

Chapter 3: Defining and measuring ecosystem services¹

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1. Introduction

The term ‘ecosystem services’ can mean different things to different people. On the one hand this is an advantage, because it can engage people in new conversations about the importance of biodiversity and the environment. In this sense ‘ecosystem services’ might be thought of a *boundary object*, that is, an idea that can be adapted to represent different perspectives while retaining some sense of continuity across these different viewpoints (Abson et al., 2014). On the other, that multi-faceted characteristic is a disadvantage once we come to measure and monitor these things called services: if we cannot agree what they are then people will not believe what is said about them or act on the evidence we collect. These problems of definition are amplified once we start to make a case for valuing or managing ecosystem services (see for example, Ojea et al., 2012) - that is to apply the concept in a *normative* way.

This *Handbook* demonstrates the different ways that people think about ecosystem services; it is, in fact, a microcosm of the wider literature on the topic. Many authors start, quite legitimately, with the definition provided by the Millennium Ecosystem Assessment (MA, 2005) which describes them simply as *the benefits that ecosystems provide to people*. By contrast, others, follow the guide of TEEB (The Economics of Ecosystems and Biodiversity), which views them as *the direct and indirect contributions of ecosystems to human well-being* (De Groot et al., 2010). Services, in other words, give rise to benefits; they are not the same thing. Despite these differences, however, both regard ecosystem services and goods as being synonymous. To add complexity to the debate, it is apparent that not all frame the ideas in this way. The UK National Ecosystem Assessment (Mace et al., 2011), for example, suggest that it is ‘goods’ and ‘benefits’ that are one and the same, and that it is ‘services’ that are quite distinct (Mace et al., 2012, and Mace (2016), this volume, chapter 50).

So what’s the problem with all these different perspectives? In a sense, we all know what people are ‘getting at’, namely the importance that nature has for people. The difficulty lies in the fact that if we want to understand how ecosystems provide benefits to people, we need a way of characterising the ecological structures and processes and ecosystem characteristics that underpin them in ways that can be analysed. The aim of this chapter is to take the reader on a journey through the terminology surrounding the idea of ecosystem services, not to convince that there is a single, consistent way of thinking about them, but to provide a guide through a complex and at times, puzzling terrain.

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2. The ecosystem service cascade

A number of commentators have noted the problems of defining exactly what an ecosystem service is (see for example, Boyd and Banzhaf, 2007; Wallace, 2007; Fisher and Turner, 2008; Fisher et al., 2009). Despite their differences all agree that there is some kind of ‘pathway’ for delivering ecosystem services that goes from ecological structures and processes at one end through to the well-being of people at the other. We have also represented this ‘production line’, describing it as a ‘cascade’ (Figure 1). Its purpose is to tease out more clearly the differences between these end-points and the steps between (Potschin and Haines-Young, 2011).

