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Understanding the role of conceptual frameworks: Reading the ecosystem service cascade

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ABSTRACT

The aim of this paper is to identify the role of conceptual frameworks in operationalising and mainstreaming the idea of ecosystem services. It builds on some initial discussions from IPBES, which suggested that conceptual frameworks could be used to: 'simplify thinking', 'structure work', 'clarify issues', and 'provide a common reference point'. The analysis uses the cascade model as a focus and looks at the way it has been used in recent published material and across a set of case studies from the EU-funded OpenNESS Project as a device for conceptual framing. It found that there are examples in the literature that show the cascade model indeed being used as an 'organising framework', a tool for 'reframing' perspectives, an 'analytical template', and as an 'application framework'. Although the published materials on the cascade are rich, these accounts lack insights into the process by which the different versions of the model were created, and so we turned to the set of OpenNESS case studies to examine how they read the cascade. We found that the cascade was able to provide a common reference for a diverse set of studies, and that it was sufficiently flexible for it to be developed and elaborated in ways that were meaningful for the different place-based studies. The case studies showed that generalised models like the cascade can have an important 'awareness-raising' role. However, we found that using models of this kind it was more difficult for case studies to link their work to broader societal issues such as human well-being, sustainable ecosystem management, governance, and competitiveness, than to their own concerns. We therefore conclude that to be used effectively, conceptual models like the cascade may need to be supported by other materials that help users read it in different, outward looking ways. We also need to find mechanisms for capturing this experience so that it can be shared with others.

1. Introduction

The aim of operationalising the ecosystem service concept has been widely taken up by researchers working at the interface of science and policy. In the most rudimentary sense, the aim amounts to 'getting the idea used' and 'mainstreamed' in decision making, because it is asserted that a range of 'nature-based solutions' are potentially available to resolve issues that confront society.

The task of demonstrating the usefulness of the concept of ecosystem services is, however, daunting. It requires not only access to evidence and the tools needed to interrogate and summarise data, but also understanding of the scientific underpinnings that make those data *meaningful*. In this paper, we focus on how we make those scientific underpinnings available through the use of conceptual frameworks. The issue is especially important when dealing with ecosystem services in a real-world, 'problem-solving' context, where there is usually a need to address issues in an inter- and trans-disciplinary way. Parties to problems involving ecosystem services often have different types and levels of expertise, as well as different agendas and values.

The co-creation of a conceptual framework is often advanced as one of the first, vital steps in any ecosystem assessment (Ash et al., 2010); such frameworks can help to define the scope and focus of the problems addressed and the assessments needed. Although they are often presented diagrammatically (e.g., Mace et al., 2012), it is clear that their pictorial simplicity masks a range of

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complex negotiations, the nature of which are fundamental to a successful outcome. This paper takes as its starting point the proposition that the *process* of building a conceptual framework is an essential part of problem solving, and that given the 'wicked' character (cf. Rittel and Webber, 1974) of most problems involving people and nature, this is best done iteratively. The general understanding is that such problems are difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize. The assumption is that with such problems there is no 'right' answer and so the goal is to clarify possible actions and their implications across a range of options. This work formed part of the EU-FP7 funded OpenNESS Project (www.openness-project.eu), whose overall aim has been to show how the concepts of ecosystem services and natural capital can be used to provide 'tested, practical and tailored solutions for integrating ecosystem services into land, water and urban management and decision-making'.

In OpenNESS in general (Potschin and Haines-Young, 2016a), and in this paper in particular, we take the 'ecosystem service cascade' (Haines-Young and Potschin, 2010; Potschin and Haines-Young, 2011, 2016b) as a starting point. We use it to consider how such conceptual frameworks can be read in different ways and how those readings can be used to bring structure to otherwise wicked problems. The cascade model is an appropriate vehicle for this kind of work because it sets out what are recognised to be the key elements of the ecosystem service paradigm by distinguishing the functional characteristics of ecosystems from services, and services from benefits. Given that there are a number of studies reported in the scientific literature that have employed the cascade in different research contexts, the OpenNESS project provided the opportunity to examine whether this experience is mirrored in work undertaken at local scales that has a strong emphasis on operationalising the concept. By engaging with a set of case studies[2] over a period of time, OpenNESS has made it possible to look at some of the social processes around the development of conceptual frameworks rather than just the reported outcomes. The ambition is to examine how conceptual frameworks are employed 'on the ground' and to draw lessons that can help people to use them more effectively.

2. Using ecosystem services to explore societal challenges

To provide a clear problem focus for the conceptual work reported here, the OpenNESS Project identified four broad 'societal challenges'. These were used to critically explore the way that the concepts could be used to better understand the dependence of human well-being on nature, the sustainable management of ecosystems for the benefit of people, governance at the interface of people and the environment, and competitiveness and the environment. These themes were identified as being of broad concern at EU level in the call for FP7 funding in 2011, to which the OpenNESS consortium responded.

Human well-being is widely regarded as a central component of the ecosystem service paradigm, and it has been argued that decisions about what it represents and how it is to be assessed are of major importance in such work (Polishchuk and Rauschmayer, 2012; Summers et al., 2012). In OpenNESS, it is viewed as a *state that is also intrinsically and not just instrumentally valuable (or good) for a person or a societal group* (after Alexandrova, 2012; see Jax and Heink, 2016). This definition was thought to be sufficiently pluralistic to accommodate the different perspectives of the OpenNESS case studies. The definition also suggests that we need to go beyond economic wealth, to include such things as health and good social relations. When looked at in this way, key questions that emerge for OpenNESS were therefore to understand how different ecosystem services relate to different components of well-being, and what trade-offs might be involved at individual and group levels.

Understanding how changes in the output of ecosystem services affect well-being is closely related to the challenge of sustainable ecosystem management, which entails issues of *what* is being sustained and *why*, as well as *how* human well-being and sustainability can be achieved by managing ecosystem services (Brussard et al., 1998; Slocombe, 1998; Szaro et al., 1998; McLeod and Leslie, 2009; Chapin et al., 2011). In the context of OpenNESS, a key focus for sustainable management (Smith et al., 2016) was the relationships between biodiversity and ecosystem services, and how through management of natural capital, biodiversity might be conserved or restored. While sustainable management connects to issues of human well-being, the challenge also addresses how ecosystem management can be supported by governance processes and institutions. Thus, we defined governance as a third societal challenge.

In OpenNESS, the analysis of governance covers a wide-ranging set of issues (Primmer and Furman, 2012; Primmer et al., 2015; Görg et al., 2016). In addition to exploring the operation and effectiveness of different polices and regulatory frameworks from national and EU-level (Heink et al., 2016), it also involves the analysis in different place-based contexts, of who is affected by ecosystem change, who makes decisions and which power relations are involved, whether different actors or groups make their voices heard, and how account is rendered. Such analyses are complex because they can involve actors and organisations operating at different spatial and temporal scales, with different motives and responsibilities. Although the effectiveness of governance mechanisms and institutions will have implications for human well-being and the goals of sustainable ecosystem management, it can also affect the standing or status of a region or country relative to others. This comparative aspect is covered by the final OpenNESS challenge, namely that of competitiveness.

