Current issues in ecosystem services valuation (ESV)

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Abstract

The concern for damage to nature has led to the emergence of a set of techniques for ecosystem services valuation (ESV) in the late 1960's. Not surprisingly, the meaning and reliability of ESV techniques themselves are subject to growing scientific debate. The current discussions has primarily focused on six issues: *i)* the complex relations between ecosystem functions and services, *ii)* the link between ESV and payment mechanisms, *iii)* the definition of a meaningful and operational classification of ecosystems services, *iv)* the link between values and economic valuation, *v)* the incommensurability debate and, *vi)* the limits of cost benefit analyses when applied to ecosystem valuation. We begin by reviewing these issues. Then we will give a few examples of valuations of particular ecosystem services or conservation programmes, that highlight both the challenge of placing ESV in a spatially explicit framework and, the so-called "environmentalist paradox".

Keywords

Economic valuation, Ecosystem services, Payments for ecosystem services, Cost-benefit analysis, Ecological complexity

Introduction

While numerous approaches to valuation exist, economic valuation is focused on allocating scarce resources based on people preferences. Economic value of the environment at large is poorly, or not at all, expressed in the marketplace. Hence valuation techniques have been developed to make visible what is presumably not, with the purpose to inform public decision making. Scientific interest in valuing what was not yet named "ecosystem services" emerged in the late 1960's both as a concern for ecologists [1, 2] and as a theoretical challenge for economists [3]. Soon thereafter interest was confirmed more broadly in the profession [4, 5, 6] and several points were clarified (see [7], [8], [9] for detailed analysis). It is commonly admitted that, aside the seminal book edited by G.C. Daily [10], the publication in *Nature* of a tentative worldwide synthesis of the value of ecosystems services and natural capital by Costanza et al. [11] acted as a launching declaration for the on-going ecosystem valuation research programme. This paper was so provocative that a few months later, *Ecological Economics* published a special section "Forum on the valuation of ecosystem services", offering room to thirteen papers that covered "a range of perspectives, from those who basically agree that this work is important but raise other important issues, to those who question the wisdom of the exercise of valuing ecosystem services itself, to those who question the validity of the methods used" [12]. Some critics of [11] have been particularly severe [13], not only about the utilitarian philosophy underlying economic evaluation, or about methods but, more fundamentally, because of the risk that science is manipulated to attract media attention.

Fifteen years later, this programme is flourishing yet many questions remain unanswered. Fisher et al. [14] identified more than 1000 papers related to ESV since a clear definition of the concept was given [6]. In a recent survey of influential articles in environmental and ecological economics in the 21st century (15], a ranking - unavoidably questionable - placed seven papers related to ecosystem services in the top ten papers (but only twelve among the top fifty, and seven in the following fifty). Whereas the survey covers the 2000-2009 period, most "influential papers" related to ecosystem services have been published since 2007, as if the lessons from the Millennium Ecosystem Assessment [16, 17] had needed some time for maturation and assimilation by the valuation scientific community.

This literature review aims to present some of the issues that frame the scientific debate. The choice of problems to be reviewed is based on: i) the selection previously made for a French report on an economic approach to biodiversity and ecosystem services for public decision-making [18], especially the sixth chapter that, building on interdisciplinary knowledge presented in previous chapters, suggests research priorities, ii) the TEEB "Foundations" report [19], specifically chapter 5 [20] and the requirement of "best practices" for the evaluation, ii) and finally our arbitrary and, no doubt, our ignorance. Clearly, we have excluded important issues, for reasons that we may sometimes explain but remain more or less arbitrary anyway. Two examples: 1) we do not expose the discussion of methods of evaluation, because mostly they are not specific to the topic and ecosystem services and because the reader can find excellent reviews elsewhere (see for instance [20]) , 2) the issue of false or distorted perception that agents may have about the impact of ecosystem services is undoubtedly very important, but we also set it aside because it seems that no robust and consensual knowledge has emerged yet .

We will successively discuss the following six issues: 1) the inherent complexity of ESV, 2) its links with payment mechanisms, 3) the challenge of a meaningful and operational classification of ecosystems services, 4) the link between economic valuation and values, 5) the incommensurability debate and 6) the limits of cost benefit analyses when applied to ecosystem valuation. Then we will give a few examples of valuations of particular ecosystem services before turning to the conclusion.

