis of reflection on this issue in the analyzed literature.

There are multiple definitions of ES. In this paper ES are considered as contributions of ecosystem structure and function – in combination with other inputs – to human well-being [30]. This ES definition takes into account interaction between natural, human, social, and built capital in the supply of ES [31], which has a meaning in splitting up ES potential and flow. Scale refers to the physical dimensions of phenomena or observations, in either space or time [32]. Depending on their properties, ecosystems are able to supply services [33]. The potential of an ecosystem to provide a service is not equal to the actual use of a service, *e.g.*, a beautiful landscape might not be used for recreation because it is inaccessible [34]. A potential is regarded as stock of ES, while the flow represents their actual use [33]. Service providing unit (SPU) refers to the spatial unit that is the source of ES [35]. Hotspot is an area that provides a large amount of a particular service in a comparably small area/spot [36–38]. The degraded service provision hotspot (degraded SPH) represents an area that has lost its capacity to provide ES to society to a great extent [39].

Flows of ES from ecosystems to people can take place via service connecting areas [35] or certain "carriers" [40]. SCAs can be both of natural origin (natural hydrologic networks, gas circulation paths, lines-of-sight) and human-made/modified (artificial waterways, transport ways, pipelines). The carrier is a mobile matter, energy, or information quantity represented in physical units or relative rankings [40]. The carrier transmits the ES by connecting ecosystems and beneficiaries. The demand refers to the amount of a service required or desired by society [41]. Spatial areas in which beneficiaries demand ES are called service benefiting areas (SBAs) [35, 39]. Times of particularly high ES supply or demand (*e.g.*, due to seasonal variations) are defined as hot moments [42].

As ecosystems produce multiple services and these interact in complex ways, different services are interlinked, both negatively and positively [29]. The ecosystem service bundle is a set of associated ES that are supplied by or demanded from a given ecosystem or are associated with a particular place and appear together repeatedly in time and space [43]. Ecosystem service synergies are described as phenomena that occur when multiple services are enhanced simultaneously. Ecosystem service trade-offs occur when the enhancement of the provision/demand of one service causes a reduction in another ES [44].

Further characteristics of ES are their excludability and rivalry status [42, 44–47]. Ecosystem service rivalry is the degree to which the use of ES by an individual reduces the amount of benefits available for others. In turn, ES are "excludable" to the degree that individuals can be excluded from benefiting from them.

In accordance with the conceptual foundation presented in Fig. 1, Section 3 discusses the constraints and opportunities for the integration of different types of ES information into the policy and practice. Although the framework presented in Fig. 1 comprises several related tiers, it is not always necessary to consider all of them in each MAES analysis. The decision whether the entire ES framework should be worked through or only a single tier of it should be used, depends on the specific applications and the needs of end-users [33]. According to the Honey-Rosés and Pendleton [48], in current research on ES the choice of what to value stems more from the researcher side and interests rather than from the policy demand. In order to strengthen the policy usefulness of ES research, the scientific community should take into account the interests, decision-contexts, and requirements of potential users [27], as well as give priority to questions that can best be answered with better information [48].

3 Opportunities and challenges of ecosystem services operationalization

3.1 Definition of appropriate spatial and temporal mapping and assessment scales

A clearly defined scale is inevitable for a successful application of the ES approach [49]. Burkhard et al. [42] consider following spatial scales for MAES: local, regional, continental, and global. For instance, noise protection by the plant zones is a service produced in scale of plants, plot scale. By contrast, CO_2 sequestration takes place in the scale of the plot and the ecosystem (plant production), but the ES is generated at global scale [50]. Similar diversity of scales can be found for demand of ES. For instance, the demand for air purification is generated at the location where people live or work, the demand for other services can be more diffuse (*e.g.*, maintaining nursery populations) or be linked at higher spatial scales (*e.g.*, many components of average daily diet have international origins) [34].