The notion of competitiveness is often equated with *economic* performance. However, it is now widely acknowledged that investment in natural capital can benefit a place or a region both socially and economically (Ambec et al., 2013; Haines-Young et al., 2016). This view was promoted under the Lisbon Treaty, but it remains unclear yet whether environmental quality is instrumentalized as a means for economic competitiveness or whether it represents a goal in itself. The Lisbon Treaty set out the goal for Europe of a highly competitive social market economy founded on social progress and "a high level of protection and improvement of the quality of the environment" (EU, 2007); investment in Europe's natural capital is now one of the seven flagship initiatives under the Europe 2020 Strategy (EC, 2011). Most recently, the EU Framework Programme for Research and Innovation 'Horizon 2020' has linked sustainability and competitiveness across its societal challenges as a means of promoting raw materials security, improving well-being, and enhancing resilience to future social and economic shocks[3] (EC, 2014). In OpenNESS, the theme of competitiveness was therefore seen as a way of exploring how the ecosystem service concept can be applied beyond the 'environmental agenda', taken into account that competitiveness as a means to achieve sustainability does not always work and that it is an empirical question whether enhanced competitiveness leads to more sustainability or not.

Although the conceptual work in OpenNESS was framed around the four challenges, the case studies came to the Project with their

[2] The OpenNESS case studies are described on http://www.openness-project.eu/cases and in Dick et al., (2018).

[3] http://ec.europa.eu/programmes/horizon2020/h2020-sections

own pre-existing concerns. Thus, it was useful to see if the case studies could, at the initial stages of the work, make any connections between their specific research questions and these more general issues. Importantly, we sought to explore if, and how, they represented the challenges in terms of the cascade.

3. The role of conceptual frameworks and the cascade model

The cascade model (Fig. 1) was developed to explain how the notion of ecosystem services can be used to understand the relationships between people and nature (Potschin and Haines-Young, 2016b). Ecosystem services are taken as the contributions that ecosystems make to human well-being. The model suggests that to understand these relationships we need to identify both the functional characteristics of ecosystems that give rise to services and the benefits and values that they support. Changes in benefits and values, it is suggested, shape the way that people deal with the various drivers of ecosystem change. It was not intended as a *complete* representation of the ecosystem service paradigm, but rather as an expression of its key components that could be elaborated and changed as people worked with them. The five elements of the cascade are intended to encourage users to scrutinise the distinction between what are understood as 'services' and 'benefits', and to examine the particular 'functional' characteristics of ecosystems that give rise to services, as opposed to the more general ecological structures and processes that support them.

In OpenNESS, the cascade was used initially as a way of comparing the perspectives of the Project's case studies, but lately as a way of looking at the way they structured their thinking and organised their work. These uses of the cascade model echo those identified in the early discussions of IPBES (The Intergovernmental Platform of Biodiversity and Ecosystem Services) (United Nations, 2012; UNEP, 2014; Díaz et al., 2015), which suggested that they can serve as:

- a tool that can help to make complex systems as simple as they need to be for their intended purpose;
- a device for structuring and prioritizing work;
- a way of clarifying and focusing thinking about complex relationships, thereby supporting communication across disciplines, knowledge systems, and between science and policy; and,
- a common reference point that encourages 'buy-in' from different participant groups.

As noted above, the cascade was selected as a starting point for the work in OpenNESS because it had already gained some attention in the wider ecosystem service literature. A review of the published material that has subsequently built up around it, allows us to critically review and refine the IPBES typology still further, and in particular reflect on the differences, if any, between 'conceptual frameworks' and 'models'. Since 'models' are often presented as means of simplifying complex systems, of clarifying thinking, and of operationalising ideas, it appears that they have the same function as a 'conceptual framework'; the cascade is intended to do all these things. However, the extent to which models like the cascade have the wider social functions that shape the *processes* involved in tackling wicked problems, such as helping to organise work and promoting engagement, remains to be seen.

The work by Tolvanen et al. (2016) and Pagella and Sinclair (2014) illustrate how the cascade can be employed as an ***organising structure*** to help clarify 'complex relationships'. The focus can be procedural as well as structural. Tolvanen et al. (2016) use the cascade to characterize the availability and applicability of spatial data for the analysis of an agricultural landscape, while Pagella and Sinclair (2014) use it to review different types of mapping tools. Both examples illustrate procedural types of usage. Other examples of the cascade being used as an organisational framework from a more conceptual perspective include: Cordier et al. (2014), who used it to design a framework for ecosystem service monetization to ensure that monetary valuation techniques are better able to contribute to the understanding of the impact of economic activities; Vihervaara et al. (2013), who used it to categorise ecosystem service research in relation to the themes of the International Long Term Ecological Research (ILTER) network; and, Kronenberg (2014), who used the cascade to look at what the current debates on ecosystem services can learn from the past in the scientific literature dealing with economic ornithology.

Applications that illustrate the use of the cascade as an organisational heuristic also include the many studies that have sought to review and develop indicator frameworks for ecosystem services. The interest in this area arises because it is often difficult to measure services directly and so proxies from other parts of the cascade may be appropriate, or because people feel that to make a comprehensive assessment metrics from across the range of cascade elements need to be considered. Work using the cascade as a general indicator framework include Maes et al. (2012a,b, 2013), Liquete et al. (2013), and van Oudenhoven et al. (2012), while Mononen et al. (2016) and Uehara et al. (2016) use the cascade elements to characterise the status of different ecosystem services.

Use of the cascade as an indicator framework has been taken further by Hering et al. (2015) and Honrado et al. (2013) who sought to make the conceptual link to the DPSIR framework (Drivers – Pressures – States – Impacts – Responses). The latter was especially concerned with finding the relationships between the cascade and the environment factors assessed in Environmental Impact and Strategic Impact Analyses. Diehl et al. (2016) have considered the cascade in relation to implementing the European Commission's impact assessment of policies, and found that as a conceptual model it helps to illustrate the different entry points to the assessment procedure, by emphasising the information flow to the different constituent organisations involved in the assessment. These kinds of study illustrate how a framework, such as the cascade, can be used to develop wider understandings of how ecosystem service concepts can inform work in other areas – that is to go beyond simply organising thinking to reconceptualising issues so as to present them in novel ways. ***Re-framing*** thus represents a second major type of application.

A number of papers have used the basic cascade to reflect on how ecosystem services can be used to better understand the way socio-ecological systems operate. For example, Spangenberg et al. (2014, 2015) argued that the cascade should be modified to highlight technology and human labour to generate ecosystem services and to make a distinction between the potential of a system to generate ecosystem services and those services actually generated. They went on to suggest a 'reverse application' of the underlying cascade logic: by reading it from right to left they suggest we can reach a better understanding of the "full cycle of ecosystem services generation and management" (Spangenberg et al., 2014, p. 14). This, they suggest, is particularly helpful in a planning context. He et al. (2016) have gone on to develop this approach for assessing and managing recreation in urban green spaces. Other planning-related re-conceptualisations include that of von Haaren et al. (2014). Elsewhere, Huang et al. (2016) have used the cascade to think about how multi-functional agriculture can be reconceptualised in the context of the ecosystem service paradigm, Brink et al. (2016) used a modified cascade to reflect on ecosystem-based adaptation to climate change in urban areas, and Schwilch et al. (2015) employed the cascade as a way to describe the mitigation of soil threats.

