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Valuing biodiversity and ecosystem services: Why put economic values on Nature?

Évaluation la biodiversité et des services écosystémiques : pourquoi mettre des valeurs économiques sur la Nature ?

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ABSTRACT

The evaluation of ecosystems and biodiversity has become an important field of investigation for economists. Although their interest has been largely motivated by the search for arguments in favour of broader conservation policies, both the methods and the meaning of the results remain controversial. This article aims at clarifying the interest and limitations of these works, by revisiting a number of issues, such as the economic qualification of the services that human societies take from biodiversity and ecological systems in general, the specificities of their contribution to human well-being and the consequences of a valuation of biodiversity based on ecosystem services. We conclude with a discussion of the purposes of evaluations: improving public policies or creating new markets?

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RÉSUMÉ

L'évaluation des écosystèmes et de la biodiversité est devenue un domaine de questionnement à part entière pour les économistes. Bien que ce développement ait été largement motivé par la recherche d'arguments en faveur de politiques de conservation plus ambitieuses, les méthodes mises en œuvre et les résultats obtenus continuent à faire l'objet de controverses. Cet article vise à préciser l'intérêt et les limites de ces travaux, en revisitant un certain nombre de questions, telles que la qualification économique des services que les sociétés humaines se procurent auprès de la Nature, les spécificités de leur contribution au bien-être humain, les conséquences d'une évaluation de la biodiversité à partir des services écosystémiques. On conclut par une discussion des finalités de ces évaluations : amélioration des politiques publiques ou création de nouveaux marchés ?

1. Introduction

Earth ecosystems provide a variety of services to human societies [1]. For several thousand years, they have been modified and managed to satisfy human needs and desires. This long history does not imply that ecosystem services can or have to be economically valued. Indeed the quantification and economic valuation of economic services remain controversial [2]. Nevertheless, the exploitation and management of natural systems implies investigating trade-offs between actual and potential

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services, and effects of human activity upon ecosystem resiliency. More generally, innumerable choices made every day by billion people impact ecosystems and many will result in biodiversity losses and, to various extents, in social costs.

The concepts and methods to value ecosystems and biodiversity have progressively emerged with roots in the core of economic theory of value [3,4]. The recent enthusiasm for such analyses appears to have been mostly initiated by the needs of conservationists of strong reasons for policies aiming at protecting biodiversity broader and more rooted than the current ones [5]. The current situation can then be characterized by a worrying gap between the perceived importance of improving our understanding of the dependence of ours economies and societies upon the maintenance of well functioning ecosystems [1,5–8] and the theoretical and practical unresolved difficulties to build consistent and reliable analysis of this dependency.

This article proposes an overview of the economic approach of ecosystem and biodiversity valuation with personal views on a few issues. Section 2 attempts at clarifying some conceptual issues raised by valuation studies. Section 3 discusses methods for approximating the value of biodiversity and nature services. Section 4 analyses the significance of the results obtained by a few large-scale studies. I conclude with a discussion of the purpose of these evaluations, mobilized both to inform public policies and to discuss the introduction of market mechanisms.

2. Practical and conceptual issues

Most economists involved in the biodiversity valuation debate entered this area, sometimes reluctantly, after they have been invited to do so by conservationists who hoped to find in economic analysis strong advocacy to stop biodiversity losses. Many economists were cautious because they knew how poorly equipped they were to build convincing and reliable arguments [9–11].

2.1. Why is biodiversity so important to human societies?

The biodiversity concern has become so pervasive in our societies that one hardly needs to recall the diversity of reasons calling for more ambitious conservation policies and a better management of biodiversity.

2.1.1. Evidence

First, biodiversity, including functions of ecosystems, offers a large variety of goods and services that support human life: provision of food; fuel and construction materials; purification of air and water; stabilization and moderation of global climate; moderation of floods, droughts, extreme temperatures and wind forces; generation and renewal of soil fertility; maintenance of genetic resources that contribute to the variety of crops and animal breeding, medicine and other products; recreational, aesthetic and cultural benefits [1].