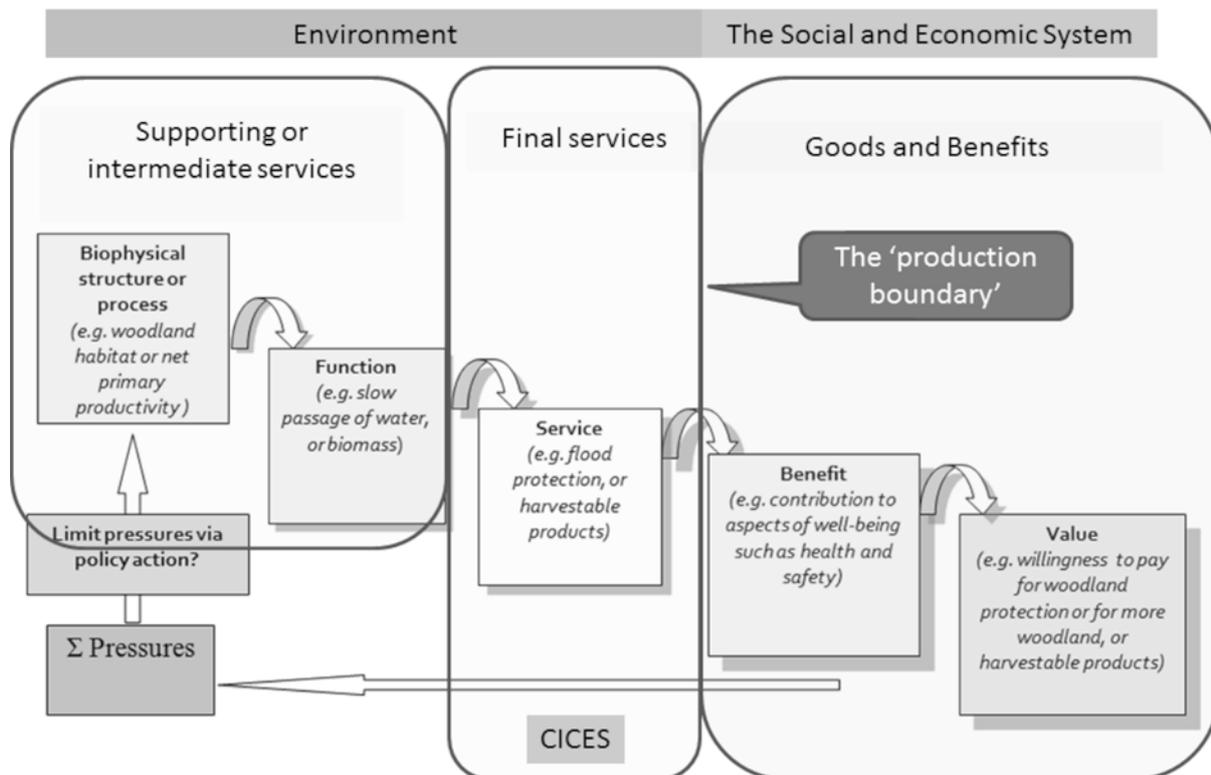


Figure 1: The cascade model adapted from Potschin and Haines-Young (2011)

Conceptual frameworks, such as the cascade, serve a number of purposes. They can be used, for example, as a communication tool, a jumping-off point for discussion between experts and laypeople. Additionally or alternatively they can be used as a way of mapping out basic concepts so that they can be applied to solve problems; they identify the types of evidence that is considered relevant and so help place work on a stronger analytical footing. It is mainly for this last purpose that we use it here.

Thus we suggest, the cascade model can help us think about the relationships between five key sets of ideas that define the ecosystem services ‘paradigm’; that is, a way of looking at the world. We are clearly interested in ecosystems, and these are represented in the cascade model as the set of *ecological structures* and *processes* that we find in an area. Often we simply use some label for a habitat type, such as woodland or saltmarsh, as a catch-all to denote this box, but there is no reason

why we cannot also refer to such things as ‘the nitrogen cycle’, with its various stores and transfers, as something that can also occupy the left-hand side of the diagram. In either case, given the complexity of most ecosystems, if we want to start to understand just how they benefit people, then it is useful to start to identify those properties and characteristics of the system that are potentially useful to people. This is where the idea of a *function* enters into the discussion. In terms of the cascade model, these are taken to be the ‘subset’ characteristics or behaviours that an ecosystem has that determines or ‘underpins’ its usefulness for people.

Insert Box 1 here (Jax)

As Jax (2016, Box 1 this chapter) notes, the term function is problematic for ecologists. For some (including those who prepared the MA) it is often just used as another way of referring to *ecological process*. Indeed, Wallace (2007) has gone so far as arguing that if ecosystem services, processes, structure and composition are adequately defined, the term ‘function’ is actually not required; Jax also suggests that we even might want to avoid it. However, there are, some advantages in thinking about what it is about an ecosystem that enables it to provide a service, and setting these characteristics or behaviours apart as a ‘subset’ can be helpful. We would suggest that it is especially helpful if we want to manage these properties in some way. In the case of woodland, for example, their capacity to mediate runoff can be controlled by their canopy characteristics, and these are not solely determined by woodland type. Similarly, while the structural characteristics of wood that make it more or less useful for timber are determined by growth processes, they can be manipulated within the same woodland type to improve its ability to deliver a harvestable crop. Given the complex nature of ecosystem structures and processes, and that a single ecosystem may deliver a number of benefits, we need to try to be clear about just what capacities (properties, behaviours) make it useful to people; identifying these as ‘functional’ characteristics is, we suggest, therefore a necessary stage in understanding how ecosystems and people are linked.

Ecosystem services play a pivotal role in the cascade, which constitutes them as distinct from the functional characteristics of the ecosystems that make them useful, and the benefits that people ultimately enjoy. A defining feature of services is that they are, in some sense, the final outputs from an ecosystem. They are ‘final’ in that they are still connected to the structures and processes that gave rise to them; they are also final in the sense that they contribute directly to some produce (good) or condition that can be valued by people. Thus, to return to the woodland example, the standing crop of trees with particular structural characteristics is the service and the harvested, worked timber is the good or benefit. Following the logic used in the UK National Ecosystem Assessment, in the cascade *goods* and *benefits* are the things that have *value*, whether that value is expressed in monetary or non-monetary terms. ‘Product’ is another term that is sometimes used interchangeably with ‘good’.