The complexity of the ecosystem services concept

Ecosystem services are defined as the benefits human populations derive, directly or indirectly, from ecosystem functions [11] or ‘‘the benefits people obtain from ecosystems’’ [17]. R. Costanza [21] considers that “this is a good, appropriately broad and appropriately vague definition” that allows people to communicate or, at least, to have the feeling to understand each other when analyzing the way our societies take advantages from well-functioning ecosystems. Working with not yet quite a clear definition can be a limit for developing formal analysis, but it can be useful to let a variety of research develop, especially of controversial issues such as the actual dependence of human well-being on these services or their potential substitutability, and identifying what is really at stake in decisions and policies. However, such a defense is problematic. For instance, it has been shown, e.g. for semi-natural grasslands [22], that this vagueness and some lexical ambiguity could lead to very different assessments of quality, quantity and location of ecosystem services.

This objection can be elaborated further with related arguments. The concept of ecosystem services has garnered widespread appeal partly because it has been interpreted in terms of economic production and how human wellbeing depends on services provided by human actions and organisations. From an economic perspective, considering the functioning of ecosystems in the same way as the activity of economic agents was rather a comfortable and useful representation that helped integrating this supply in standard valuation analysis. But the analysis of ES has to cope with the evidence that, on the contrary to activities of firms, the services provided by ecosystem are unintentional [23]. Instead of direct or indirect voluntary contributions of ecosystems to human well-being [24], it would be more appropriate to consider them as what human societies are obtaining or taking from ecosystems. And despite the statement of a potential for “capturing the value of ecosystem services” in real markets [25], most ES are *commons*, and the values of nature are not thoroughly visible in the functioning of advanced market economies [26]. In fact, it has been argued that ecosystem diversity may not always be a source of benefits and can constitute a dis-service. This possibility has been studied in the case of agricultural production [27] and, to a lesser extent, wetlands restoration [28].

More generally, several works have shown that focusing on services could result in not guaranteeing sufficient interest to the complexity of ecosystems [29, 30, 31] and the incomplete knowledge we have on their functioning and interdependence [32, 33, 34]. Also, since biodiversity does not necessarily identify with ecosystem services, it must be understood that enhancing human welfare and preserving biodiversity may be conflicting objectives [35, 36, 37]. Should we prioritize welfare over any other social goals? Many analysts have emphasized the large variety of reasons to protect nature [38]. Clearly, the concept of ecosystem services plays an integrative role in many papers in ecological economics and conservation sciences. But, despite evidence of the positive aspect of species richness on primary biological production [39], a larger provision of service is not necessarily associated with a wider diversity or a deeper wilderness of ecosystems, especially for provisioning services and cultural services related to recreation and tourism [40]. The extent to which we can rely solely on these services to value biodiversity remains questioned [41, 42, 43, 44, 45, and 46].

So, are we so focused on the concept of ES that we can’t see the forest for the trees? The lesson that can be drawn is certainly that ecosystem services and biodiversity are different things, thought interacting, that can be jointly preserved by appropriate human actions [47, 48]. Therefore they must be thought in terms of arbitrage, trade-off and “hard choices” [49], *i.e.* decision-making regarding ecosystem services is to some extent amenable to economic analysis.

Are payment mechanisms the sole purpose of the valuation of ecosystem services?

PES are often vaguely defined as monetary incentives offered to farmers or landowners in exchange for managing their land to provide some ecological service. There is evidence that, after empirical beginnings, related to various policy and institutional contexts, PES have become a generic term to describe a heterogeneous set of incentives to manage ecosystems [50, 51, 52, 53, 54, and 55].

PES are definitely a relevant framework for thinking the main issues related to ecosystem conservation and management and a large body of literature has been devoted to two of them : how the practical efficiency of these mechanisms relies on appropriate institutional arrangements; how PES can contribute to development and poverty alleviation. Actually, two opposing views are advocated between analysts that study primarily contracting and informational issues [56, 57, 57] and those who consider larger institutional issues and suggest alternatives analysis of what is really at stake in the implementation of PES, especially equity and poverty reduction [59, 60, 61, 62, 63, and 64], institutional or property rights issues [63, 64, 65], and sometimes more fundamental critics [68, 69, 70, and 71].