Besides location, temporal scale is of high importance at ES mapping and assessment. Temporal scales include short-term, seasonal, annual, medium-term, and long-term periods [42]. The selection of appropriate temporal scales has to be carried out very carefully to capture the potential of particular ES, its flow and demand patterns. For example, the provisioning potential of agroecosystems is determined by seasonal growth and harvest phases, but timber shows decade-long rotation periods. Respective temporal patterns can be identified for regulating and cultural ES supply, flow, and demand as well.

Spatial and temporal scales and their appropriate selection are a recurring challenge of ES science and practical application. The problem is that the scale of MAES and the scale of decision making are not necessarily identical. ES mapping and assessment units should match scales of their geobiophysical supply origin, and their flow and demand units, on the one hand. On the other hand, they should match scales of administrative units (such as communities, counties, states) for better application in decision making [51]. Spatial mismatches can influence the results of the MAES analysis and, consequently, have an effect on their applicability [52]. For example, in terms of freshwater ES conservation, it would make sense to have a map of an entire watershed. However, regional planning is usually done within administrative boundaries and it is not always possible to cooperate across boundaries. This entails the risk that interregional effects, *e.g.*, downstream pollution, are overlooked by upstream planning [53].

Another big challenge of ES operationalization is related to the fact that stakeholders ask for very precise and spatially explicit information at a local scale. However, detailed data are often not available, and collecting and processing them is costly [53]. Wainger et al. [54] comment that in applying an ES approach to local scale, "the devil, truly, is in the details." According to Koschke et al. [55], the ES concept is at the moment better suited to the stakeholders who work on a larger scale than at the local scale. Certainly, this should not discourage from seeking the ways of the efficient use of data resources. As Daily [56] said, even imperfect measures of ES

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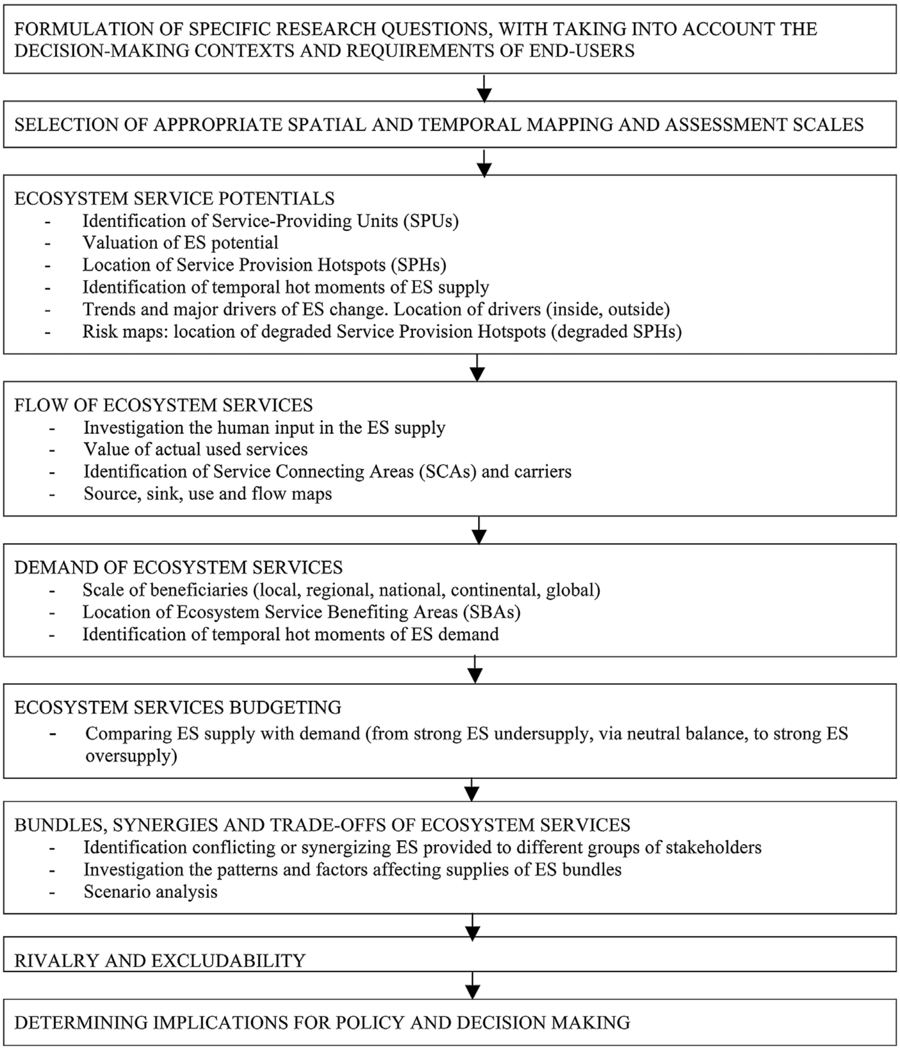