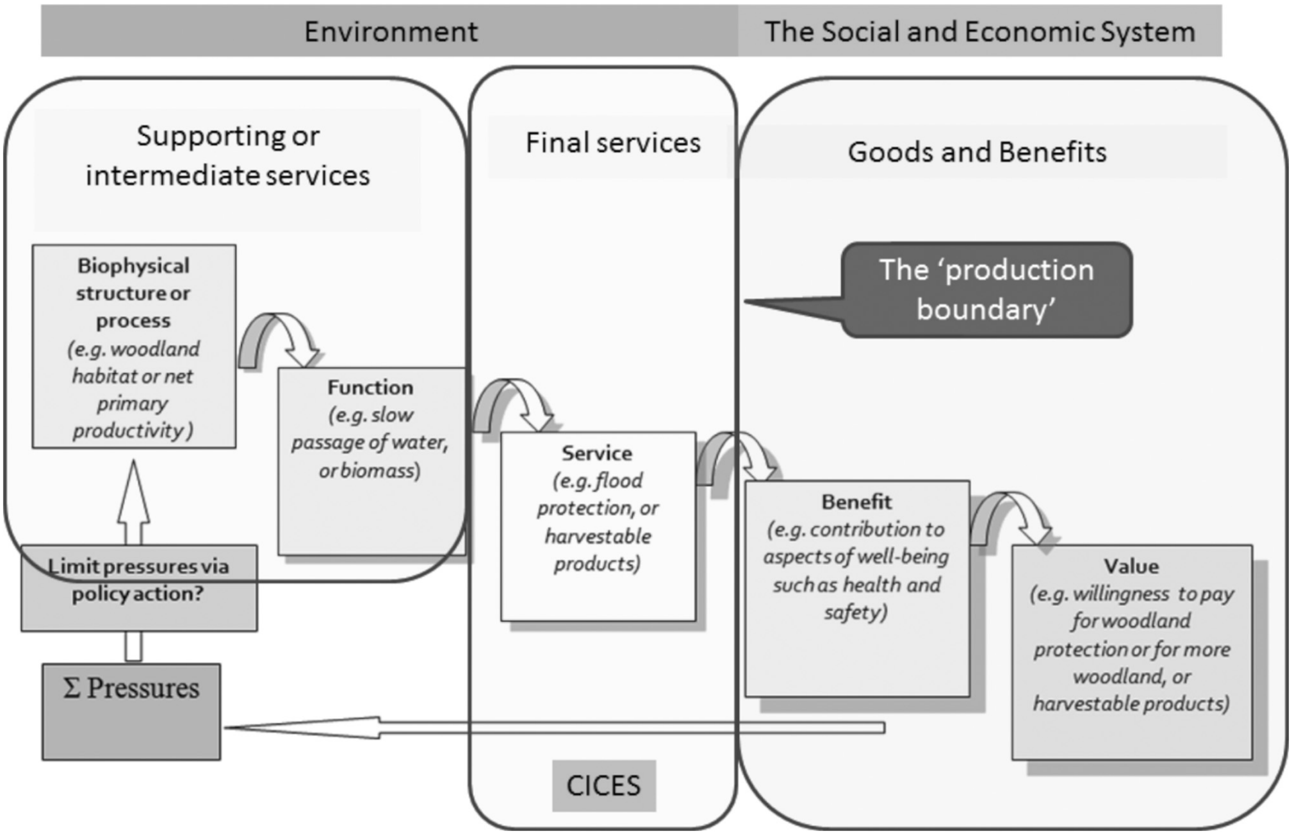

Fig. 1. The cascade model adapted from Potschin and Haines-Young (2011).

The third type of application of the cascade model that can be observed in the literature is that of an ***analytical framework***. There is of course some overlap with the 'organisational' and 're-conceptualisation' roles, since the construction of a coherent investigative logic is a pre-requisite of any sound piece of research. However, there are a number of papers that go beyond the development of theory and use the cascade to guide empirical work. These include the body of work that used the cascade to look at ecosystem service supply-demand relationships (Hansen and Pauleit, 2014; Martín-López et al., 2014; Bürgi et al., 2015; Geijzendorffer et al., 2015; Baró et al., 2016), trade-offs amongst services (Maass et al., 2016), and the status of ecosystem services in specific types of ecosystems, including: coasts (Guisado-Pintado et al., 2016; Boulton and Ekebom, 2016); rivers and freshwater bodies more generally (Large and Gilvear, 2014; McVittie et al., 2015; Liquete et al., 2011; Boulton and Ekebom, 2016); wetlands (Zhang et al., 2015); forests (Saarikoski et al., 2015); and urban areas (Buchel and Frantzeskaki, 2015).

There is of course a fine gradation between analytical studies whose main purpose is to advance scientific understandings and those which seek to apply concepts. Our review of the current literature suggests, however, that there is a fourth group of work that can be identified that has, as its main concern management or policy issues. These ***applied*** uses of the cascade conceptual framework include: Plant and Prior (2014), in their work on statutory water allocation planning in Australia; Ratamäki et al. (2015) also explored pollination from a multi-level policy perspective in the EU; and Chapman (2014), who proposed a modified cascade to support monitoring and assessment work linked to an adaptive co-management program in western Kenya. The latter found that the framework helped decision makers identify programme needs, program activities, pathway process variables, moderating process variables, outcomes, and programme values. Examples of work involving policy analysis include Gissi et al. (2016), who followed the earlier approach based on the cascade suggested by Meyer and Priess (2014), and used the model to look at the design of certification schemes to mitigate the negative effects of biomass energy supply chains. Elsewhere, van Zanten et al. (2014) adapted the cascade to help analyse the influence of commodity markets and policies on the behaviour of land managers and the influence of consumer demand on flows and values of the ecosystem services that originate from the agricultural landscape; the results, they suggest, help us better understand the impact of the EU Common Agricultural Policy (CAP) on European agricultural landscapes and ecosystem services.

Although it is clear that the cascade can support applied work, our review of published material suggests that much of the available literature speaks to the types of application that IPBES described as involving 'making complex things simple' or 'clarifying thinking'. Few explicitly deal with the application issue from a *process* perspective, detailing the way in which groups come together to develop a common understanding of a problem and to agree strategies for resolving it. This gap in the literature provides the context for this study. It seeks to draw lessons from the way that a diverse range of case studies, each involving multiple partners, has interacted with the cascade model, so that ultimately better guidance can be developed to support people using the concepts of natural capital and ecosystem services.

4. Using the cascade operationally

The operational focus of OpenNESS meant that effort was directed towards identifying if and how the cascade could be used to help groups containing different types of expertise to develop their understanding of the problems that they were dealing with, and ultimately how they might be resolved. This was achieved by working with the 27 case studies that were included in OpenNESS in an iterative way. Although each case study had their own distinctive aspirations, it was considered useful to test the ability of the cascade to provide a general framework for discussion of what seemed initially to be a diverse range of interests. Given this diversity it was also considered useful to examine the extent to which their work resonated with the issues covered by the four challenges. The ambition here was to determine whether the challenges themselves offered a way of understanding commonalities across the range of place-based studies included in the OpenNESS consortium.

Thus, representatives of the OpenNESS case studies were brought together in a workshop in 2013 in Loch Leven, Scotland. They were asked how their broader thinking could be represented in terms of the cascade model, and in particular to consider how their concerns related to the four OpenNESS challenges. Participants were encouraged to interpret the cascade and the challenges from their own perspective and, if appropriate, to adapt the structure and the ideas to better reflect their needs. The responses were recorded in note form from verbal reports at the workshop and by collecting the annotated graphical outputs produced by the groups, both at the time of the meeting and afterwards if groups needed further time for reflection. Later, towards the end of the Project, in 2016, a subset of seven case studies was asked to revisit their initial ideas and describe via a structured questionnaire if and how they had changed, what had shaped the process, and especially whether their stakeholders had been involved. The work programme was therefore designed to be both iterative and deliberative in character. It was intended to help all parties unpack, understand, and critically reflect on the role of the cascade as a conceptual framework.