The distinction between functions, services and goods and benefits can be clarified still further, by recognising that a service may depend on a number of functional characteristics. For example, the utility of a standing crop of trees is dependent on a range of properties other than the characteristics of the woody material, such as the branch and stem characteristics of the stand, stem density and stand age. Similarly, a stand of trees can give rise to several different types of goods and benefits. In addition to its capacity to slow the passage of runoff, for example, those same trees can offer benefits in terms of shelter against winds, dust or noise, as well as a range of recreational activities.

A benefit is basically seen as something that can change people's 'well-being', which is understood to be things like people's health and security, or their social relations, or the kinds of choices that can make. These benefits are thus important to people, and that importance is therefore expressed by the values they assign to those benefits. 'Value' is therefore the final box in the cascade model, on the right-hand side, and as suggested, these values can be expressed in a number of different ways. Alongside monetary values, people can express the importance they attach to benefits using moral, aesthetic or spiritual criteria. And it is by reference to these values that people and societies chose to act (or not) to modify or manage the pressures on ecosystems and ultimately the benefits they deliver to society. This feedback is what is being highlighted in the arrow running from values back to the left hand side of the cascade model.

Clearly, a limitation of the cascade model is that it seems to suggest a rather linear relationship between ecological structures and processes on the one hand, and benefits and values at the other. In the 'real world', of course, things are more complex and cannot easily be captured in a simple model such as this. Even for a single ecosystem, we can usually identify a network of linkages between a number of different ecological structures and processes, the different functions they support and a suite of benefits that ultimately arise. Nevertheless, the elements of the cascade do give us some of the vocabulary we need to represent and understand the richness of these relationships.

3. Using the cascade

The novelty of the ecosystem services paradigm stems from the willingness of researchers and practitioners to connect up the study of biophysical and social systems. The cascade model can be seen as an entry-point into the discussion – as a tool for representing important elements in the production chain linking nature and people. In any real problem situation there will be many difficult judgements to be made about, for example, about what counts as a function or a service or a benefit, etc., because how we interpret these ideas will change with the application context. As Boyd and Banzhaf (2007) memorably point out in their discussion of final ecosystem services: if we take potable water from a lake, the water is a final service, but if instead we eat the fish that live in the lake, then it is the fish and not the water that is the final ecosystem service. What the cascade model brings to these situations, is therefore a framework that can structure our thinking. The ideas represented by the 'boxes' in the model are rather like words in a sentence that we can use to tell the ecosystem service story; each has meaning by virtue of the way we arrange the other 'words' (ideas) around them.

The point about the cascade model is not to put the world into tightly prescribed boxes, but to help more clearly understand the ways in which nature can influence people's well-being. Whatever terms we choose, the distinction between the contributions that an ecosystem makes and the way that well-being is changed is critical – hence our particular preoccupation with the service-benefit issue. The language used in the MA has helped all of us to make a start, but the basic concepts still need probing more deeply (cf. Lamarque et al., 2011; Portman, 2012).

We can see how the cascade model has helped people work through the logic of the ecosystem service paradigm by reference to some of the published literature. One of the key areas of analysis that it has encouraged people to think about concerns the patterns of supply and demand for

ecosystem services. For example, Hansen and Pauleit (2014) have developed and modified the cascade to look at demand and supply relationships in relation to green infrastructure in urban settings, while Bürgi et al. (2015) have looked at the evolution of supply and demand interactions for ecosystem services over time, in a Swiss landscape, to gain a deeper understanding landscape history. Elsewhere, Martín-López et al. (2014) have used the cascade to undertake an empirical study of patterns of supply and demand in the Dõnana social–ecological system, in south west Spain, while Geijzendorffer et al. (2015) have more generally reviewed some of the literature on the mismatch between the demand and supply. The latter concluded that to properly account for such mismatches studies should include multiple stakeholders groups with their different requirements, recognition that supply is not only determined by biophysical factors but also the services needed by people and hence management inputs, and that temporal and spatial scale sensitivities also need to be considered.

Studies using the cascade to assist in understanding the services associated with particular ecosystems include those of Large and Gilvear (2014), who applied it to the analysis of ‘riverscapes’, and Liqueste et al. (2011) in their work on mapping and assessing ecosystem services associated with freshwaters in Europe. In other applications, Plant and Prior (2015) used the cascade to develop a framework for statutory water allocation planning in Australia, while Zhang et al. (2015) applied the framework to help identify the components of plant diversity that are most correlated with ecosystem properties in a restored wetland in northern China, and Ratamäki et al. (2015) used cascade to explore pollination from a multi-level policy perspective.

