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The diversity of the ecosystem services concept and its implications for their assessment and management

Implications de la diversité des définitions du concept de service des écosystèmes pour leur quantification et pour son application à la gestion

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ABSTRACT

The ecosystem services concept is used in different scientific disciplines and is spreading into policy and business circles to draw attention to the benefits that people receive from biodiversity and ecosystems. However, the concept remains multiform and is used interchangeably with a range of other terms such as ecological, landscape or environmental services. We argue that lexical differences, in fact, result from different understandings of the concept, which could slow its use in nature conservation or sustainable resource use. An application to semi-natural grasslands shows that such differences could lead to very different assessments, of quality, quantity and location of ecosystem services. We argue that a compromise must be found between a broad and simple definition, which is useful for communicating the concept and large-scale policies, and a more refined definition for research and implementation goals such as environmental management and national and international assessments and accounting.

RÉSUMÉ

Le concept de service écosystémique est utilisé par de nombreuses disciplines scientifiques et commence à être largement utilisé dans le domaine politique et entrepreneurial. Pourtant plusieurs définitions et usages du concept coexistent, ainsi que des termes tels que services écologiques, environnementaux ou du paysage. Nous suggérons que cette variété terminologique traduit des différences de compréhension du concept. Celle-ci peut compliquer son utilisation pour la conservation de la nature et la gestion des ressources naturelles. Une application aux services fournis par des prairies semi-naturelles montre que ces différences peuvent amener à des évaluations très contrastées, que ce soit en termes de qualité, quantité ou localisation des services. Afin d'éviter ces problèmes, un compromis doit être trouvé entre une définition élargie et utile pour la communication et les politiques à grande échelle et une définition plus précise et donc plus adaptée aux actions de gestion des écosystèmes et aux exigences d'une comptabilité nationale ou internationale des services.

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1. Introduction

Although the deliberate identification of the range of goods and services that people obtain from nature (e.g. game, berries and fruit...) is not new, it has received increasing attention in recent years under the banner of "nature's services" or "ecosystem services" [1]. This new way of framing the relationships between biodiversity, ecosystems and human well-being first gained strength in the field of nature conservation during the 1990s and later spread through a wide range of scientific disciplines [2,3] and more recently into policy and business circles [4,5].

The concept has provided a new, anthropocentric, justification for conserving species and ecosystems, based on our dependence on the goods and services they provide. Not only has it been widely used to draw attention to the importance of the benefits that people receive from biodiversity and ecosystems, it has also developed into a useful concept for framing the study of the relationships between nature, including both species and whole ecosystems, and the livelihoods of the communities that use or benefit from it. Part of the ecosystem and community ecology research communities took up the term as it shifted its focus from the effects of species number [6] on ecosystem functions such as productivity to the effects of the identity and abundance of species with particular sets of traits (i.e. functional diversity [7]) on ecosystem services [8,9]. Scientists working in the fields of agriculture, rangelands, forestry or natural resources in general have now taken up the concept of ecosystem services when referring to their positive outcomes for society, which were previously framed in terms of amenities or functions (as in multifunctional agriculture) [10]. These are used to better justify their practices or the considerable public support they sometimes receive (e.g. agri-environmental schemes under the European Union Common Agricultural Policy). The valuation of ecosystems by economists is not a new endeavour [11–13] but its importance has grown considerably as market-based instruments have gained strength in the formulation and implementation of conservation policies worldwide [14,15].

As the number of scientific disciplines that refer to the ecosystem services concept grows, and with its incorporation into political and corporate discourse, the concept is becoming multiform and harder to grasp, and it has generated debates about definitions and classifications [2,16–20]. The aim of this paper is to highlight the implication of terminological diversity around the ecosystem services concept rather than open a semantic debate. We first review the general terminology that has gained currency in the environmental literature, with a specific focus on the diversity of meanings and approaches that have been applied for the use of the ecosystem services concept in the recent literature. We then briefly illustrate the implications of such definitional choices for a case study that aimed to quantify ecosystem services provided by mountain grasslands. We end with a discussion of the implications for scientific and operational purposes of the use of a diversity of definitions for the ecosystem services concept.