Finally, the relation between valuation and PES is not obvious. In a recent analysis of the history of ecosystem services in economic theory and practice [9], the payments for ecosystem services (PES) appear as the natural aim of economic valuation, as mechanisms that would translate non market values for the environment into real financial incentives for local agents. But, as Heal [72] puts it: "valuation is neither necessary nor sufficient for conservation. We conserve much that we do not value, and do not conserve much that we value". The devil is in the details: valuation is not necessary to establish incentives in a cost-efficiency perspective (to reach a given objective at the least cost); it would be useful to define the appropriate incentive to reach an optimal level of conservation. But this level is usually not considered as being practically knowable nor reachable, and the PES are calibrated on the base of the opportunity costs borne by the agents that hold control on the service and are to be compensated for their effort [51, 54]. The main evaluation issue associated with PES and related to institutional arrangements is eventually the need and opportunity of a systematic assessment of their scope, limitations, and practical effects [73, 74].

The classification of ecosystem services unfinished business?

Unlike the classification of firm activities which has been built for statistical purpose related to national accounts, there exists no comprehensive taxonomy of the services delivered by Nature. Several tentative typologies have provided more or less comprehensive canvas [11, 14, 17, 21, 35, 75, 76, 77, 78, and 79]. For instance the MA initiative distinguishes four core kinds of ecosystem services: provisioning, supporting, regulating, cultural. Table 1 below gives more details about this classification and a few existing others that aimed at: i) integrating ecosystems in national accounts, and ii) improving cost-benefit analysis for decision-making.

The idea to integrate environmental aspects into national accounts emerged in the 1970's as a central issue. The presentation of the economic value of ecosystem services and natural capital in an input/output (ecosystems/services) table [11] follows a comparable rationale to the formalization of national accounts. Reference to national accounts or GDP is explicit in several papers that suggest disentangling the imprecise idea of ecosystem services as an economically rooted concept of “final ecosystem service units” [76] but recognize the practical difficulty not to mix means (the processes underlying the services) and ends (the services themselves) within the classification categories [74]. A distinction would nevertheless be useful between intermediate services, final services and benefits in order to operationalize tradeoffs in natural resource management [79].

A central motive for including ecosystem services into national accounts is to build a systematic monitoring of their contribution to the wealth of nations which allows comparability with the definition of conventional goods and services found in GDP and the other national accounts. An appropriate monitoring would imply not only to measure total values (as it is usually the case with contingent valuation of non-markets goods and services), but to follow quantities and prices separately in order to “track the evolution of ES, compute indices of them, and enter them into National Income accounts, all of which are important goals” [80].

The importance of ecosystem services and natural capital of soils, though more and more recognized, remains poorly understood and informed [78]. A recent study [81] mobilizes recent scientific knowledge on soil formation, functioning and classification, and current thinking on ecosystem services to develop a framework to classify and quantify soil natural capital and ecosystem services, including cultural services, and identify human needs fulfilled by soil ecosystem services.

As a matter of fact, the System of Environmental and Economic Accounting (SEEA) is to be revised in 2012 in order to allow to better taking into account ecosystems and their diversity. Aside of the *Central Framework* completed in 2011 and adopted by the United Nations Statistical Commission in 2012, as the first international standard for environmental-economic accounting, an additional *Experimental Ecosystem Accounts* is expected to be completed before the 44th Session of the Statistical Commission in February 2013. But the concern for resilience remains unsolved: “*while the SEEA is an important advance in national accounting it remains deficient in a number of ways in regard to natural resources. The dynamic and interactive nature of ecosystems means that any linear, compartmentalized system of accounting will miss significant changes that influence human well-being. In particular, losses in resilience of critical capital stocks (through changes in underlying ecosystem variables that do not contribute directly to valued flows, and are therefore not included in the accounts) means that the accounts will not recognize that such stocks are becoming riskier, likely to collapse, and are therefore over-valued*” [82].

Integrating ecosystem services in decision-making also faces informational issues [83, 84, 85]. There is of course the hurdle of clarifying ambiguities in the definitions of key terms, such as ecosystem processes, functions and services [86]. However, those informational issues also raise somewhat distinct challenges, since the valuation must be explicitly related to the impact of the decision as described in appropriate scenarios and the list and hierarchy of the values at stake must be related to the context [87]. Making the concept of ecosystem services useful for conservation policy requires clear definition and placement into a framework so that it is usable for the societal decision-making [77].