There is considerable interest in the scientific and policy communities in devising appropriate indicators of ecosystem services to ‘mainstream’ the concept (see Müller et al., 2016 this volume). Examples of the way the cascade has stimulated debate include that of Liqueste et al. (2013a), who used it to propose three novel coastal protection indicators for European coastlines that cover the main anthropogenic pressures on the coastal zone. Maes et al. (2012b, 2013) have also used cascade to develop spatial indicators of potential and supply, with a view to identifying synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation, while van Oudenhoven et al. (2012) have used the cascade to develop a framework for indicator selection to assess effects of land management on ecosystem services in the southern part of the Netherlands. In the context of the work on indicators, a number of authors have attempted to make a link between the cascade and the DPSIR framework (see Felix Müller et al., 2016 this volume), including Hering et al. (2015) in their work on indicators for the management of Europe's water resources; and, Honrado et al. (2014), who have identified a set of indicators that can sit within the DPSIR framework, by looking at the relationships between the cascade concept and the environment factors assessed in Environmental Impact and Strategic Impact Analyses. As Maes et al. (2012a) argue, the policy relevance of work on ecosystem services, indicators and mapping is especially important, and have proposed a stepwise framework to support EU policies in a more effective way.

From such work it is clear that, despite its simplicity, the cascade can provide a foundation for building a number of different assessment approaches. Thus Chapman (2014) has proposed a modified cascade to support monitoring and assessment work linked to adaptive co-management program in western Kenya; the suggested framework helped decision makers identify programme need, program activities, pathway process variables, moderating process variables, outcomes, and programme value.

In other published work, van Zanten et al. (2014) have used the cascade to explore the impact of CAP on European agricultural landscapes and ecosystem services. These authors have 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. In other developments, Cordier et al. (2014) have used the cascade to design a framework for ecosystem services monetization in ecological–economic modelling. Their aim was to ensure that monetary valuation techniques are better able to contribute to the understanding of the impact of economic activities on changes in ecosystems services and the impact of these changes on economic activities. Applications of the cascade in a broader modelling arena include the work of McVittie et al. (2014), who uses the cascade to operationalizing an ecosystem services-based approach using Bayesian Belief Networks (BBNs) in the context of modelling the dynamics of riparian buffer strips, and Landuyt et al. (2013) who consider the relevance of the cascade to BBNs more generally.

In contrast to its use as an empirical, analytical framework, the cascade has been used to develop broader theoretical understandings. Pagella and Sinclair (2014), for example, have used an earlier version of the cascade to build a typology for understanding the different types of mapping tool. From their review of over 40 published studies they concluded that the major gaps in relation to our understanding of ecosystem services were the lack of analyses at scales relevant to management interventions; understandings of the pathways linking supply and use of services; synergies and trade-offs between services and the inclusion of stakeholder knowledge and uncertainty. Elsewhere, Vihervaara et al. (2012) used the cascade to categorise ecosystem service research in relation to the themes of the International Long Term Ecological Research (ILTER) network, and Kronenberg (2015) has used the cascade to look at what current debate on ecosystem services can learn from the past in the literature dealing with ‘economic ornithology’. Huang et al. (2015) have also considered agro-ecosystems, but this time from a multi-functional perspective. They observe that these systems have been studied by two scientific communities, and that while they have the same interest in understanding these landscapes from a holistic perspective, an analysis of the literature suggests there has been limited interaction and exchange. Each group faces research challenges according to independently operating paradigms. These authors propose a conceptual framework based on the cascade that they suggest could stimulate a dialog about how to analyse bundles of ecosystem services and the nature of multifunctional agriculture, and provide insights into strategies such as land sharing and land sparing.

Finally, the cascade has stimulated other theoretical approaches or readings of the links between ecosystem services and human well-being. Buchel and Frantzeskaki (2015) used the cascade as a starting point to develop a method that can be used to ‘translate’ ecosystem services for people using an urban park in Rotterdam. They suggested a modification to the cascade that to distinguish cultural ecosystem services from other types of service, because, they argued that fundamentally they arise from the perception of nature, rather than from nature itself.

A modification to the cascade has also been suggested by Spangenberg et al. (2014, 2015) so as to include the notion of the potential of a system to generate ecosystem services, and argued for a ‘reverse application’ of the underlying cascade logic, so as to understanding the ‘full cycle of ecosystem services generation and management’. This, they suggest is particularly helpful in a planning context, where we need to identify uncertainties, the legal and participative foundations of decision making, and the potentially conflicting private and public interests. Von Haaren et al (2014)

go on to describe a 'practice-oriented ES evaluation model (PRESET) as a reaction to the cascade, again specifically adapted to the requirements of local and regional planning.

The studies that have used the cascade illustrate the motivation for proposing it, namely to help focus thinking and stimulate discussion. While the cascade can be criticised because there are 'missing links', it never was intended as a complete picture of the world. Rather, as we have suggested here, it is intended as a heuristic, that is a way of starting the kinds of conversation that people with different perspectives need to have in relation to the idea of ecosystem services. For particular applications frameworks for showing the links between people and nature will need to be more fully specified – but in the case of the general use of the cascade, simplicity is perhaps a virtue.