Apart from these actual benefits and despite possible ambiguous effects [12], biodiversity plays a significant role as an insurance in a changing world, especially for the most vulnerable human populations whose well-being depend often more directly upon productive ecosystems [13]. On a global scale, biodiversity must be considered in connection with major issues such as poverty reduction [14], food security and fresh water availability, economic development, conflicts over the use and ownership of resources [15], human, animal and plant health, energy and climate change.

There is massive evidence and consensus on two main points. First, two centuries after the so-called industrial revolution and despite major changes in agriculture, manufacturing, mining, transportation, and technology, human societies remain strongly dependent on well functioning ecosystem for life support, production inputs or amenities [6,16]. Second, human activities threaten ecosystems and biodiversity to an unprecedented level [1,17].

2.1.2. Freedom of choice

The Millennium Ecosystem Assessment synthesis report [1] highlighted the links between ecosystem services and the elements that contribute to human well-being. MEA proposed a scheme organising constituents of well-being (security, basic material of good life, health, and good social relations) plus a "background" category: the freedom of choice and action, defined as the "opportunity to be able to achieve what an individual values doing and being".

The clearest lesson form the MEA scheme is the existence of a symmetry between supporting functions, which make possible the ecosystem services to human societies, and the freedom of choice that render human being able to draw benefits from this services. Clearly, without the freedom of choice, the question of the value of ecosystem services remains meaningless. The nature of economic value implies, at least implicitly, the existence of an alternative choice.

2.2. The value of nature and the nature of economic value

Values are norms that allow judging, individually or collectively, if something is good, beautiful, true, useful, moral, etc. Value can be analysed in many ways, from objectivist approaches that tend to establish a universal hierarchy among things, to subjectivist ones that relate the value of an object to its relative desirability. The economic conception of value is often summarized in the idea that economics values things according to their utility and scarcity. Several points have nevertheless to be made explicit here.

2.2.1. The nature of economic values

The economic perspective is purely anthropocentric. This statement does not mean that economic analysis only considers human direct interests. It means that only the effects on human psychology and well-being will be part of the economic analysis.

Economic values are consequentialist. Economic value of choices and actions is not judged according to deontological principles, but only to their consequences on human well-being. Intrinsic values have no economic meaning. This is why economic valuation is said instrumental and in most cases utilitarist. Any more sophisticated reason to conserve biodiversity must be considered through the filter of human preferences.

Despite recurrent attempts to establish the foundations of an objective approach of value, subjective approaches are now widely prevalent, i.e. economic valuation explicitly refers to individuals' preferences [18]. This creates a problem when there is no clear awareness of benefits [3,19]. For instance, humans, especially in developed economies, often consider that food production processes are no longer dependent upon ecosystem functioning. An immediate consequence is that it cannot be expected that they spontaneously value biodiversity very high.

Finally, the standard approach of value is marginalist [11,20,21]. Valuation does not aim at providing absolute measures. It relies on so-called marginal rates of substitution to determine how much of an increase in B can compensate the utility loss due to the reduction of one unit of good A. As most economic analyses rely on ordinal rather than cardinal approaches of utility, valuation aims more at comparing situations than measuring total welfare.

The latter characteristic immediately raises the question of the universality of valuation: Are all things comparable? The idea that every good or service can be substituted to any other one is certainly not spontaneously easy to accept and certainly deserves discussion. Indeed "substitution" may mean replacing the object, substituting the service, maintaining the well-being. The difficulty in replacing technically some goods does not necessarily mean that their derived benefits cannot be compensated in terms of well-being by some other elements.

2.2.2. Biodiversity as a commodity?

From the perspective of an economist, biodiversity is of interest for two main reasons. First, biodiversity is valuable to the society: the greater the biodiversity, the better we are, and if we lose some biodiversity, we judge ourselves to be in a worse shape [16]. Second, choices by society have impacts on biodiversity. Indeed many choices, even incidental, have adversely impacted biodiversity. Clearing land or draining wetlands for agriculture or development, harvesting timber from primary forests, overfishing, for example, have caused huge biodiversity losses. These statements led the economist to consider that biodiversity is a scarce and valuable resource, and can thus to some extent be looked at as a commodity: biodiversity provides or enhances ecosystem productivity, insurance, knowledge, and ecosystem services [22]. Can biodiversity, however, be regarded as an economic good?