The people attending the 2013 workshop (mainly researchers and some case-study stakeholders) were given a briefing on the role of conceptual frameworks, and in particular what the cascade model represented within the Project. In the subsequent discussion sessions six groups with around 8–10 participants were formed, organised by 'broad ecosystem type'; these were forest, urban and peri-urban, fresh water, and two groups on mixed rural landscapes. Each group selected one OpenNESS case study from those included in the group, and this was used initially as the basis of exploring the usefulness and applicability of the cascade model in relation to their issues. After the workshop, all case studies were asked if they could represent their work in terms of the cascade. Some cascade models were added to the relevant OpenNESS Project Deliverable (Dick and Turkelboom, 2013), while a follow-up was done bilaterally and it was on the basis of these discussions that a final subset of case studies was selected for a further review at the end of the project, the aim here being to find out how ideas evolved.

In the general discussion that followed the group sessions in 2013 participants reported that the cascade model can be helpful for clarifying the problems and the specific relations between the biophysical components leading to ecosystem services, and the benefits and values deriving from them. Moreover, this was thought to be especially so in participatory work. However, some cautioned that if researchers are uncertain of the elements of the model (as they partly were), how could stakeholders be expected to use the framework? Some participants argued that 'no single model is applicable for all situations', rather that conceptual representations were 'context dependent'. Nevertheless, there was general support for the thinking about conceptual frameworks because the *process* of constructing them was seen as having an important 'awareness raising' role. These points can be evidenced by reference to individual case study material.

As a result of the 2013 workshop and subsequent contacts in the period shortly after the meeting 24 of the 27 case studies provided diagrammatic material; these are taken as capturing the thinking at the start of the OpenNESS Project. The characteristics of each conceptual representation of the different case study perspectives were reviewed and the observations made about them are summarised in Table 1.

The case study diagrams were assessed in terms of content, rather than layout, for example in terms of the number of boxes or additional arrows. The extent to which they used elements of the cascade was assessed in terms of how many of the components of the conceptual framework were present in the representations. These were the elements: structure and process, function, service, benefit, and value. Note was also taken as to whether there was any indication of feedback between the elements, and whether there was any reference to the four OpenNESS challenges, and where they were included in the models provided. Finally, the need to merge, expand, or re-label the elements of the original cascade was recorded.

4.1. The cascade as an organising framework

The majority of the case studies found it possible to represent their work in terms of the main elements of the cascade, demonstrating the use of conceptual frameworks as 'organising structures'. Eleven of the 24 studies provided diagrams that contained all five elements of the cascade, and a further eight generated representations with four. The general conclusion that can be drawn here, therefore, is that the cascade probably provides a satisfactory base-line for thinking about problems that link to ecosystem services.

A review of the ways in which the case studies that broadly followed the cascade suggested, however, that there were very different understandings of what the elements in the original represented, or what their relevance was to specific situations. From the examples provided it was clear that participants sought to reconceptualise or reinterpret the cascade in ways that was meaningful or useful to them. For example, the number of elements used in case study representations was sometimes reduced, by dropping the notion of 'function' (CS#24, Fig. 2) or by merging 'benefits' and 'values' (CS#1, 2016 written response). In fact, as Table 1 shows, compared to the notions of structure, service, and benefit, only around two-thirds of the case studies felt the need to include the notion of 'function' or 'value' in their diagrams.

Some of the rationale for these changes to the cascade can be illustrated by a case study that sought to apply the ecosystem service concept in a planning context; it was reported in the follow-up interview for this case study in 2016 that "planners found it somewhat difficult to use as it has so many steps and it is not clear where the boundaries are between them. For instance, it would seem simpler to pool structure and function because they are interlinked. Also the distinction between service and benefit is not always clear. So, for the purpose of planning three steps may be sufficient: (1) structure and function, (2) service and benefit, and (3) value" (CS#1). Elsewhere, however, participants felt that additional elements were needed to enable the cascade to capture what was being considered as relevant in their work.

For example, in the context of ecosystem services in the East Godavari District, Andhra Pradesh, India (CS#23), researchers found it helpful to identify 'policy structures and mechanisms', together with community-based 'institutions' and forms of 'social regulation' as important 'entry points' for reading the cascade in this rural situation (Fig. 3); the general point about whether the cascade should be read from left to right or right to left was made by several participants at the 2013 workshop. Similarly, by the later stages of the project in 2016, another case study concerned with establishing the relevance of urban ecosystem service assessments to policy making in Spain (CS#27), felt it necessary to identify the role of 'goals' and 'planning' explicitly in the

Table 1
Fit between the cascade model and the initial set of conceptual representations used by OpenNESS case studies (source of cascade models see EU FP7 OpenNESS Project Deliverable 5.1, see Dick and Turkelboom, 2013). Stakeholders' perspectives on the operationalisation of the ecosystem service concept: results from 27 case studies, Dick et al. in prep (note: at the time of writing no materials were available from case studies 8 and 16.)

Case Study Number	Cascade elements present in case study conceptual representation					Changes to original cascade model			Challenges addressed				
	Structure	Function	Service	Benefit	Value	Merge Structure and Function	Merge Service and Benefit	Merge Benefit and Value	Human well-being	Management issues	Governance issues	Competitivness issues	Feedback in model
1	X	X	X	X	X				X				
2			X			X							X
3	X	X	X	X	X				X				
4	X	X	X	X	X								
5	X	X	X	X	X								X
6	X	X	X	X									
7	X	X	X	X	X								X
9	X		X	X	X								
10			X		X						X		
11	X	X	X	X	X					X			
12	X	X	X	X					X				
13	X		X	X									X
14	X	X	X	X	X								
15	X	X	X	X	X								
17	X	X	X										
18	X	X	X	X									
19	X	X	X	X				X			X		X
20	X		X	X	X								
21	X	X	X	X	X								X
23			X	X	X	X		X	X		X		
24	X		X	X	X								
25	X	X	X	X	X								
26	X		X	X	X								
27	X	X	X	X	X					X			X
Total	21	16	24	21	17	2	0	2	4	2	3	0	7
	88%	67%	100%	88%	71%	8%	0%	8%	17%	8%	13%	0%	29%