Figure 1. Scope of ecosystem services mapping and assessment.

value "if understood as such, are better than simply ignoring ecosystem services altogether, as is generally done in decision making today."

3.2 Information on ecosystem service potential

Individual ecosystems have different functions based on their structures and processes. Consequently, their capacities to supply particular ES can vary strongly [57] and are linked to natural conditions, *e.g.*, climate, relief, soil, hydrology, vegetation, and fauna. Burkhard et al. [30, 42, 58] indicate a high potential of many near-natural land cover types (as forests, wetlands, water bodies) to provide a broad range of ES. Also, many agricultural land cover types show high potentials for food supply. The more anthropogenically influenced land cover types have considerably lower ES potentials (*e.g.*, urban fabric, industrial or commercial areas, dump sites), except for some cultural services available in urban areas. These latter can provide high recreation and tourism services as well as knowledge and religious experiences.

For most regulating ES, the supplying of ES can be fully attributed to the ecosystem – there is no or hardly any human contribution. For example, forests may sequester carbon without human intervention. For most provisioning and cultural ES, however, the current level of ES supply is determined by a combination of ecosystem properties and human contribution [59], as technology, labor, energy, and knowledge. Additional inputs can lead to higher ES flows as compared to naturally available ES potentials [42]. Disentanglement of human and ecosystem contributions in the generation of ES in strongly modified cultural landscapes remains a complex and challenging issue.

The supplying of several ES relates to specific spatial process units such as floodplains, catchments. ES supply mapping and assessment should be preferably carried out in these units or in areas affected by related processes instead of artificial system boundaries formed by administrative units. The concept of service providing units developed by Luck et al. [60, 61] makes it possible to describe the capacity of a particular area to supply ES without explicit mention of the species, attributes, functional groups, interaction networks, or habitat types that provide the services. This approach enables investigating the ES supply on the basis of easily available land cover data, like CORINE (*e.g.*, [52, 62–67]). However, for some provisioning ES, location of SPU's is not related to land cover or land use forms identified on the study area's surface (*e.g.*, aquifer localization in case of groundwater withdrawn). Appropriate SPU delineations remain also delicate for cultural ES. Many of them have an intangible nature such as landscape aesthetics, spiritual experience, or knowledge systems. Researchers are looking for different ways to solve this dilemma, *e.g.*, for landscape aesthetics Bagstad et al. [40] propose to consider viewsheds as SPUs. Viewsheds are delineated by lines of sight which connect aesthetic landscape features and areas of potential enjoyment.

The mapping and assessment of ecosystem potentials constitute an important basis for policy-making, as the use and management of services (often regulated and controlled by legislation tools) can modify or change the properties and potentials of ecosystems. A particular benefit of ES information is seen in its capacity to provide quantitative estimates of the impacts of land use policy on service provision [27]. The suitability of an ecosystem to carry different land use systems can be established, the available but still unemployed potentials can be put to actual use, and risks can be estimated [33]. Mapping and assessment of potentials can also help to make decisions on minimal service supply. In principle, all landscapes are multifunctional but only some functions will supply enough services to be of interest for decision making [49].