Biological diversity is a characteristic of ecological systems (populations, ecosystems, landscapes), which only partly satisfy the properties of rivalry and excludability that describe standard economic goods. The benefits that somebody receives from the pharmacological interest of a natural molecule or from the beauty of a landscape, as far as there are not too many people, are not reduced if another agent receives the same benefit. It would be difficult to deny access to a service, such as the regulation of pollution or local climate that certain ecosystems produce, of which humans benefit even when they have no direct interaction with these ecosystems. Biodiversity appears therefore as having some properties of a public good. But most uses, whether they involve takings or are related to aesthetic and scenery, can suffer of congestion or excessive demand can create rivalry. The most appropriated economic qualification thus appears to be that of common property resources, which generally are not efficiently produced or maintained solely through market mechanisms [23].

As a characteristic of ecosystems, which enhances their social value, biodiversity thus appears both as a local and a global common. As the conservation of biodiversity provides benefits at different organisation levels, a well-designed management framework should articulate local and global public benefits [24]. More generally, Ostrom [25] argues in favour of a polycentric governance of biodiversity based on the "law of requisite variety", which states that any regulative system needs as much variety in the actions as there is in the system to be regulated. However, at each level, there must be a narrow enough congruence between the effective management rights and the awareness of the social values at stake.

2.3. Biodiversity, values, and public policies

2.3.1. Is Nature substitutable?

Since ecosystems and biodiversity appears as valuable resource, economists logical aim is measuring a Total Economic Value (TEV). The TEV is typically defined as the integration of direct and indirect use values, option values and non-use values in a common framework [26] or, more fundamentally, as the sum of use and non-use values.

The various use values, albeit sometimes difficult to identify in practice, do not really raise conceptual issues today. Social debates may nevertheless concern the social distribution of these values [27]. Although of importance to decision making, this issue is not specific to biodiversity as it is a general critic of "utilitarism", only referring to the sum of the interests, not to their distribution.

The case of non-use values is quite different, and is still the subject of controversies concerning their economic meaning or nature. An alternative might lie in a dualist view of the individual [28], both as a consumer who seeks the satisfaction of his preferences and as a citizen who makes judgements on objectives that may exceed his own interests. Within these interests "for others", Sen [28] distinguishes "sympathy" reflected by the existence of altruistic arguments in the utility function, and "commitment" expressing ethical principles which may make the individual approve changes that reduce his utility.

The relation to Nature is particular since it appears impossible to avoid it: human beings are the product of their co-evolution with other living beings, irrespective of the progress in human autonomy, human life and survival remain dependent on ecosystem functioning. Some authors [29–31] explored the hypothesis that there is a critical level below which a decrease in "natural capital" could no longer be replaced by human activity, but instead resulted in a decrease in its effectiveness. If such a threshold exists, then, as suggested by D. Pearce [32], the economic analysis of biodiversity is relevant only insofar as this limit is not reached. When an option may lead to reach it, the question of substituting Nature or even nature's services raise issues on our scientific understanding of our biophysical dependence [33] and fundamental ethical issues [34].

2.3.2. Biodiversity as merit goods?

Turner et al. [21] provides a comprehensive framework on the foundation of the value of nature that goes far beyond the usual economic categories and the sole interests of human beings. They distinguish anthropocentric values and non-anthropocentric values, the latter being related to the interests that biological diversity presents for other species and the ecosystems themselves. Is the utility for human beings the only or even the main reason for preserving biodiversity? Answering this question would go far beyond the scope of this article.

One can first oppose situations in which human point of view remains of interest and those in which relying on human judgement is not acceptable [34,35]. In the first case, one has to define deontological principles making practical choices possible and avoid too many dilemmas [11,35]. In other cases it seems necessary to consider more general ethical frameworks that go beyond the sole human interests, such as the moral right to existence of any life form [34].