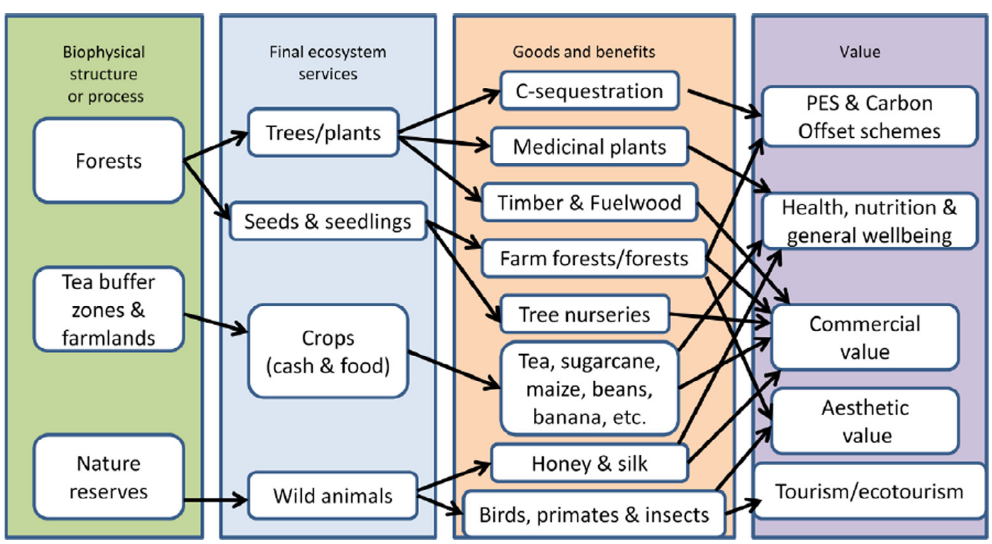

Fig. 2. The cascade redrawn by the case study from the Kakamega Forest Ecosystem, Kenya (CS#24), (source: EU FP7 OpenNESS Project Deliverable 5.1, see Dick and Turkelboom, 2013).

framework (Fig. 4). In 2016, better elaboration of the role of policy and governance was also identified as being necessary in the work dealing with spatial planning in Doñana, Spain: "Probably the main concern that we have encountered is the lower part of the cascade [...] From behavioural ecology to drivers, institutions or governance, several aspects could fit in that part of the graphic. Given the aim in our case study to implement the ecosystem service approach into decision-making, a more detailed description of this part of the graphic would be desirable" (CS#19).

The evidence from the case studies suggests that the cascade can provide a framework for organising and representing thinking across a range of studies, as well as some flexibility in terms of adapting the concepts to different application contexts. Organising thinking is clearly a first step in any application, and so it is not surprising that the two types of use were closely associated in the case study materials; indeed, it may be essential if the development and co-creation of conceptual frameworks is seen as part of a deliberative approach to problem solving.

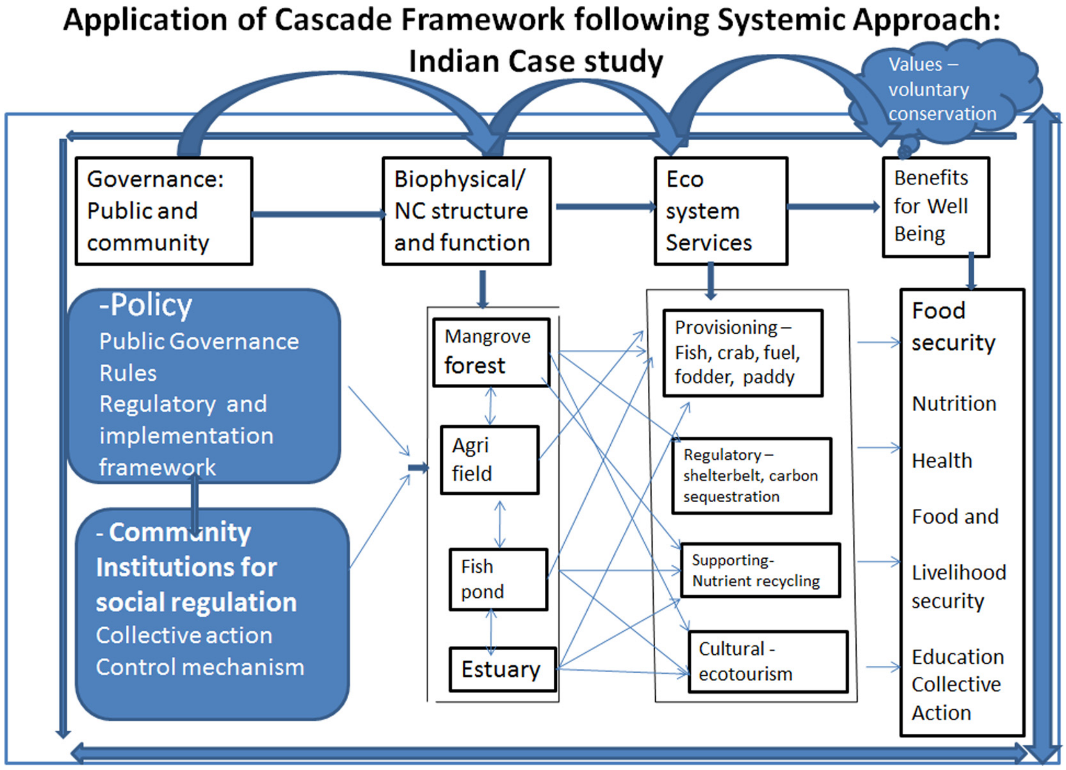

Fig. 3. The cascade redrawn by the case study from the East Godavari district, Andhra Pradesh, India (CS#23), (source: original in EU FP7 OpenNESS Project Deliverable 5.1, see Dick and Turkelboom, 2013) modified: personal communication with case study representatives, 2014).

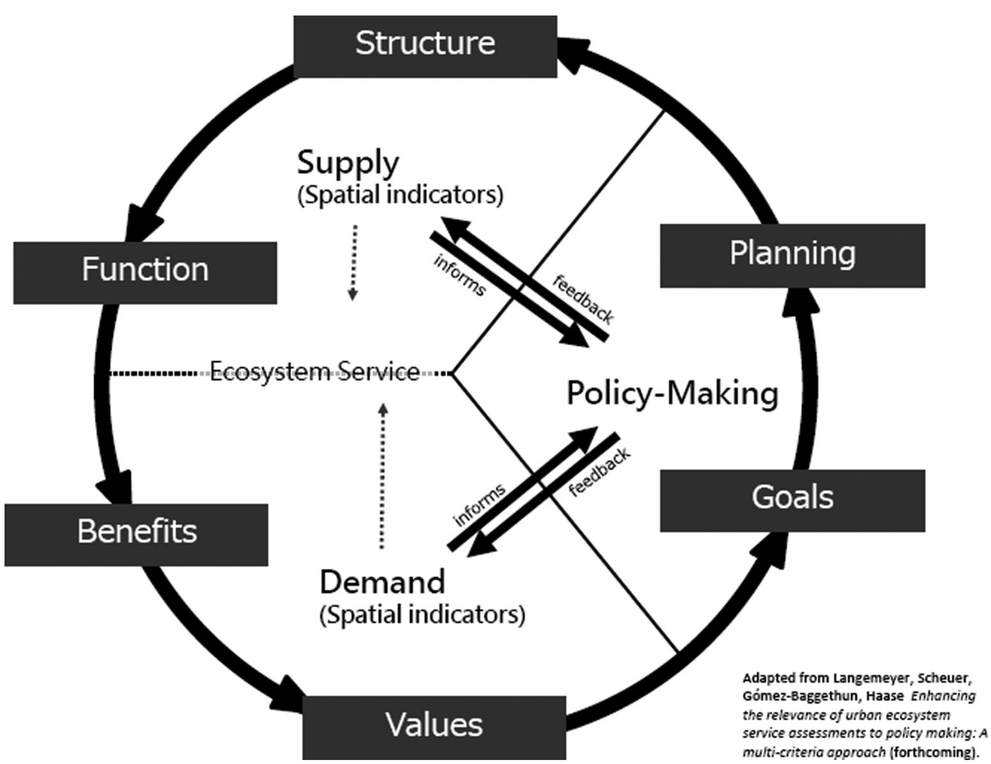

Fig. 4. The version of the cascade provided by the Barcelona case study (CS#27); (source: personal communication with case study representatives, 2014; adapted from Langemeyer et al., 2016).