Place based information on ES can play a crucial role to address many of the outstanding policy questions related to restoration of ecosystems [53, 68]. According to Palomo et al. [39], contributions of ES potential maps to management of protected areas include identification of (i) priority conservation areas for ES preservation that are currently unprotected; (ii) areas under protection that provide relatively few services; and (iii) areas suitable for ES restoration inside the protected area because a high level of degraded SPHs.

However, it should be taken into account that comparing ES potentials directly with human demands carries the risk of being abused for new land conversions towards more intensive forms of use or even grabbing exploitation of natural resources. In the case of many ES, for sustainable resource management potential cannot be depleted to its full extent, *e.g.*, fish stocks or forest stands. Therefore, information on ES potentials has to be prepared and documented carefully and has to fulfil certain criteria for end-use [42].

3.3 Spatial dynamics of ecosystem service flows

To benefit from ES, a flow is necessary from the ecosystem to society. Ecosystem service flow can be regarded as the spatially explicit routing of an ES from sources to beneficiaries [40]. The flow route different ES to people (*e.g.*, riverine flood regulation, water supply) or for some services route people to service provision locations (*e.g.*, flow of people to recreational areas).

The character of flow depends on spatial relations between areas of ES supply and demand. Fisher et al. [69] classified the following types of SPUs–SBAs spatial relationships: In situ, omni-directional, and directional. The in situ type denotes that the service is provided and the benefits are realized in the same location. The omni-directional type indicates that the service is provided in one location, but benefits occur in the surrounding area with no directional bias. The directional type denotes that the delivery of a service benefits a surrounding place due to the flow direction. Burkhard et al. [42] consider it a decoupled type flow where the ES is traded over long distances.

Many regulating ES show in situ, omni-directional, or directional SPU-SBA relationships. The example is pollination, where SPUs and SBAs have to be physically connected because pollination cannot be imported from decoupled remote regions [70]. In turn, provisioning and cultural services can show decoupled supply–demand relationships, and demand for them can be met by moving resources or people [41]. In the case of cultural ES, flows are generally more difficult to grasp, because most of them are intangible assets.

Conservation actions can alter the flow of ES. Willemen et al. [71] show how the establishment of a protected area influences the flow of five ES (food, timber and fuel wood production, carbon sequestration, and tourism) to the different beneficiary groups. The most evident difference is between the food and carbon ES, and beneficiary groups. A protected area increases the carbon stock and the benefit flow to the global population. At the same time, conservation leads to less favorable conditions in terms of crop production and the flows of benefits to local villagers. Timber and fuel wood stock increase; however, the access limitations form a barrier to the benefit flow to humans.

Quantified ES flow information can provide policy-relevant information. A comparison of flows of ES with capacities of ecosystems to sustain these flows would be an important method to analyze the sustainability of ecosystem use. Areas where the flow exceeds the capacity indicate unsustainable ecosystem use which leads to depletion of stocks [72]. Policy implications of understanding how services flow across the landscape are widely discussed by Bagstad et al. [40]. According to these authors, an analysis of ES flows allows for planning interventions more precisely to minimize loss of important services, and to restore or enhance impaired ES. Understanding the efficiency of service flows in the given area helps to redirect flow paths in order to increase or decrease the quantity of ES available to users. There may be room for policy interventions if services are produced by ecosystems but cannot get to people due to pollution or flow capture by infrastructure or natural landscape features, or because of a lack of connectivity between the source and use locations. Additionally, flow analysis can highlight critical pathways, where multiple flows converge in high density or where single flows transmit all of the service to group of beneficiaries. These places will be valuable for protecting access to services. Flow paths can also clarify which groups of beneficiaries have the earliest or easiest access in case of competition for a finite number of services. Perhaps the most important, mapping the flows opens the door to novel approaches to managing landscapes for ES. Instead of planning just to protect ecosystems which provide services, it supports more holistic conservation that takes into account both service providers and the flow corridors needed to transmit the benefits to users.