2. Terminological diversity in concepts of nature's services to society

2.1. The different broad terminologies of nature's services

While the main term used in the ecological and nature conservation literature to describe all things nature provide us is "ecosystem services", a series of related terms and concepts (merge here under a generic term "nature's services") (borrowed from [1]) have been developed in other contexts and disciplines.

Ecosystem services sensu stricto are broadly defined in the reference [21] as the benefits people obtain from ecosystems (Table 1) and are classified in four categories: provisioning services (i.e. products obtained from ecosystems, such as food, fibre or timber), regulating services (e.g. flood or pest control and climate regulation), cultural services (i.e. non-material benefits such as aesthetic and recreational enjoyment) and supporting services (i.e. those services that are necessary for the proper delivery of the other three types of services, such as nutrient cycling). The validity of this last category has since been questioned as it amounts to mixing "ends" (i.e. services) and "means" (i.e. the ecological processes necessary) [17]. In a farming context, the concept of ecosystem services has also been used to refer to "input services" and "output services" for agriculture [22]. In addition, the term ecosystem goods (as in goods and services) is sometimes used for those services that have a direct market value such as food but both tangible goods and immaterial services provided by ecosystems are now generally labelled as ecosystem services.

Ecological services have been used by some authors as a synonym to ecosystem services [23,24] but the term sometimes refers to services provided by a particular species or group of species rather than processes occurring at the ecosystem level [25].

Landscape services and the terms land, land-use and landscape functions are widely used when referring to services supplied by regions, landscapes or land-use systems with the technical and socio-economic characteristics of the land-use system being taken into consideration together with abiotic and biotic components [26,27]. Landscape functions are often considered in terms of their "potential" for human use [28]. Other authors suggest that landscape services differ from ecosystem services in that they take explicitly into account the underlying role of spatial patterns, landscape elements and horizontal landscape processes [29].

Environmental services are often used as a synonym of ecosystem services in PES schemes (Payment for Environmental Services), where stewards are paid by third party beneficiaries for an activity aimed at intentionally transforming or maintaining some useful characteristics of an ecosystem (or landscape) [30]. Other authors have proposed to use the term environmental services to label human-made services, which totally or partially substitute ecosystem services [31]. This fits with the use of the term to label waste and water management services (as in the case of the company Veolia Environnement© which claims to be a "world leader in environmental services"). The term

Table 1

Inventory of main definitions of ecosystem services, functions and benefits used in scientific literature and difference of interpretation in the framework of the cascade. Column headings follow the different boxes of Fig. 2.

Authors	Ecosystem components or processes	Function(s)	Service(s)	Benefit(s)
	Services providers	Potential services	Services used, consumed or enjoyed by human beneficiaries	Benefits obtain from ecosystem services and/or human-made services which improve human well-being
de Groot et al., 2002 [48], Teeb, 2009, Haines-Young & Potschin, 2010	Ecological structure, habitat, ecosystem properties and supporting services	The potential that ecosystems have to deliver a service. 'Things' needed to deliver services	The direct and indirect contributions of ecosystem to human well-being	Welfare gains generate
MA, 2005	Supporting services		Benefits people obtain from ecosystem	
Daily (ed), 1997	Complex natural cycle		The conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life	
Costanza et al., 1997	Functions: Refer variously to the habitat, biological system properties or processes of ecosystems		Services: the benefits human populations derive, directly or indirectly, from ecosystem functions	Human welfare are the results of ecosystem services [...] from natural capital stocks combined with manufactured and human capital services
Wallace, 2007	Ecosystem function as a synonym of ecosystem processes which are the complex interactions among biotic and abiotic elements of ecosystems that lead to a definite result. For urban or rural system with few natural elements could also be cultural elements of ecosystem or some combination with natural elements		Point where ecosystem directly provides an asset that is used/consumed by one or more humans	
Boyd and Banzhaf, 2007	Function and processes are intermediate to the production of final ecosystem services. Intermediate services		Final ES are components of nature, directly enjoyed, consumed, or used to yield human well-being. Ecological things or characteristic, not process or function	Use both ecological services and conventional goods and services (man-made input)
Fisher et al., 2009	Ecosystem structure and processes provide services		The aspects of ecosystems utilized (actively or passively) to produce human well-being. Ecological phenomena do not have to be directly utilized	Point at which human welfare is directly affected and the point where other forms of capital (built, human, social) are likely needed to realize the gain in welfare
Diaz et al., 2006 and 2007	Ecosystem processes: Intrinsic processes and fluxes whereby an ecosystem maintains its integrity	Relevant ecosystem properties to ecosystem services	Benefits provided by ecosystems to humans	Ecosystem services contribute to making human life both possible and worth living
Kremen, 2005	Ecosystem services providers (species or entities)	Ecosystem services are the set of ecosystem functions that are useful to humans		
Hooper et al., 2005	Various pools and fluxes	Ecosystem goods and services are the subset of function of utilitarian value to human		
Termorshuizen and Opdam, 2009	Landscape: spatial human ecological system. Interaction between physical structure and human actions	Functions are translated into services when they are valued by people	Uses and values of landscape by people	
Willemen et al., 2008 et 2009	Socio-economic and biophysical variation of the landscape and the spatial and temporal interactions between the different components of the landscape	Landscape function: capacity of a landscape to provide goods and services to society	Landscape services	
Verburg et al., 2009	Land use systems and ecosystems within the landscape	Land function: goods and services provided		