Table 1. Different classifications for ecosystem services (from [88])

Source	Daily (1997)	MA (2005)	Boyd and Banzhaf (2007)	Wallace (2007)	Fisher et al. (2009)	UK NEA (2011)
ES definition	The conditions and processes through which natural ecosystems… sustain and fulfil human life	Benefits people obtain from ecosystems	Components of nature directly enjoyed, consumed, or used to yield human well-being	Benefits people obtain from ecosystems	Aspects of ecosystems utilised (actively or passively) to produce human well-being	The benefits people obtain from ecosystems
Classifications and ES value[a]	Production inputs Sustenance of plant and animal life Provision of existence and option values	Cultural Provisioning Regulating Supporting	Intermediate components Services Benefits	Processes Ecosystem services Benefits	Abiotic inputs Intermediate services Final services Benefits	Ecosystem process/intermediate services Final ES Goods Well-being value[b]
Economic values	Use and non-use values	Use and non-use values	Use values	Use and non-use values	Use values	Use and non-use values
Nature of the ES	Ecological and anthropogenic	Ecological and anthropogenic	Ecological functions	Ecological and anthropogenic	Ecological functions	Ecological and anthropogenic

a. The category in which economic valuation is performed under each classification is highlighted in bold.
b. UK NEA also uses the MA classification but establishes the links between processes, services and goods, which are valued.

Of course, no framework can accommodate the multiplicity of situations. "*Ecosystems are complex, dynamic, adaptive systems with non-linear feedbacks, thresholds, hysteresis effects, etc.* (…) *all ecosystem services are in fact means to the end of human well-being, ecosystem processes can also be services (they are not mutually exclusive categories), and the same services can be both intermediate and final. The real world is complex and messy and our systems of classification and definition of ecosystem services should recognize that and work with it, not ignore it in a misguided attempt to impose unrealistic order and consistency*" [21]. The conclusion is unavoidable: multiple classification systems are needed, according to the variety of situations and the diversity of decision-making perspectives. "*There are many contexts in which ecosystem services can be used and the* *context should help to determine which classification scheme is the most appropriate for decision making*." [14].

It would understandably be more appealing to build an integrated view of ES typologies and values that make both a bridge between natural capital and the diversity of the decision contexts and with national accounts, but despite undeniable progress, scientific understanding remains a limiting factor [33, 73, 89, 90] and the possibility to use the category of ecosystem service to improve resource management decision in practice is still questioned [91].

Quantification and valuation

"*What are birds worth—what is their actual dollar value to human society? To most of us in the ornithological community, birds are invaluable. But in these times we need more specific rationales to convince policy makers and business leaders to include bird conservation in land-use and development decisions*." [92] This recent statement expresses, among many others, the perception by experts from various fields of conservation science of the usefulness of quantifying and valuing ES.

Quantification and valuation are directly related since values allow the aggregation, in a broad sense, of services of heterogeneous nature. But, beyond this technical aspect, valuation raises many issues that have been clearly addressed by leading authors in the field [93]:

"*Economic, or monetary, measures of value are only one type of measure that can be useful in managing human activities. But they are particularly useful because most societies have some intuitive notion of economic value, and the sources of human impacts on natural systems are frequently economic, such as the construction of a dam or harvesting timber. They are also especially useful insofar as they can be used to provide signals to regulate human activity, as in the case of environmental taxes and adjustments to national income accounts. However, like any signal in complex systems, they can also provide false or misleading information*".

Since a large majority of ES lack market prices [72, 94, 95], valuations are *ad hoc*, motivated by policy purposes which must be explicit about whose value has to be accounted for [96]. Economic values, though numerous, diverse and sometimes complex [38], obviously do not cover all the reasons that may justify social choices and actions [97].

The Millennium Ecosystem Assessment [16] provided a simple general framework for ESV which, starting from the identification of ecosystems structures and functions, switches to the characterization of ES and results in their evaluation in terms of human well-being. This scheme has recently been clarified [37, 24] by distinguishing between "services" that describe what human societies can obtain from ecosystems in biophysical terms, "benefits", defined as positive change in well-being from the fulfillment of needs and wants, and "values" which are related to the goals and objectives of the societies (at least as they are perceived by the analyst who must also pay attention to possible substitutes that may allow the society to reach this objective).