Economic analysis is not easy when the preferences of individuals cannot be used for decision making. There are strong arguments telling us that, when it comes to choices involving biodiversity, individuals' preferences are not adequate for efficient decision making. The complex biophysical relations and regulation that drives biodiversity and associated ecological functions are poorly taken into account in the preferences of economic agents or political citizens. This inaccuracy, which should decrease as people becomes increasingly aware of these questions, leads us to pay special attention to the notion of "merit goods" [36], which are goods for which an evaluation resulting from the agents' preferences cannot be used directly for collective choices. Merit goods, for which agents are not able to express reasoned preferences, are sometimes related to public goods, for which the problem is not that preferences are biased but that there is no incentive to translate preferences into behaviour ("free riding" issue). The two categories often overlap [37] and this is the case for biodiversity. The agents' relationship with the public authority can therefore be considered to be a delegation of choice. Concrete public decisions often rely on expert knowledge and in the best case on the benevolence of the policy makers. As a matter of fact, the expertise process related to biodiversity is mostly managed through specialised NGO. Then, the appropriate choice, e.g. for biodiversity the level of protection or conservation, implies the intervention of an authority.

In face of this difficulty, constructing a measurement of the goods to be produced or preserved commensurate with the other economic goods could be a useful step. Doing so nevertheless remains a challenge both to economic valuation methods that unavoidably depend on observable costs or behaviours and to the choice of the objects that will materialize biological diversity for the purpose of evaluation.

3. Material and methods

Although facing severe conceptual issues, the valuation of biodiversity has become a widely developed area of research, and we have to come back to the methods and techniques that economists have build in attempts to circumvent these obstacles.

3.1. On the valuation techniques

During the last decades, a large scientific and administrative literature has repeatedly reviewed the available methods to produce practical measurements of ecosystem services values [38]. First, the "total economic value" approach does not pretend at estimating an absolute value of ecosystems, but rather to allow adding the multiple economic reasons [5] that underlie the social values associated with ecosystems. The valuation and the comparison inherent in it must be built from observations. What is observable? Ultimately, it is the individuals' preferences that must be made observable, which may involve helping individuals to build them.

3.1.1. What is observable?

Indeed, valuation methods have to deal with empirical data. Following textbooks, these techniques can be reviewed according to the nature of the data used: effective technical costs, observable behaviours and choices, statements when confronted to questionnaires. These data have then to be treated in order to obtain price-equivalents, under the assumption that individuals' preferences, which are admittedly the foundation of economic value, are adequately summarized in willingness to pay or to accept compensations.

In Table 1 valuation techniques are ranked by rows according to the type of observation and by columns according to the method for expressing preferences.

The valuation of the benefits of biodiversity conservation raises two main problems. First, as discussed about biodiversity as a merit good, many people are poorly informed about the meaning and issues related to biodiversity. Using stated preferences techniques is thus made difficult. Hanley et al. [9] found that willingness to pay for biodiversity protection increases with the level of information provided. Second, individuals' preferences for biodiversity protection may be lexicographic rather than "utilitarist". Preferences are said "lexicographic" when individuals do not consider the possibility of compensating the loss of biodiversity through an increase in the availability of another good or service. As in a dictionary, the value of the first item is what it is, and cannot be changed by varying the following. If this were true for many individuals, the cost-benefit analysis would become invalidated as a guide for decision making. Despite evidence that below a certain limit (unfortunately difficult to determine) [30,31] ecosystem services become less substitutable, multiple observations [35] tend to show that

Table 1
Valuation methods for non-market goods and services (adapted from [39]).

	Revealed preferences	Stated preferences
Direct methods	Monetary valuation at market prices Avoided costs, productivity effects Costs of restoration, replacement	Contingent valuations
Indirect methods	Prevention or protection expenditures Travel costs Hedonistic prices	Contingent ranking Comparison by pairs Joint analysis: choice experiment, choice modelling

individuals have the ability to make trade-offs between biodiversity and other assets when faced with situations of choice.