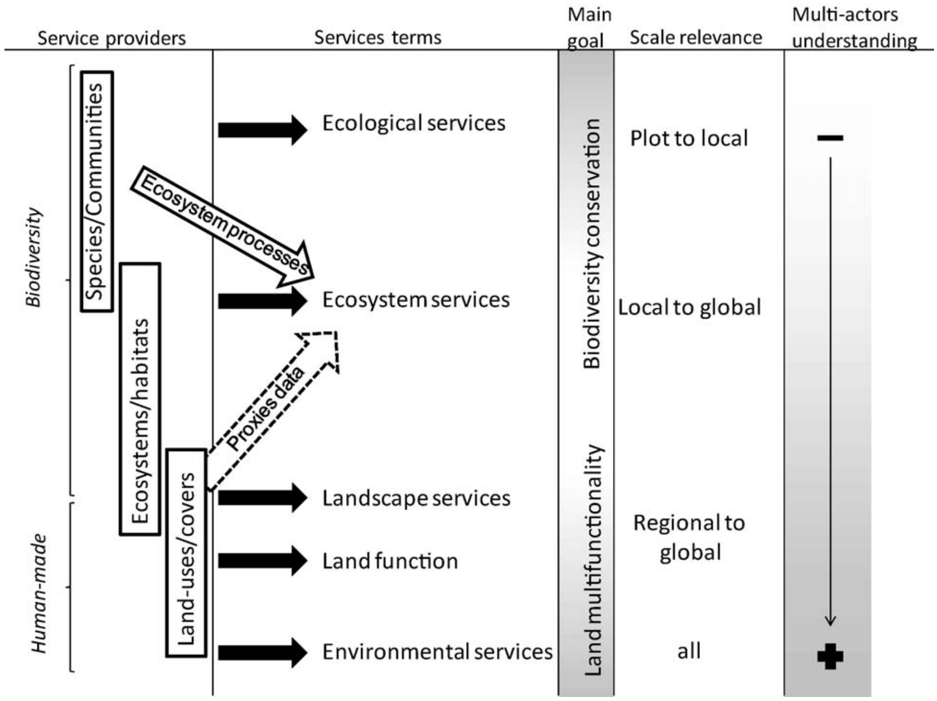

Fig. 1. Differences between terms used to describe nature's services in their services providers units, management goals, scales of relevance and consideration for multiple actors.

sometimes also refers to the services provided by the abiotic environment such as the wind or water regimes used for generating electricity. In this case, the links with fauna and flora (i.e. biodiversity) are indirect [32].

These terminologies (Fig. 1) differ in terms of (1) the key components and processes necessary to deliver an ecosystem service, called hereafter "services providers" (this term include the "service-providing units" [33] and the "ecosystem services providers" [34]), ranging from species to landscapes, and (2) human interventions in their delivery. Fig. 1 illustrates how a shift in focus from specific biotic components of ecosystems to whole ecosystems, landscapes and finally man-made substitutes leads to a decrease in the importance of biodiversity to the provision of services. In parallel, the ecological knowledge required to understand the role of biodiversity decreases, whereas knowledge on human processes is increasingly incorporated.