4. Classifying ecosystem services

The fluid nature of the concept of ecosystem services can be an advantage in stimulating discussion, but it poses problems if when we try to measure them, or design a system for classifying them so that we can report results clearly. An illustration of some of the difficulties that can arise is provided by Ojea et al. (2012), who looked at the problems that arise in the context of valuing the water services associated with forests from overlapping and ambiguous definitions in the MA classification. Elsewhere, Wong et al. (2015) have highlighted the difficulty of operationalising ecosystem services unless measurable 'endpoints' that unambiguously represent final ecosystem services can be identified. These kinds of difficulty are compounded by the fact that even assuming that such endpoints can be agreed, the naming of services is often different between initiatives and service categories that appear in one system are not always included elsewhere.

In an attempt to provide a framework that could at least be used to translate between the systems, work was undertaken as part of the development of the revision of the System of Environmental and Economic Accounting (SEEA), led by the United Nations Statistical Division (UNSD). It resulted in the so-called *Common International Classification of Ecosystem Services* (CICES, Haines-Young and Potschin, 2013), which aimed to help people identify what constituted a final ecosystem service and navigate between the different typologies that have evolved around the ecosystem service concept, and especially to report in a standardised way (e.g. La Notte et al., 2012). While developed initially in an accounting context, it has been taken up more widely by the ecosystem services community, and is, for example, the framework being used in the EU MAES Process, which aims to map ecosystem services at the European Scale, in order to meet the commitments made under Action 5 of the EU's Biodiversity Strategy to 2020 (Maes et al., 2014). In other work Crossman et al. (2013) suggest that such a classification might be seen as part of a more general systematic approach or 'blue print' for mapping and modelling ecosystem services. In looking to develop these more standardised approaches, Busch et al. (2012) have argued that it is especially important to develop classification systems, such as CICES, that are 'geographically and hierarchically consistent' so that we can make comparisons between regions, and integrate detailed local studies into a broader geographical understandings.

4.1 The CICES framework

The evolving nature of the science of ecosystem services and the way it is practiced, together with a field that brings together a range of disciplines each with their own terminology, means that the

design of a classification system that meets all needs is a major challenge. The development CICES illustrates many of the issues involved, and the fact that we must probably think of the creation of a classification system as a process rather than a design problem that can be solved in a single step.

CICES was created through a consultative process, initially as part of the efforts to design integrated environmental and economic accounting systems, but latterly by involvement of the wider ecosystem service community. A key initial consideration in 2009, when the process began, was that wherever possible the system should have resonance with the other widely used classifications, especially in relation to terminology. Thus CICES took as its starting point the typology of ecosystem services suggested in the Millennium Ecosystem Assessment (MA, 2005), and refined it to reflect some of the key issues identified in the wider research literature. For example, it explicitly attempted to identify what are considered to be ‘final services’, and was designed around the idea of a hierarchy, to accommodate the fact that people worked at different thematic as well as spatial scales.

The version of CICES that is now widely used was published in 2013, and is known as ‘version 4.3’ (Table 1)². At the highest or most general level are the three familiar categories used in the MA: provisioning, regulating and maintenance, and cultural. Below these major ‘Sections’ in the classification are a series of ‘Divisions’, ‘Groups’ and ‘Classes’. Figure 2 shows the way in which the hierarchical structure works for Provisioning Services.