4.2. Using the cascade to re-frame issues: dealing with the OpenNESS challenges

The four societal challenges, namely human well-being, sustainable management, governance, and competitiveness were used in OpenNESS as a way exploring the similarities and differences between the case studies. More importantly, they were devised as markers that might enable place-based studies to reference their local concerns to broader issues. While case study work can provide deep and rich insights into real-world problems, given their often unique concerns it is often difficult to generalise from them. The four challenges provided a 'problem-focussed' way of doing this, rather than by using more conventional groupings around ecosystem type, etc. Thus, the extent to which the cascade material provided by the case studies made reference to the challenges was therefore of particular interest.

A particular issue of interest in the work was whether there was any evidence that case studies attempted to link their work explicitly to any of the challenges in the conceptual models that they devised. As Table 1 shows, however, collectively the challenges did not seem to figure in many of the representations provided by the case studies. Only ten case studies in total made reference to one or more of the challenges; human well-being, management issues were each cited as elements in four, governance in three, and competitiveness was not referenced at all.

A feature of the different ways in which the case studies framed notions of benefits and values suggested that better guidance for those using the cascade is probably needed, in terms of the explaining differences between the concepts, and especially how they related to overarching notions of human well-being. The difficulty that some case studies had in representing with human well-being in the cascade was noted by CS#15 (Multipurpose wetland in northern Italy), CS#19 (Spatial planning in Doñana, Spain), and illustrated by CS#9 (Cairngorms National Park, Scotland), which flagged up a question on their diagrams about how these issues should be located on the cascade. The case study dealing with impacts of bioenergy production on native vegetation in interior São Paulo, Brazil (CS#26), questioned how 'harms' or 'disbenefits' should be handled. In those case studies that attempted to deal with human well-being explicitly, such as the work in Kiskunság, Central Hungary (CS#12), the suggestion was to merge 'benefits' and 'well-being' into a single element (Fig. 5). The Indian case study (CS#23) replaced the separate 'benefits' and 'values' elements in the original cascade with a single component 'benefits for well-being' (see Fig. 3, above), while another case study suggested that beneficiaries also needed to be identified (CS#10, Multifunctional Landscapes, Sierra Nevada, Spain).

Where management issues were cited (e.g., CS#13, Landscape and nature management, 'De Cirkel', Belgium and CS#18, Stevoort flood control, Belgium) they were often handled simply by merging management issues with elements dealing with ecosystem structure, rather than by unpacking the various drivers of change and their relationship to management interventions. In CS#13 for example, it was reported in the initial feedback that "the distinction between ecosystem structures, processes and functions became quite complicated" and so "ecosystem structures, processes and functions has been merged in one box: Ecosystem structure & management". In the three case study responses where governance issues were included, these were largely represented in terms of feedback mechanisms linking values to structures (e.g., CS#23, Fig. 3, and CS#13, Fig. 6). These kinds of model capture the notion of reading the cascade from right to left thus using values as alternative entry-points into the discussion of the importance of ecosystem services.

Our findings in relation to the way the case studies referenced their work to the four challenges suggests two perspectives on the notion of re-framing. The first is the internal focus that case studies developed in trying to use the cascade to represent their work. Given the evidence presented here and in Section 4.1, it seems that the cascade was helpful in achieving this dimension of re-conceptualising issues. The second aspect of re-framing concerns locating work in a broader context, in other words of making new connections to more general issues and concerns. The extent to which the cascade was able to support this second dimension of re-framing was more limited: researchers could read it in relation to their own work, but not so easily in relation to that of others. This finding suggests that additional material and support might be needed for conceptual frameworks, like the cascade, to be used in this way.

4.3. Towards analysis: handling complexity

The analysis of the case study materials suggests that the cascade provides a reasonable base-line model for representing the concerns of a diverse set of studies. Only rarely did the case studies choose to omit elements from the prototype cascade, or replace them with other ideas. For example, CS#27 did not distinguish between structures and processes, on the one hand, and functions on the other, but used the concept of 'ecosystem capacity' (Baró et al., 2016), which nevertheless has strong resonances with the concept of 'function' in the prototype cascade. This example illustrates the point that while the basic structure captures key ideas in the ecosystem service paradigm it can be adapted to specific case study issues. As CS#27 (Urban planning, region of Barcelona) focused more on the social valuation of ecosystem services, a distinction between ecological processes and functions was of little interest to them. In addition to offering a base line against which a range of case study concerns could be represented, the cascade also helps gain some insights into the overarching goal of operationalisation. It is, in a sense, possible to use the framework to identify where the case studies were in terms of getting the 'idea used', according to which parts of the basic model they emphasised or expanded.

Nevertheless, it was clear from the case study materials that while the cascade could serve as a baseline, the basic model could rapidly become complex as more and more specific issues were included. This situation often arose because case studies were dealing with more than one service. The feedback from CS#13 was especially informative in terms of the complexity issue. The case study representative reported that "[t]he cascade worked very good for one ESS [ecosystem service] or a few related ESS (bundles), but it got quickly very complex, when we tried to include all the relevant ESS." The strategy used in this study was to limit the model to "the most important ESS" (Fig. 5). Several other studies attempted to include a number of different services in the same graphical representation, as is illustrated by Figs. 2, 3, and 6. In contrast, the strategy adopted by the Oslo urban case study (CS#3, Valuation of urban ecosystem services, Oslo), for example, was to develop a separate cascade for each of the services considered. The advantage of this alternative strategy was that the links between the services could be indicated, and the potential for trade-offs and synergies identified.

The experience of the case study dealing with landscape-ecological planning in urban and peri-urban areas in Trnava, Slovakia (CS#2) illustrates the conceptual richness that can be generated by thinking through the way the cascade might apply in a particular place. The feedback from this case study is especially interesting because, as Table 1 shows, the analysis of the material initially provided suggested only a limited correspondence with the original cascade model. During the 2016 follow-up, however, the case study leaders reported that the cascade had been used "within a complex general model of ecosystem service valuation"