3.4 Demand for ecosystem services

Independently of the actual ecosystem service supply, demand for it can change over time and space [41]. Demand calculations are mainly based on data about human population density combined with average consumption rates, but also on land use activities and on their demands for certain services [30, 73]. For example, all agricultural activities show high demands for whole bundles of regulating ES, as pollination, nutrient and erosion regulation, pest and disease control. Demands for ES are highest in human-dominated land cover types, such the urban, industrial, and commercial areas. More near-natural land cover types are characterized by generally lower population numbers and less ES-consuming activities and consequently, lower demand rates [42].

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Burkhard et al. [42] reckon that ES demand should be located at the site of the final beneficiary, usually the end-consumer. Schröter et al. [47] argue that in many cases people do not have a demand for the actual ES (*e.g.*, round wood) but for final processed goods that are the result of a production chain (*e.g.*, firewood or table). For these processed goods they suggest to map and assess the demand either at the location where the final beneficiary uses the ES (for spatially confined services, *e.g.*, flood protection, recreation) or at the place of the last contribution of an ecosystem to the existence of ES (for spatially non-confined, transportable services, such as crops, timber).

As complementary to SPUs, service benefiting areas (SBAs) can be determined. In contrast to SPUs, SBAs do not relate primarily to ecosystems or geobiophysical units but to beneficiaries of certain ES. Therefore, typical locations for SBAs are urban areas or rural settlements and respective assessment units are administrative or planning units [35].

As the value of ES emerges from the interaction of three domains, biology, economy, and culture [74], social-economic factors might influence the demand for ES. Thus, ecosystems offer different benefits depending on who asks for them and on local human values and needs [75]. Orenstein and Groner [76] reported the results of trans-border research regarding perception of ES in the Arabah Valley of Jordan and Israel. Rural residents largely perceive their dependence on such ES as soil, water, and sun for the agricultural sector. Urban focused mainly on the sun, sand, and sea that enable recreational and tourist activities. From the psychological perspective, ES are motivations – they initiate, in personal and social processes, direct and sustain human action toward ecosystems [77]. Thus, the perceived benefits that people get from ecosystems are the reasons why they might be likely to engage or not in behaviors that ensure the continuous supply of desired ES. Muhamad et al. study [78] on dwellers' perception of ES in a forest–agricultural landscape of West Java shows that local people promote conservation of regulating ES and maintenance ES bundles only when their provisioning needs are accommodated.

Ruijs et al. [79] emphasize that demand studies provide information about people's preferences especially for analyses at low spatial scales, such as local or regional. For analyses at higher spatial scales, revealed or stated preference approaches are less reliable. Moreover, as noted by Geijzendorffer and Roche [34], even without an expression of demand by individuals, there can be use of a service. For instance, many regulating services are continuously used without people being aware of them, leaving it up to institutions to generate an expression of demand and to ensure supply.

Demands can be mapped and assessed without considering where ES actually are produced, or detailed origin patterns as a part of the ES footprint can be identified [30]. The latter (linked to the ecological footprint concept, [80]) calculates the area needed to generate particular ES demanded by humans in a certain area at a certain time. However, in today's globalized world, it is difficult to track and define the origin of services used by people in a given region. Many services are imported from remote places, so the environmental impacts of service production leave ES footprint elsewhere [30]. For instance, as many Europeans must have their coffee first thing in the morning, this small-scale event cumulates to affect the state of ecosystems in producing countries, such as Brazil, Vietnam, Colombia, and Indonesia [81].