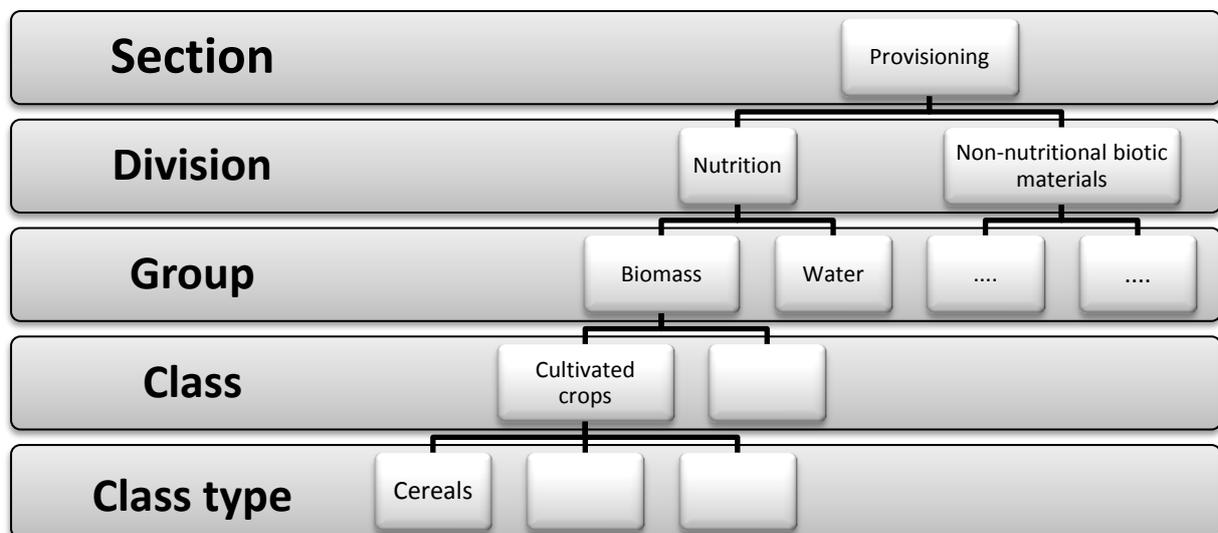


Figure 2: The hierarchical structure of CICES

² www.cices.eu

Table 1: CICES V4.3 to Class Level with equivalences for TEEB and the MA (for full CICES classification see www.cices.eu)

CICES V4.3				MA	TEEB					
Section	Division	Group	Class							
Provisioning	Nutrition	Biomass	Cultivated crops	Food	Food					
			Reared animals and their outputs							
			Wild plants, algae and their outputs							
		Water	Wild animals and their outputs							
			Plants and algae from in-situ aquaculture							
			Animals from in-situ aquaculture							
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Fibre, Timber, Ornamental, Biochemical	Raw materials, medicinal resources					
			Materials from plants, algae and animals for agricultural use							
			Genetic materials from all biota							
		Water	Surface water for non-drinking purposes							
			Ground water for non-drinking purposes							
Energy	Biomass-based energy sources	Plant-based resources	Fibre	Fuels and fibres						
		Animal-based resources								
		Animal-based energy								
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	Water purification and water treatment, air quality regulation	Waste treatment (water purification), air quality regulation					
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals							
			Mediation by ecosystems			Filtration/sequestration/storage/accumulation by ecosystems				
		Mediation of flows	Mass flows			Mass stabilisation and control of erosion rates	Erosion regulation	Erosion prevention		
						Buffering and attenuation of mass flows				
						Hydrological cycle and water flow maintenance				
	Maintenance of physical, chemical, biological conditions	Liquids flows	Flood protection	Water regulation	Regulation of water flows, regulation of extreme events					
			Storm protection							
			Gaseous / air flows			Ventilation and transpiration				
		Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal		Pollination	Pollination				
				Maintaining nursery populations and habitats						
				Pest and disease control			Pest control			
			Soil formation and weathering processes	Disease control			Soil formation (supporting services)	Maintenance of soil fertility		
				Decomposition and fixing processes						
				Water conditions					Chemical condition of freshwaters	
		Atmospheric composition and climate regulation	Chemical condition of salt waters	Global climate regulation by reduction of greenhouse gas concentrations	Atmospheric regulation	Climate regulation				
							Micro and regional climate regulation			
	Cultural		Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions				Experiential use of plants, animals and land-/seascapes in different environmental settings	Recreation and ecotourism	Recreation and tourism
							Intellectual and representative interactions	Scientific		
								Educational		
		Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes		Spiritual and/or emblematic	Aesthetic	Knowledge systems and educational values, cultural diversity, aesthetic values		Inspiration for culture, art and design, aesthetic information		
					Sacred and/or religious					
					Other cultural outputs		Existence			
			Bequest	Spiritual and religious values	Information and cognitive development					

Ecosystem accounts, like more general ecosystem assessments, have to be based on a well-defined and credible metrics which are often specific to particular geographical situations or ecosystem types. For the purposes of reporting or comparison these may need to be aggregated and generalised. The hierarchical structure illustrated in Figure 2 allows users to go down to the most appropriate level of detail required by their application, but then group or combine results when making comparisons or more generalised reports. Thus moving down from Section, through Division, Group and Class the 'service' is increasingly more specific, and these detailed service types are nested within the broader categories that sit above them. In the classification system there is therefore 'dependency', in the sense that the characteristics used to define services at the lower levels are inherited from the Sections, Divisions and Groups above them. There is also a sense of 'taxonomy' in that elements within the same Group or Class are conceptually more similar to each other, in terms of the ways they are used by people, than they are to services elsewhere in the classification. At any level in the hierarchy the categories are intended to be exclusive and non-overlapping, so that CICES can be regarded as a classification system, rather than an arbitrary nomenclature.

Table 1 sets out the basic structure of CICES and also shows the equivalences with the categories the typologies of the MA and TEEB³. In many cases there is a fairly simple read-across at the group level, but there are categories included in CICES, such as bioenergy, that are not covered by the others.