The debate on incommensurability

Different assets are said commensurable if it is possible to align them on a common cardinal scale of value. Should the values of any asset or choice to which humans attach importance be made commensurable? This question is in fact at the root of the opposition between environmental economics and ecological economics [98, 99]; it is also the cornerstone between strong and weak conceptions of sustainability [100, 101]. When applied to the value of ecosystems, the idea is that their contribution to human well-being is multidimensional, related both to satisfaction of short view preferences and to the cognitive and emotional traits of human life [102], to physiological and mental health, or even to what constitutes the identity of the subjects [103]. More generally the complexity of ecological and social systems make valuation of ecosystems services with non-linear properties based on short term human preferences poorly reliable and their main purpose might be to identify potential catastrophes rather than to inform some fine tuning in resource allocation [104].

Some critics are even mobilizing an Hayekian perspective on markets as gathering mechanisms of dispersed and heterogeneous information, which is contrasted with the collective and centralized knowledge characteristic of science, and argues that "*the conceptual distance between market-based and science-based methods of assembling information and applying knowledge defeats efforts to determine the "value" of ecosystem services in any integrated sense*" [105].

Is monetary valuation a problem by itself? The use of money as unit is perceived, namely by ecologists [106] as puzzling, since real markets are not always very convincing of their ability to converge toward efficient equilibriums. As noted by several authors, the numeraire matters in economic analysis: since money is the most commonly used interchangeable commodity, valuation in monetary terms may send the message that a service is more easily substitutable by human manufactured providers than it actually is [100, 107]. The final words might be given by the ironic statement that monetary valuation would be "precisely incorrect" [108].

The limits of CBA when applied to ES

Cost-benefit analysis (CBA) is the general framework for the economic valuation of ES. It consists of comparing alternative policy options, including *laisser-faire*, by quantifying their impact on ecosystem services in monetary units. The net present value (NPV) resulting from the difference between positive and negative impacts (benefits and costs) of each option allows to rank them according to their contribution to social well-being [99]. If the goal of maximizing well-being is considered unreachable because the informational basis on preferences is too hard to elicit or the decision maker is unable to take into account the full range of services and their values, the analysis can focus on the cost-efficiency goal of maintaining the ecological potential [109] or any other objective such as the "no net losses" of the UN Decade on Biodiversity.

The definition of ES includes the benefits people perceive, and many that they do not. The conventional economic approach to ''benefits'' appears too restrictive, in this regard, since it tends to limit the benefits to those that people perceive and are ''willing to pay'' for. Since people's information about ecosystem services is rather limited, it can be expected that many ecosystem services will only be noticed by most when they are destroyed or degraded. The contrast here is to be made with private goods and services provided on the marketplace. We benefit from consuming those items and we are fully aware of the utility they bring to us, .even when they have not disappeared.

In recent decades, several approaches have been proposed to measure empirically the values of ES, based either on revealed or stated preferences, or on observable costs for restoration, replacement, and supply of the service or through productivity effects. The chapter 5 of the "Foundations" book of TEEB study offers an outstanding review of the existing literature published or in press up to 2009 [20]. The key messages insist on: the importance of uncertainty about ecosystems functioning and the double value of ecosystems as output providers and as insurance mechanisms (whose importance in captured in option values when they can be estimated); the limits of methods and the interest on hybridizing methods (e.g. stated preference and deliberative approaches); the influence of social, cultural and economic contexts; the practical, swift and cheap potential of benefit transfers; the importance of being realistic and honest with the limitations of valuation techniques; considering the possibility of irreversible and heavy costly changes when approaching thresholds, ecosystem management should be based on "safe-minimum-standards" and "precautionary approaches".