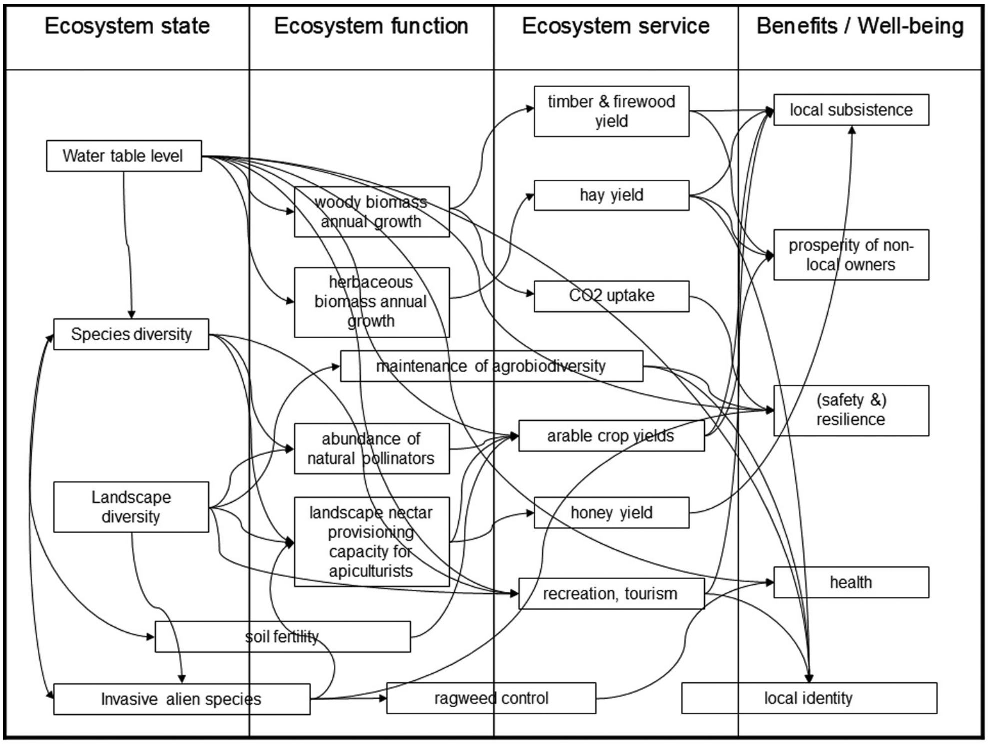

Fig. 5. The cascade provided by the case study of Kiskunság, Central Hungary (CS#12), (source: personal communication with case study representatives, 2014).

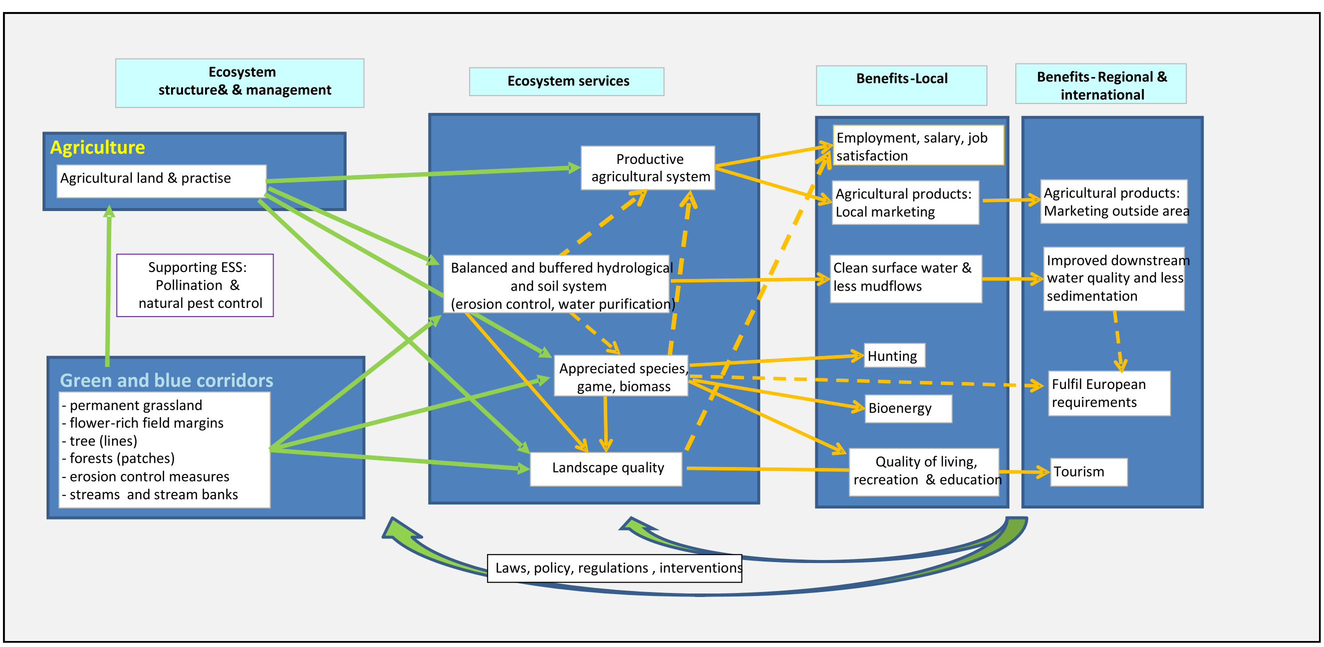

Fig. 6. The version of the cascade developed by the 'De Cirkel' case study, Belgium (CS#13), (source: personal communication with case study representatives, 2014).

that was developed with the stakeholders. As Fig. 7a shows, the conceptual framework developed to include a number of additional elements, but the basic proposition linking ecological structures through functions, services, and benefits is largely retained, with 'supply side' issues being covered on the left hand side of the diagram, and demand-related issues to the right. Interestingly, the case study also provided a "simplified version of the framework" (Fig. 7), which had been used to identify its four major components, referred to as "real" and "potential" geo-ecosystem landscape structures, "socio-economic processes", and "valued ecosystem services".

A particular issue that arose in terms of moving from re-framing to application was the issue of how to represent and explore the 'supply' of ecosystem services and 'demand' for them. This was an issue that was emphasised in the 2016 feedback from the Trnava case study (CS#2), as well as those from the Sierra Nevada (CS#10) and Barcelona (CS#27) case studies. The Trnava case study located supply and demand issues along a left-right axis (Fig. 7),