2.2. Diversity of ecosystem services definitions

We analysed how the most common and contrasted definitions of the term "ecosystem services" are distributed along a cascade of contributing elements that helps to dissect the ecosystem services concept into "functions", "services" and "benefits", as proposed by Haines-Young and Potschin [32,35] and illustrated in Fig. 2. The different definitions are summarized in Table 1.

In this cascade, structure and process are the biophysical components (e.g. species and their abundance) and processes (e.g. interactions between species and ecosystem compartments), which underpin the potentiality for the ecosystem to deliver one or multiple services. This potentiality is referred to as ecosystem functions. Functions are themselves translated into services when they are used, consumed or enjoyed by humans [2]. This makes ecosystem services location (e.g. avalanche regulation is

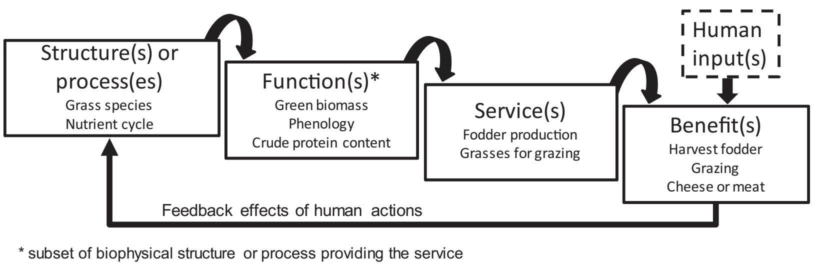

Fig. 2. Conceptual cascade of ecosystem services from processes to benefits (adapted from Haines-Young and Potschin [32] and de Groot et al. [36]) and example of fodder production in mountain grasslands.

only relevant if there are people living downhill) and time-dependent as well as beneficiary-dependent (different individuals or collectives benefit from different services [36]). Finally because many benefits are in fact obtained by combining natural and human capital it can be useful to distinguish benefits from their strictly ecological inputs [16].

The main definitions considered here are not all located at the same place along the conceptual cascade (Fig. 2) and the same terms can be used to describe different steps. Generally, confusion occurs at four critical points:

- defining function and services; the confusion between services and function comes from the use of the word 'function' to describe the functioning of ecosystems [37] which is sometimes used as a synonymous of ecosystem properties [2,14,16,17]. Of the many structures and processes that occur within an ecosystem, not all are relevant to a particular service. For example, the avalanches protection service depends on the function of snow retention by trees, which depends on forest structure;
- identifying the structure(s) or process(es) which allow the delivery of services: these ecosystem properties can be species, communities or ecological structures (e.g. layers in a forest or length of hedges) as well as complex cycle processes or fluxes or a combination of all the former. For example, through photosynthesis, a forest might provide a global service of carbon sequestration, and some species in the forest can be used for firewood while others are used for ornamental woodwork. Some ecosystem properties are affected by the ecosystem's location in the physical and ecological landscape (such as water flow, which also results from the ecosystem's location);
- defining services and benefits: MEA [4] and Costanza et al. [14] define services as benefits while more recent papers separate benefits and ecosystem services, considering that the former are a product of the latter and other forms of capital [2,16]. The distinction is important in order to avoid double-counting in monetary valuation. For example, clean drinking water for consumption is a benefit dependant on a range of intermediate services such as clean water provision and processes such as nutrient cycling but the contribution of these intermediate services is already encompassed in that of the water;
- defining direct vs. indirect provision: Boyd and Banzhaf [16] and Wallace [17] stressed the importance of taking into account services only directly used or consumed by humans. In response to their paper [2,18] pointed out that ecosystem services do not have to be utilized directly because "as long as human welfare is affected by ecological processes or functions they are services. This raises the question of differentiating "intermediate services" from the services that directly benefit individuals or collectives [16,18].