4.2 The problem of abiotic ecosystem outputs

A key problem with any classification system is to set its boundaries – what should CICES cover and what should it exclude. A key difference that emerged during the consultation was the extent to which the notion of ecosystem services included abiotic outputs from ecosystems such as hydro or wind power, minerals such as salt and so on. On the one hand people argued that although such things were produced by 'natural processes', the fact they were not dependent on *living* processes, meant that the classification would 'water down' the importance that 'biodiversity' had in any future assessments. The position was reinforced by the argument that if abiotic output from nature were included where would we stop – should fossil fuels, for example, also be included? The danger here, people felt was that if these were included their 'values' as 'ecosystem services' would outweigh many of the others. The counter argument was that many people, especially the 'public' who might be consulted during an ecosystem assessment, would not really see the distinction between the biotic and abiotic outputs of ecosystems so clearly. By excluding renewable energy sources such as wind and wave power, for example, would we not tend to exclude a whole category of things that 'nature can do for us'.

The argument about whether abiotic ecosystem service outputs should be included in CICES or any other classification system is a complex one, which is not made easier by the fact that in all the systems currently used 'water' is generally included as a provisioning service. Although living processes certainly affect both quantity and quality issues, in both the MA and TEEB, water is regarded as a provisioning service, notwithstanding the fact that the 'material' output is generated by abiotic, hydro-physical processes.

³ A simple tool for helping people make the translation is available at: <http://openness.hugin.com/example/cices>

In CICES V4.3, abiotic ecosystem outputs were in the end, excluded from the classification, although a parallel table, covering these elements was provided; it applied the same classification logic to define provisioning, regulating and cultural outputs, as for the services dependent on living processes. There was no attempt to restrict this list to only those abiotic outputs that were 'renewable' within the human time-frame, or to exclude 'sub-soil' assets. At this stage, however, the provisional classification of abiotic outputs is merely intended as a 'maker', to highlight the fact that we still probably need to develop a more all-encompassing vocabulary for discussing the trade-offs and synergies between the different types of output that ecosystems can provide.

4.3 Supporting services

A key difference between CICES and the typology used by the MA, for example, is that it does not include 'supporting services'. This is not because those developing CICES felt that they were unimportant, but that for them the problem was to identify the 'final' outputs from ecosystems that might form the basis of valuation and assessment. As Figure 1 suggests, CICES attempts to classify services which sit at the interface between the biophysical and socio-economic components of an integrated 'socio-ecological system'.

In any ecosystem assessment, once the important final services had been agreed or identified, then discussions about sustainability and appropriate management strategies would have to focus on the underlying ecosystem structures and processes, and functional characteristics that give rise to them. Thus the final services are seen as the entry-points for these kinds of discussion, and it was felt that broad labels like 'nutrient cycling' or 'primary' production' were not particularly helpful in this respect; for most final services there are probably multiple structures, processes and functions that 'support' them. This is not to say that some kind of agreement about how we describe these processes and functions is unnecessary – but only that it is probably part of another 'conversation'.

There is, however, one aspect of the debate about supporting and intermediate services that is relevant to the structure of CICES, and it relates to the difficulty of specifying what a final service is in a particular situation. The difficulty was illustrated above in the discussion about if and when water in a lake or fish were the final service. Thus there are other services listed in CICES that could be regarded in some situations as having an underpinning role, such as soil formation or pollination. The point here is that while the classification makes space for them, largely on the basis of customary practice, in any particular assessment a judgement has to be made about their status. Pollination might indeed be regarded as a final service if, for example, its value or importance were being compared with some alternative that depended on human intervention. Alternatively it might be regarded as a 'supporting service' or ecological function delivered by a particular ecosystem if the harvestable fruit crop was being used to sum up the value of all the relevant ecosystem outputs (including pollination) necessary for its production. The responsibility of avoiding 'double counting' is down to the user of the classification and the purpose to which it is put – not only the designer.

4.4 Distinguishing services, goods and benefits

A particularly difficult problem that the design of CICES illustrates for those interested in classification systems for ecosystem services, is the distinction between services and benefits. For those who regard services *as* benefits there is of course no problem. For those who argue that that

there is a difference between them, in the sense that services are regarded as an ‘activity or function of an ecosystem that provides benefit’ while benefits are ‘the many ways that human wellbeing is enhanced through the processes and functions of ecosystems via ecosystem services (Mace et al. 2012) there is a problem of terminology. The problem with a consultative process such as that which led to CICES is that different people mixed the approaches and in some areas there is a blurring of categories.