The year after the publication of the TEEB "foundations" book [20], one of the lead authors published with a colleague [110] a multidisciplinary critique of the use of CBA in the context of ecosystem services. They particularly stress the difficulties raised by the articulation and aggregation of individual well-beings into a measure of social well-being related by welfare economics and alternative theories of value when applied to ES; the bias that spatial and temporal frame can introduce in valuation; and explain the persistence of CBA "despite its own predicament" with four rationales: expediency, democracy, value neutrality, and the inescapability of trade-offs. They pragmatically conclude on the coming pluralistic framework for ecosystem services decision making. Temporal inconsistency, that is to say the fact that a chronicle of decisions may not remain optimal once reconsidered at a later date, is a complex issue on its own [111]. One important feature was the emphasis put, in the context of climate change, on the dynamics of relative prices as a pragmatic but sounded solution to the apparent paradox of discounting [112]: when some asset becomes endangered on a large scale one must anticipate that its price, or implicit price if there is no market for it, will increase dramatically and overcome any reasonable discount rate.

Time to deliver: some examples of ESV

Applied (and less applied) economists involved in ESV have recently attempted building analytical frameworks that overcome several critics [19]. They insist on the necessity of ESV to serve an explicit purpose (CBA, Accounting, Payment, Evaluation of action/inaction, etc.), which is not to demonstrate the importance of ES or biodiversity to society but to help decision makers facing tradeoffs, choices between competing resources and conflicting goals. ESV has to be context specific, ecosystem specific, and guided by the perception of beneficiaries. The spatial and temporal scale must be defined and clear linkages with biophysical change scenario would not only facilitate the valuation exercise but will improve its credibility for public policies. Since uncertainty is a real issue that can undermine the credibility of the results, sensitivity analysis would be appreciated by the decision makers.

In recent years, a growing body of work on the valuation of a range of ES have been published: ecosystem services in a river basin [113], services to agriculture [27] or from agriculture [114, 115], provision of productive inputs [116], protection against hurricane [117], pollination [118], services derived from forests [119, 120], the assessment of conservation policies [121], the service loss related to invasive species [122] or the ambiguous effects of restoring ecological function [28], constructed wetland [123], etc.[1]. The most impressive recent accomplishment might be the valuation of the change in the ecosystem services which should result from the whole UK Biodiversity Action Plan (UK BAP) undertaken on the initiative of the DEFRA. The valuation of such a bundle of services related to a large set of changes of heterogeneous ecosystems was made possible by combining a large public survey (a "choice experiment" that aimed at determining the values people place on these ES changes) with an innovative *Ecological Weighting Matrix* that pooled "experts' judgments and an assessment of the ecosystem services provided by a broad range of habitats" [126]. Though implemented by recognized experts of contingent valuation, this study relies on a stated preference approach that was argued to be unsuitable for extracting appropriate information from such surveys [127].

[1] We do not take in consideration in this paper other works related to the value of nature or biodiversity like the value of endangered species [124] or genetic resources [125].

Table 2: Headline results on the value of the UK BAP by ecosystem service (from [126])

Ecosystem service	Current spend scenario (£m per annum)	Additional benefits beyond current spend in the increased spend scenario (£m per annum)
Wild Food	24.86	21.20
Non food products	29.96	8.85
Climate regulation	413.31	163.69
Water regulation	429.54	168.76
Sense of Place	131.34	167.40
Charismatic species	253.68	175.17
Non-Charismatic species	83.27	41.74
Total	1365.97	746.80

Recently under the understanding that decision and policy-making generally impact large territories, the mapping of ecosystem services and values have become an intense research field. Since the first large scale studies [10, 11] the project of mapping ES values was implicit, including by using satellite imagery [128]. But linking GIS and value transfers remains a central challenge [129]. An alternative recognizes that resources for conservation are scarce and the policies have to be spatially explicit in order to improve the efficiency of each unit of expenditure. A first demonstration of the importance of these choices has been made from five ecosystem services related to Atlantic Forests in Paraguay [95][2]. Analyzing changes in the delivery of ES related to land cover and land use change was made possible by production function approaches [130, 131, 132, and 133] as integrated in the InVEST Model[3]. In recent years, integrating ESV in a spatially explicit analysis of the impacts of projects or policies has become a very active research field which raises complex issues [85, 135, 136, 137, 138, 139, 140, 141, and 142].

Despite the many controversies that have been discussed in this paper, ESV has become such an important issue that we might forget the evidence that, for centuries, social development was built on ecosystem destruction and degradation, and declines in the majority of ecosystem services assessed have been accompanied by steady gains in human well-being at the global scale [17, 143]. A recent study [144] discusses the four main explanations to this so-called “Environmentalist paradox”: critical dimensions of human well-being are not captured adequately in monitoring; only provisioning

[2] Conservation policies paid little attention to ecosystem services before 2000 [130] and apparently none to ESV before the conclusion of the *Millenium Ecosystem Assessment* [17].