3. Case study

To discuss how the different definitions reviewed in Table 1 apply in a real world situation, we have applied them to the identification, quantification and mapping of ecosystem services provided by a 1300 ha area of mountain grasslands in the French Alps. The grasslands are mainly managed for livestock and for the sake of illustration we focus our discussion on fodder production (Fig. 2 for examples), although tourism and nature conservation are important activities in the area as well, each relating to an additional set of ecosystem services.

Before exploring how the definitions reviewed in Table 1 would label these different steps in the cascade we first focus on how local stakeholders understand the ecosystem services concept and map the different steps mentioned above along the cascade. This is important as ecosystem service scientists need to consult with beneficiaries of these services to establish the links between ecosystem functions and benefits [2,29]. Stakeholders also expect scientists to produce results such as quantitative data and maps of ecosystem services that are framed according to their own terminology and needs.

3.1. Stakeholders understanding and expectations

We conducted semi-guided interviews on ecosystem services and biodiversity with 13 professionals of agriculture, nature conservation, tourism and rural development working in regional-level public administrations and NGOs and with 6 inhabitants (including farmers) of the case study area. Interviewees were asked about their knowledge and understanding of the notion of "ecosystem services", and in the case of regional professional of the term itself. Only half of the regional professionals had heard about the concept, and half of these defined it correctly. Some of those who had heard of the term confused it with the broader concepts of amenities or agricultural multifunctionality on the basis of which farmers are subsidized. The representations by stakeholders of the different steps of the conceptual cascade for fodder production are shown in Table 2. Other ecosystem services identified by interviewees are in fact benefits as

Table 2
Fodder production services illustrated by stakeholder's identification of ecosystem services delivered by grasslands (terms mentioned by interviewees to describe ecosystem services).

	Structure(s) and process(es)	Function(s)	Services(s)	Benefit(s)
Maps of Fig. 3		Map a	Map b	Map c and d
Terms mentioned by interviewees	Biodiversity, soil fertility, soil genesis Water availability		Fodder (quality and/or quantity)	Cheese
	Generally not precise but people say that some component or process are needed to deliver ecosystem services		Fodder for cattle, animal production, cheese, meat	

they imply labour or technical skills. They include honey production, ski resort and related recreation or job opportunities. Thus, although their understanding of the term "ecosystem services" was imprecise, interviewees acknowledged linkages between biodiversity and benefits they obtain from the area with economic or other values.

Interestingly, when identifying services delivered by grasslands interviewees tried to compare them to other ecosystem types such as forests in terms of their importance for the delivery of each service. They stated for example that well-managed grasslands can decrease the risk of avalanches but that this service is better supplied by a forest. This highlights people's general knowledge of landscapes and ecosystem types. They have less insight into the particular processes that generate services within a given ecosystem. This could make the concept of ecosystem service harder to grasp than that of "landscape services" (Fig. 1).

Stakeholders interested in implementing the concept and using it as a communication tool (i.e. for providing multiple arguments to conserve biodiversity) mentioned the need for precise identifications, measurements and maps of the services in their area. Obtaining such data requires first that they know what it is they want to map: functions, services or benefits.

3.2. Implication for quantifying and then mapping ecosystem services

In order to illustrate the implication of the different definitions, four different variables around fodder production, each corresponding to different steps in the conceptual diagram (Fig. 2), were used to quantify and then map ecosystem functions and services (Fig. 3). The methodology is explained briefly below. Maps at the landscape scale were obtained by extrapolating data collected in 57 plots representing 8 different land-uses. For further details on data and mapping methodologies [38].