Geijzendorffer and Roche [34] highlight the existence of unsatisfied demand and its role for policy ambitions for maintenance of future services supply and sustainable ES management. The extent to which a stakeholder group is able to access the demanded ES depends on factors such as accessibility, ownership, social status, education, and gender. As most mapping and assessments focus on the potential of ecosystems to supply services to society, there is a need to determine whether these services are actually delivered and whether there is any demand remaining which is not met by services.

3.5 Budgeting of ES

For analyzing source and sink dynamics and to identify flows of services, the information about ES supply and demand can be merged. As a result we get budgets of ES supply and demand [30]. Budget analyses are useful in the context of identifying supply–demand mismatches across landscapes and their changes over time. On a global scale, supply–demand budgets have to be zero in the long-term as a depletion of natural capital is to be avoided. However, regional budgets for particular ES do not necessarily need to be neutral [42]. The focal points of human ES demands are urban regions, as the majority of the human population is located in cities [73]. Some ES with omni-directional, directional, or decoupled supply patterns may be better and more sustainably provided to the cities by their hinterlands or more distant regions [30]. It is one task of future-oriented ES management to balance land use decisions toward the sustainable flow of ES.

Supply–demand analyses enable to determine the role of remote locations in the management of protected areas. Exploration of the consequences for the protected area of demands for ES originating from remote locations allow for extending the scope of action associated with protected areas to places that are located far from them and to build broader ES management strategy [39].

The providers and beneficiaries of ES can be regarded as single persons, groups, or society as a whole. Comparison of supply and demand patterns can help to identify the appropriate institutional scale for environmental decision-making [73]. Various studies (*e.g.*, [37, 76, 78, 82]) have shown that local stakeholders recognize the importance of provisioning services in a major way and more distant users value regulating and cultural services. This implies that the design of the environmental management policies should be based not only on the scale at which services are produced but also on the scale at which beneficiaries demand them [50]. However, additional development is needed in the conceptualization of ES demand with regard to regulating services. For many of them the spatial beneficiaries localization is problematic, mainly due to the lack of clear (direct) benefits to human societies [41], or their continuous distribution over time and space [42]. If there is no demand for ES, the concept might not serve as a useful management strategy [83].

3.6 Ecosystem services bundles, synergies, and trade-offs

In recent years, the investigation the relationship between ecosystem management and the provision of the total bundle of ES has become a major field in ES studies (*e.g.*, [84–93]). The synergies and trade-offs between ES provided to different users under current and alternative scenarios have significant implications for decision-making. According to Ruijs et al. [79], this type of analyses should provide grounds for answering the following question of practical relevance: Is it better to generate a bundle of ecosystem services in a given region or to specialize in one of them? The study of these authors for 18 Central and Eastern European countries shows that in the case of agricultural production and carbon sequestration, specialization in one of the ES seems to be cost-effective. The relationship between agricultural production and habitat or cultural services is more complex. In most areas, combining bundles of these ES is cost-effective. But if biodiversity levels are especially high, focusing on habitat conservation, instead of combining agricultural production and biodiversity, it becomes cost-effective.

Braat and de Groot [29] notice that delivery of many services is positively correlated, but when an ecosystem is managed principally for supplying of a single service, other services are almost always influenced negatively. Simultaneous supply of maximal ES bundles is the ideal policy target designed to enhance and guarantee ecosystem stability and the well-being of people [44]. However, most services are still neglected in ecosystem management decisions. As a consequence, highly productive, multiservice landscapes are converted into simpler and often single-function land use types, such as croplands. This approach provides short-term economic gain to a few at the expense of the long-term wellbeing of the wider community [49].