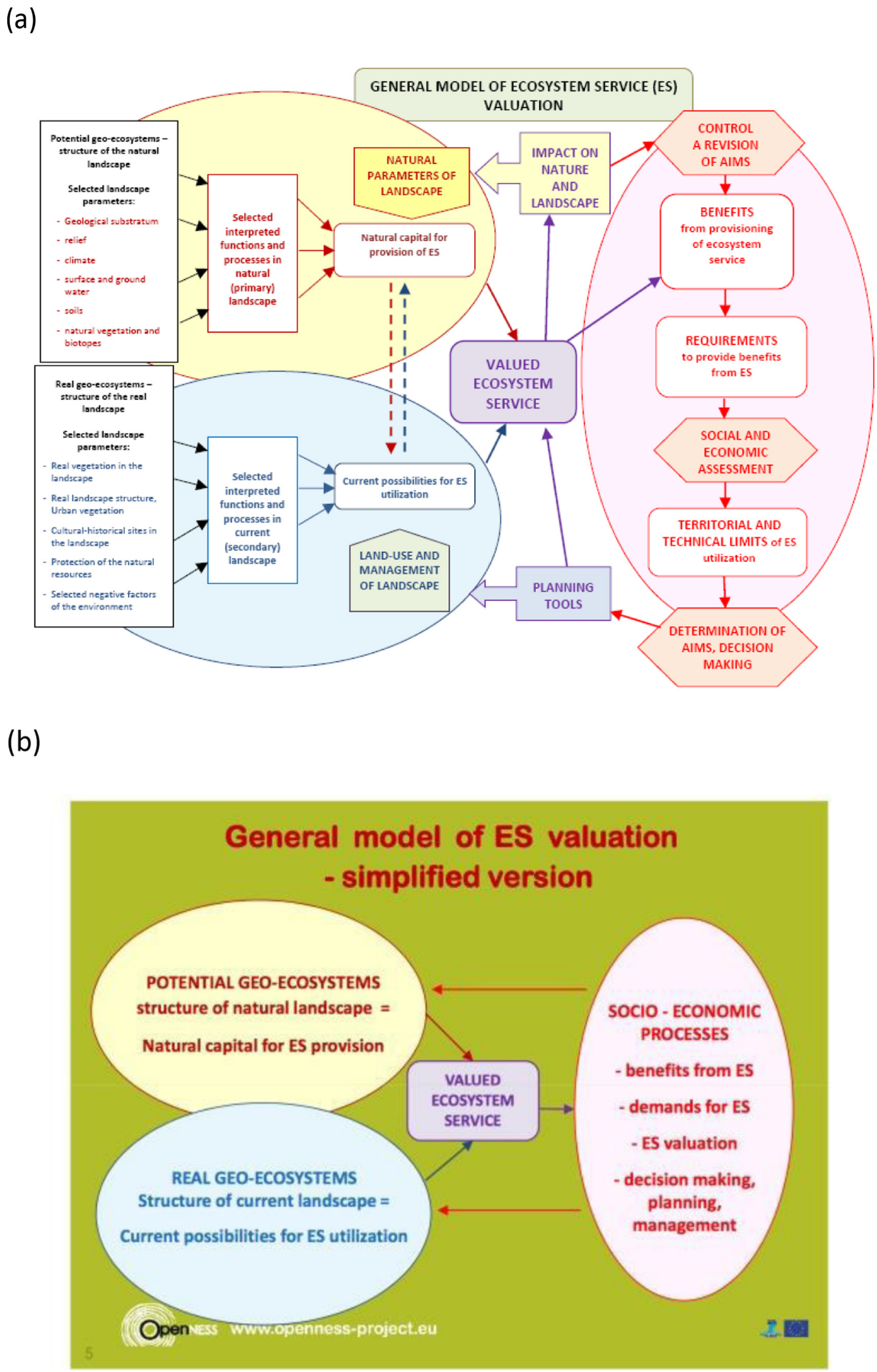

Fig. 7. a & b: Conceptual frameworks based on the cascade developed by the case study from Trnava, Slovakia (CS#2), (source: personal communication with case study representatives, 2014).

similar to the original cascade. In the case of the Sierra Nevada study, the researchers felt the need to develop another kind of representation entirely: "For mapping and analysing the supply side the researchers considered it important to detect service-providing units (SPUs), for assessing demand to identify ecosystem service beneficiaries (ESBs) who assign values to ES" (CS#10). They went on: "In contrast to the prototype cascade [....] instead of highlighting singular processes and structures of ecosystems, a focus was put on ecological units which harbour these structures and functions." In the Barcelona case study (CS#27), the researchers reflected in 2016 that it had been important for them to work with the notion of potential supply or 'capacity', as well as actual flow, because of "their importance for triggering political action".

The development of richer, more complex conceptual models based on the cascade should not be taken as a limitation because it was developed for just such a purpose. Although researchers and stakeholders may develop different perspectives, the 'five components' of the cascade (Fig. 1) provide a common denominator, on which context specific elaboration can be made; further refinement of the basic model is therefore unnecessary. The key challenge to emerge, however, is that unless we can find ways of capturing and documenting the thinking that takes place during this evolutionary processes, the ability to generalise from these individual studies may be lost by simply regarding it as a graphical model.

5. The role of conceptual frameworks

The aim of this paper has been to look critically at the role of conceptual frameworks in relation to work involving ecosystem services, and to draw from it any lessons that might help transdisciplinary groups to use them. Our work illustrates that they can be used as an organising structure to help clarify 'complex relationships', to re-frame biodiversity-related issues, and provide an analytical template for empirical research and operational strategies or applications, which are key functions of conceptual frameworks (Section 3). The contribution of this review is that it highlights in more detail the ways that they can support collaboration in mixed groups containing different types of expertise. The limitation of any review of published material is that much of the work around the conceptual framing represented by the cascade is not reported. In this context, a contribution of the work in OpenNESS is to provide better insights into the thinking that underpins such work.

Our work with the OpenNESS case studies generally mirrors the ways in which conceptual frameworks can be used that were identified in the literature review, but provides additional insights into the processes behind their use. Despite its simplicity, we found evidence that the cascade provides a suitable tool to structure projects which analyse or value ecosystem services. Moreover, it offers a reference-point for the comparison of an apparently diverse set of studies. It was found to be capable of providing an entry-point for groups to develop their own view of an operational problem or issue. And in developing their own versions of the cascade, the work in OpenNESS suggests that groups can be driven by practical necessities, such as the need to either simply accommodate different stakeholder perspectives and levels of knowledge, or add complexity as groups understand their problem situation more deeply. In this sense, the cascade model *is* a conceptual framework in its broadest sense; models, like the cascade, can become a template or platform on which case specific applications can be built; this conclusion is supported by recent work reported by Dick et al. (2017). However, there is evidence to suggest that despite the versatility of the cascade model, some of the differences in the ways groups used it also arose from differences in understandings of what the constituent elements represent. We found, for example, that participants were sometimes confused by the notion of 'ecological functions' in relation to 'ecosystem services', and often the distinction between services and benefits was not clear to them or their stakeholders. This suggests that while a graphical model can 'speak for itself' to some extent, guidance or supporting material is essential to help interpret the model appropriately. Rather than suggesting that modifications to the cascade are needed, our work suggests that in an operational situation the main task is to find ways of identifying the social learning that it can stimulate so that it can be shared more easily.

Our findings suggest that given the range of things conceptual frameworks are supposed to do it is therefore helpful to think of them as more than the diagrammatic representation of ideas. Our work on the four 'OpenNESS challenges' of human well-being, sustainable ecosystem management, governance, and competitiveness suggests that while there may be merit in using the cascade to explore general issues, in practice this may be difficult if one only focusses on the task of graphical representation. While the cascade was a useful template for case studies to represent their own concerns and issues, it was more difficult for them to use the model to make connections to broader themes and issues which could nevertheless enrich their work. Once again this argues for the need for better supporting materials to enable the cascade to be read in different ways. The work on the four challenges suggests that in thinking about them there is probably no single place in which to locate them diagrammatically, but rather they are better seen as outputs or performance characteristics of the socio-ecological system that the cascade represents.

Understood in this way, the four challenges could be seen as some initial archetypal issues that could provide entry points for work on ecosystem services and lead to further specifications of the cascade; other themes to encourage different readings could be added to widen perspectives still further. The cascade model therefore provides a way of tracing the implications of a given research, management, or policy issue (represented by a case study, for example) for specific aspects of human well-being, sustainable management, governance, and competitiveness, or indeed any other general topic that is relevant when dealing with ecosystem services.

The aim of this paper has been to explore the different roles that conceptual frameworks can play in thinking about ecosystem services. The conclusion that we draw is that to support such work we must recognise that as a 'short-hand' depiction of complex, connected issues, the nuanced nature of the relationships that are depicted in a graphical model are often difficult to communicate. The process of building the conceptual framework may have enabled those concerned to achieve a better understanding of their problem situation, but the general lessons learned from the outcomes are more difficult to convey to others using a graphical representation. Without being prescriptive, general diagrammatic models like the cascade should be supported by other types of material that help groups containing different types of expertise to understand, discuss, and apply key ideas in ways that are relevant to their situation. These materials should enable them to read and develop the cascade in different ways, and set down that thinking so that it can be shared with others. We suggest the goal of developing such guidance is an important next step for those seeking to make the idea of ecosystem services 'operational'.

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