In the discussion of the cascade model (see above) we suggested that final services were at the ‘production boundary’ where the link to ecological structures, processes and functions was broken. This is easy to visualise in the case where a crop is harvested. Thus the wheat growing in a field is the ‘service’ (in the sense that it is the result of all the activities and functions in the biophysical part of the socio-ecological system), while the grain in the combine harvester is the good (or benefit) – the thing that can be valued. The ‘production boundary’ is also easy to imagine when waste streams are reconnected to ecological processes to take advantages of ‘bio-remediation services’. It is more difficult to visualise in the case of some other regulating services and especially cultural ones.

It is in the area of cultural services where many of the issues surrounding the problem of distinguishing services and benefits can be illustrated. In order to resolve the different positions in the consultative process, the design of CICES took a mixed approach by using the notion of ‘environmental settings’ to frame cultural services at the higher levels in the classification, and the more familiar terms used to refer to cultural services such as ‘recreation’ or ‘education’ at the class level. As Chan et al. (2012) have noted the classification of cultural services is particularly challenging, and these authors suggested that they might be regarded as the “ecosystems’ contributions to the non-material benefits (e.g., capabilities and experiences) that arise from human–ecosystem relationships” (Chan et al., 2012, p.9). This is also the approach taken in the UK National Ecosystem Assessment, where these ‘contributions’ are attributed to the locations (settings) or ecological features (e.g. species) that generate some benefit by virtue of some set of cultural practices (see also Church et al., 2014 and Tratalos et al., 2015). Thus ‘walking’ might generate the benefit of ‘recreation’ or ‘spiritual fulfilment’ from a woodland or coastal setting; the cultural practice of ‘bird watching’ might similarly generate a number of cultural benefits. These examples illustrate that for the non-material ecosystem outputs the ‘production boundary’ is crossed when that output is linked to some kind of relationship that people have with an ecosystem that then changes their well-being in some way. As Chan et al. (2012) argue these non-material cultural benefits can include capabilities and experiences; by extension to the non-material regulating services equivalent regulatory benefits would include such things as protection from storms or mediation of the ambient environment in which people live. An attempt to use a previous version of CICES in this way, to look at the interface between services and benefits is provided by Staub et al., (2011) in an insightful study undertaken by the Swiss Federal Office for the Environment.

4.5 Developing our classification systems

Costanza (2008) has argued that multiple ways of classifying ecosystem services are needed, and usefully pointed to how they might be described in terms of spatial scale, or according to characteristic such as excludability and rivalness. It is indeed the case that we need to develop much richer vocabularies for describing the way people and nature are linked. As for CICES, the purpose of

stabilising the framework in 2013 as ‘version 4.3’ was to encourage people to test it in a practical way, so that future refinements could be informed by evidence rather than just opinion. Coming from an initiative that saw ecosystem accounting as ‘experimental’ meant that it was accepted that ideas need to be tested and refined.

In terms of its application, CICES has been used as the basis of the German TEEB study (Naturkapital Deutschland – TEEB DE, 2014) as well as the German National Ecosystem Assessment, NEA-D (Albers et al., 2014). Elsewhere it has been refined at the most detailed class level to meet the requirements of ecosystem assessment in Belgium (Turkelboom et al., 2013). Saastamoinen et al. (2014) have used it to classify ecosystem services associated with the boreal forests of Finland. Accounting applications include those of Schröter et al. (2014). Elsewhere, CICES has been used to look at the basis for developing or comparing indicators of ecosystem service supply and demand; examples include the work of Castro et al. (2014), Kosenius et al. (2013) and von Haaren et al. (2014). And, in other work, Bürgi et al. (2015) have used CICES to examine how ecosystem service output had changed for a Swiss landscape since about 1900; the classification framework was used to code the reports from achieve sources about whether things that we would now regard as ecosystem services were documented as important in past periods. However, while these applications of CICES suggest that the current framework is appropriate for many uses, it is clear from the work of Armstrong et al. (2012), and Liqueste et al. (2013b), for example, that it may need to be adapted to ensure that it is suitable for the assessment of marine and coastal ecosystems, or integrated more closely with typologies for describing underlying ecosystem function. The recent development of the ‘FEGS’ system by the US-EPA (see Landers et al., 2016, this volume) also suggests that there may be some scope to look at the way services, benefits and beneficiaries are aligned in different classification systems, so that a more complete picture of the service cascade can be established.

5. Conclusion

Although the idea of ecosystem services is simple in concept, its application in management and policy is complex. If we are to deliver the practical benefits of managing natural capital in ways that can help sustain human well-being, it is clear that to overcome some of these challenges we need to find ways of describing and measuring ecosystems and their services in consistent ways. Thus a discussion of how to define and classify services is not simply an academic matter, but rather central to any efforts to operationalise the ecosystem service paradigm. A critical discussion of the cascade model and the attempts to develop a Common International Classification for Ecosystem Services (CICES) is, we suggest, an important part of this evolutionary process.

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