Understanding the patterns and factors affecting supplies of multiple ES could help us to better manage ecosystems. The potential benefit of trade-offs analysis is weighing the improvements in one ES against the decrease of another [94]. For example, a study by Grêt-Regamey et al. [95] on trade-offs for forest ES delivers results which can support forest managers in balancing such services as timber production, habitat provision, carbon sequestration, avalanche protection, and recreation. In turn, Ryffel et al. [96] investigate preferences for land use trade-offs to support water flow regulation and flood protection services. The results may serve as an input for watershed managers to develop strategies for increasing the natural capacity of catchments to provide flood protection in addition to technical solutions, such as river dams and barrier lakes, which are often not able to completely prevent flooding.

3.7 Rivalry and excludability

To meaningfully map the ES, it is also necessary to consider the degree their rivalry and excludability [45–47]. An ecosystem service is rival if beneficiaries who use it leave it less reachable for others. For instance, water used for irrigation is not available for a service of others located downstream. In the case of a non-rival ES, the use of the service by an individual does not have a significant impact on the quality or quantity available of others. For example, one person benefiting from the protection of the ozone layer does not have an impact on other people benefiting from it. Rivalry is an intrinsic property of ES that cannot be altered by policy or legal institutions [45]. Excludability occurs if the cultural and institutional mechanisms or technologies exist that prevent other individuals or groups from using the service. For example, fish collected from a given water body can be claimed by a particular stakeholder, thereby excluding the right of others from accessing any fish caught [97]. In turn, water utility infrastructure, irrigation systems and hydroelectric dams are examples of technology and infrastructure that create exclusive intermediaries between service providers and ultimate beneficiaries [98]. Unlike rivalry, excludability is created through policy and institutions. However, some ES can be inherently non-excludable [98]. This occurs if it is impossible to create property rights or the costs of enforcement are too high [46]. It would be virtually impossible, for instance, to exclude someone from the benefits of maintaining water cycle or climate regulation.

The specific configuration of rivalry and excludability of a particular service influences the arrangement of the respective PES scheme [46]. Markets are better prepared for the allocation of private goods, *i.e.*, goods with high excludability and rivalry [99]. If there is no excludability and no rivalry, the services are public [100], which is the case of most regulating and cultural ES. The implications are of practical nature. As we move along the continuum from ES with private to public good character, the transaction costs of exclusion enforcing increase to levels that do no longer make markets a practical option [101]. This market failure drives to the under-valuing of, and inadequate investment in the protection of ecosystems [102]. In such cases collective institutions must either create appropriate conditions for private sector payments, or accept the public good character of the service and pay for it directly [98]. For instance, some of the forest ES are private goods (*e.g.*, wood) and some are public (*e.g.*, viewshed services or habitat for wildlife) [103]. Private landowners may not manage their forests in a way that provides the socially best mix of services through time. Timber production activities can impact regulating and cultural services directly and via roundabout effects. Creating incentives for forest landowners to deliver multitude of ES is a very complex and difficult policy problem [104]. Bartczak and Metelska-Szaniawska's study [105] on attitudes towards payments for forest ES in Poland suggests that the provision of a forest services considered a public good type should be financed by the entire community or society through local governments or the national government (public-financed scheme).

4 Concluding remarks

Until present, it has been challenging to turn the concept of ES into a practical tool for the policy and practitioner communities. The operationalization of ES requires better reflection on the usefulness of different MAES products for solving the questions faced by potential end-users. This article discusses opportunities and challenges of integrating ES information in different policy areas. This insight could be helpful guidance for studies that aim at addressing the ES information needs and requirements of planners and decision makers. As the ES concept is a multitier framework, there is no ideal entry point for conducting useful ES research. The entry point depends on the specific empirical or policy question under investigation. The presented paper may be a support in matching the scope of ES analysis with several of the possible MAES goals relevant for policy making.

The reflection presented in this article obviously needs further development. In order to bridge the science-practice gap, transdisciplinary case studies of ES application in real-world policy-making contexts should be carried out. An important platform for further discussion of the main issues of operationalizing the ES concept is the European Union-funded ESMERALDA project (carried out from February 2015 to July 2018), entirely dedicated to enhancing ES for policy and decision making.

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