[3] The *InVEST* model (Integrated Valuation of Ecosystem Services and Tradeoffs) is developed since 2009 at the Stanford University within the “Natural Capital Project”, in partnership with “the Nature Conservancy” and WWF. It builds from scenarios of land use changes and landscape management [133], as a support to decision-making [134].

services (food production) has been considered critical for human well-being; technology and social innovation have decoupled human well-being from ecosystem degradation; and there is a time lag between ecosystem service degradation and impacts to human well-being. None of these fully explains the Environmentalist paradox, but these theories, which arise from different academic disciplines, are interacting in complex dynamics. Available data show the existence of local declines in populations' well-being but no evidence of a global decline. They conclude that we have a better understanding of the human impact on ecosystems, than of the ways the evolution of ecosystems impacts human well-being, and draw a research avenue toward ES synergies and trade-offs, technology enhancing ES, and ES forecasting. These are positive contributions toward a better understanding of the condition to maintain a "safe operating space for humanity" [145].

Conclusion/Summary

In a posthumous published paper, David Pearce wondered "Do we really care about biodiversity?" [146], and responded dubiously. In a policy oriented paper related to the objectives to be reached during the 2011-2020 *Decade on Biodiversity* [147], four research directions were prioritized: *Functional diversity; Environmental uncertainty and target adjustment; Interactions between targets; Trade-offs between targets.* Ecosystem services valuation does not appear at that level of generality, but the ideas of a better understanding of the hierarchies, the uncertainties and the trade-offs are at the core of this roadmap, and valuation is implicitly the intellectual framework that underlies these issues.

The two objectives of the quantification and valuation of ecosystem services are not independent. The construction of aggregate accounts, for example at the national level, likely requires of a mapping of ecosystems and their conservation state. Specialists, while stressing the importance of accounting in physical terms, are aimed at moving to monetary values so as to link them with the national accounts. On the other hand, the integration of ecosystems and biodiversity in the economic analysis of choices or policy instruments does really matter for choice with a strong spatial dimension (development of transport infrastructure, urban expansion, agricultural policies, etc.).

The central issue in the valuation of biodiversity and ecosystem services certainly lies in the fact that, to a large extent, these services are merit goods or credence goods whose utility for growing fractions of the population, and especially urban population, does not result from direct conscious experience but from mediatized information relayed by various more or less truthful means. Since it is considered that significant parts of their total economic value are non-use values, their elicitation has to rely on stated preferences methods. And the general opinion of a lack of reliability of these methods has led scholars to seek to improve the robustness of the results by combining these techniques with deliberative approaches [148, 149, 150, 151, 152, and 153] to enable the construction of rational preferences among respondents.

The last word has to open on a rather stringent question: is ecosystem service valuation really useful? Twelve years ago Geoffrey Heal [72] wrote: "*Valuation is neither necessary nor sufficient for conservation. We conserve much that we do not value, and do not conserve much that we value*." Valuing ecosystem services and biodiversity is in no way an end by itself, but a means to improve the choices our societies and the public bodies that design and implement conservation policies make to frame our relation to nature. In recent decades many analysts, conservationists and economists, have stated that valuation was a way to enlighten the importance of well-functioning ecosystem for our societies [16, 24, and 154]. In the economists' view, ecosystem services would then be considered as "Veblen goods", i.e. goods for which individual demands increase when the prices increase, since higher price (whereas there are in most case no "market price" for ecosystem services) confers higher status. But other analysts argue instead that linking economic values to ecosystems might be interpreted as an encouragement to drop deontological principles or "moral sentiments" [155] in choices that involve their conservation, resulting in lesser precautionary attitudes (this is the so-called *crowding-out effect*). Whatever views prevail in the coming decades, the valuation of ecosystem services will likely remain a central tool for clarifying choices involving ecosystems; and it seems likely that an increasing number of hard decisions will have to be made and more importantly concrete choices to be implemented. Any tool that will help to clarify the issues and legitimize the choices will be useful and have to be upgraded.

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