Ecosystem services were identified on the basis of interviews with local farmers on their need and uses of grasslands. For them a good meadow for mowing or grazing (i.e. fodder production services) is the result of quality and quantity of grasses that corresponds to a combination of different ecosystem functions: grass quantity, quality and flowering phenology [39]. Those functions are translated by researchers into measurable indicators such as annual green biomass production ($g.m^{-2}$) to evaluate grass quantity (Fig. 3 – map a). Because some authors, especially in the ecological literature, confuse ecosystem functions and services, these maps could be considered by some as ecosystem services maps (see Table 1 for examples of such definitions of ecosystem services). However, a simple visual observation between green biomass ecosystem function (Fig. 3 – map a) and agronomic quality ecosystem service (Fig. 3 – map b) shows a different spatial pattern. For example, zone 1 (Fig. 3) corresponding to summer meadows have low biomass production but have high quality and zone 2 (Fig. 3) related to mown and fertilized grasslands are mainly valued for the biomass production and their early flowering. Hence, the area assessed as providing a high agronomic service is the same as the area with high biomass production. These differences illustrate the important distinction between function which can be delivered by several grasslands around the world and service which include the manner grasslands are used in a given farming system and which do it context-dependent (eg. culture, socio-economic). Finally, biological or ecological data are not sufficient to quantify or map benefits. These require agronomic, social or economic information on other inputs (which are anthropogenic rather than provided by ecosystems). Fodder benefits farmers as it is incorporated into the farming system (i.e. used to feed their flocks which then produce meat and thereby contribute to their livelihoods). It also benefits consumers outside of the local area in the form of food such as cheese or meat. Here we mapped benefits to cattle production

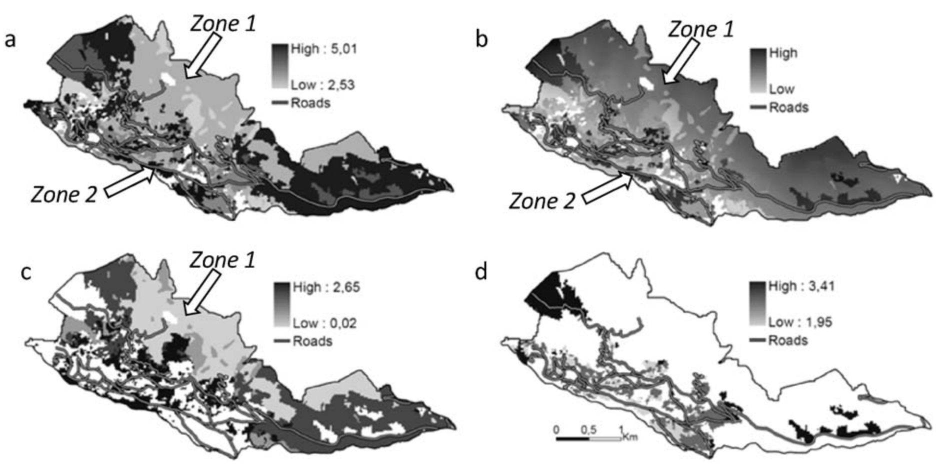

Fig. 3. Maps of nature's services related to fodder production according to different definitions: (a) ecosystem function: green biomass (tons/ha); (b) ecosystem services: agronomic value (unitless) obtained from a combination of different functions (green biomass, digestibility and phenology), and benefits; (c) the number of days of livestock units/ha and (d) hay production (tons/ha). Roads and tracks are added on maps as they are important elements of analysis.

using data of the number of days of livestock units/ha aggregated by land use based on farmers' interviews data. Map (c) in Fig. 3 shows that cattle grazing is on grasslands of high agronomic quality only for a few months on summer meadows (Fig. 3 – zone 1), and rather more concentrated and longer on areas close to farm buildings used for spring and autumn pastures. In the same way, a map of harvested fodder for hay (d) shows that topography and access constrain farmers to not always harvest the more productive areas. Note, that depending on the production system cattle grazing or harvested fodder are only one dimension of the benefit and are in this type of mountain system combined to determine the total benefit of grasslands to farmers. In spite of this, these last two maps demonstrate that ecosystem functions are not sufficient to assess benefits, additional human inputs such as labour, machinery (tractors), infrastructure (roads) and so on are needed.

All those differences between maps demonstrate that ecosystem function, services and benefits are not equivalent (Fig. 3). Hence, this makes comparative studies (eg., between ecosystem services deliver by mountain grasslands sites) difficult.

4. Discussion

We subscribe to the idea that definitions and classifications of ecosystem services are purpose-dependent and should be judged on their usefulness for a particular purpose [22]. Yet our review also shows that the coexistence of different terminologies and definitions could impede the on-the-ground use of the concept because of the difficulties in translating it into tangible, manageable, "things" to measure, count, qualify or map.

4.1. Precision and broadness of nature's services and associated definitions

There are advantages and drawbacks to a precise definition that distinguishes each step of the conceptual cascade relative to a broader definition that does not make these distinctions. The case study shows that different definitions lead to different spatial patterns of delivery. This would lead to divergent identification of areas with high ecosystem service delivery, with possible consequences for management choices or payments for ecosystem services. Therefore, the specifications of definitions for ecosystem services can have strong implications in the context of biodiversity conservation, the sustainable use of natural resources, or even rural development where site managers and decision-makers expect concrete, practical and precise data on which to base their decisions. Hence, the distinction is useful for scientists aiming to quantify and then compare services. It is also useful in helping scientists clarify the needs and expectations of stakeholders in a context of increasingly participatory research in natural resource and ecosystem management [40]. We showed that differences between definitions are important sources of variations in assessment outcomes but we did not address differences within definitions due for example to quantification methods such as the use of proxy versus field data which can lead to inaccurate maps [41].

Building on-the-ground assessments on the basis of a broad definition can also lead to misunderstandings or departures from the original concept [42] that could be amplified through dissemination and gradual transformation of original definitions. Yet, a precise and complex framework is inappropriate as a communication tool. A broader definition, carrying the main message that nature is useful to humans, is probably more appropriate for the general public and higher-level policy makers. It has in fact contributed to the concept's success [3]. A simple definition also has the benefit of matching peoples' definitions and understanding (Table 2). It is important to communicate on both services providers and ecosystem services in order to increase public awareness of the dependence of services upon ecosystem processes and components such as biodiversity in order to adopt sustainable management of ecosystem services.

We conclude that the full distinction between the four components of the conceptual cascade (Fig. 2) is useful for the quantification of ecosystem services, for mapping or valuing for example, but that for general public communication purposes, a simplified distinction that merges service providers units and functions on the one hand, and services and benefits on the other should be sufficient.

4.2. Two contrasted but complementary uses of services

According to our analysis of uses and definitions of nature's services by different authors, it appears that the term has two audiences. The concept is used as a tool for natural resources management or biodiversity conservation ([43] for a review) by those who adopt an anthropocentric and utilitarian approach. This approach is distinct from the intrinsic value pleading for the inherent worth of biodiversity, independent of its value to anyone or anything else [44]. A second use of the term is that observed in land use planning studies [45] where nature's services are used in a holistic approach centred around the conciliation of different human activities with environmental constraints and biodiversity. In the context of agroecosystems, this approach is consistent with others such as agricultural or landscape multifunctionality which suggest that "agriculture can provide numerous commodity and non-commodity outputs, some of which benefit the public without compensating the farmer" [46]. Some authors consider not only nature's services from agriculture but also to agriculture [22].

Faced with these two audiences, two solutions emerge: keeping a common term and accepting ambiguity or using two different terminologies. We propose "ecosystem services" for use in the context of biodiversity conservation and natural ecosystems, both because it was its original goal and because most ecosystem services depend on biodiversity components, and the term "landscape services" for use in land-use planning, because it is based on land-use patterns and practices and it is open to human inputs (labour, technology, etc.).

5. Conclusion

By accepting that the value of biodiversity and ecosystems can be weighted against other components of human well-being, in particular using the tools of economic analysis, conservationists have opened the door to closer cooperation with policy makers and business circles [15], in keeping with their objectives of "mainstreaming conservation into the everyday decisions of the business and public sectors" [47]. However, the complete consequences of this shift in vocabulary and in the underlying sets of values, from bio- or eco-centric to anthropocentric and utilitarian justifications for the conservation of wild nature, are yet to be revealed. Ecosystem services and more broadly nature's services is one tool among many to communicate and justify biodiversity conservation. But as this paper demonstrates, this concept is difficult to grasp. The concept's integrative and federating approach is appealing and helps translate complex ecological processes into a common and simple vocabulary understandable in multidisciplinary scientific and political discourses [3], yet it has also become important to move towards more precise definitions of what ecosystems services are, not only for effective implementation and use, but also to avoid misrepresentations which could undermine the credibility of the concept.

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