3.1.2. Stated preferences: helping individuals to build their preferences

When individuals are faced with complex choices, the assumption of pre-existing stable preferences may be unrealistic. The *discovered preference hypothesis* [41] considers that preferences pre-exist and need to be uncovered through a process involving practice, repetition and experience. This process will result in stable preferences that are consistent with economists' standard beliefs. On the other hand, the *constructed preference hypothesis* assumes that preferences do not pre-exist but rather are created at the moment of choice [42]. This theory predicts that preferences will be malleable to the choice environment. It is more and more considered that market behaviour does not reveal underlying *true* preferences but rather *context-dependent* preferences. The growing evidence of a design effect in stated preference methods is consistent with this theoretical framework.

There is, indeed, a long lasting debate on the reliability and the robustness of the results. Since these techniques are not based on observable facts but on hypothetical scenarios, many questions arise, such as those on bias related to the design of questionnaires in stated preferences methods [43].

In the last decade, growing interest has gone to procedures that could help individuals construct reasoned preferences, namely through collective and deliberative process [44–46]. As long as the stated preferences remain the most elaborated methods to address the social value of ecosystem, any methodological evolution that may lead to improve these approaches, and especially to help individuals to build consistent preferences, has to be studied seriously.

The elicitation format is at stake also. After the *NOAA Panel* identified [47] the dichotomous choice as the only methodologically acceptable elicitation format for contingent valuation, this technique appeared limiting since it implied large sample sizes and appeared poorly able to handle scenario involving multi-dimensional changes. For these two reasons, valuation analysts have been increasingly interested in choice modelling [48]. Moreover, choice modelling studies appeared to show a better sensitivity to scope since they give larger values than contingent valuation for the overall bundle and smaller values for individual components [49]. More generally, it is widely acknowledged that stated preference methods results are design-dependent, especially when related to non-use values.

3.2. On which basis can biodiversity be valued?

Biodiversity is not an object, but a characteristic of sets of objects, such as ecosystems at various scales. The question of what can be valued is then not trivial and the literature brings many different answers, from theoretical approaches to more observable objects. Since the Millennium Ecosystem Assessment [1], valuing biodiversity from ecosystem services has become a kind of standard approach [4,39,50], but several points remain questionable.

3.2.1. Theoretical objects

Since markets and even human preferences can be inadequate for decision making, there is a need for alternative information. Biodiversity indices, build by scientists to compare situations, appears inappropriate for social management. Nevertheless, many analyses, considering the absence of relevant information on individual preferences and collective interests, are trying to derive usable indexes [51].

Weitzman [52] proposed to value biodiversity from a measure of dissimilarity between taxonomic units such as species that can be extended to a broader set. Later [53], he builds on this index a cost-effective approach useful for ranking alternatives. This ranking criterion has been applied [54] to assess the cost-efficiency of the public expenditures related to the Endangered Species Act. The authors created proxies for the main variables and found that the most suitable dependent variable was the expenses for each action and the most significant explanatory variable was the size of the species which also is indeed a strong determinant of their demographic sensitivity [Lebreton, this volume]. Even if calculating the index requires impractical amounts of information, the conceptual model can nevertheless be applied to ecosystem functions [55]. Empirical measures of the value of biodiversity and ecosystems are in fact based on real world objects [56], sufficiently diverse, to be chosen in relation with the purpose of evaluation.

3.2.2. Empirical objects

Because ecosystem and biodiversity assessment implied collaboration between scientific disciplines sharing the same empirical objects, or simply because many studies were initiated by social demand or aimed at policy-making, a large body of the scientific literature on biodiversity valuation focuses on biophysical objects. These objects generally chosen to represent one aspect of biodiversity can be very diverse and were: species [57,58]; genes [59,60], ecosystems and habitats [7,61], ecological functions [62,63]; landscapes [64–66].

Whatever the object submitted to valuation, such a valuation is related to changes in well-being associated with changes in the characteristics of these objects, especially their availability as a source of goods and services. This is certainly why since early publications [67], the notion of services has been more and more widely used to introduce the beneficial uses of ecosystems in the utilitarian framework.

3.2.3. Ecosystems services

Ecosystem services are usually defined as the benefits people obtain from ecosystems [Lamarque et al., this volume]. These include provisioning services, such as food, clean water or raw material; regulating services, such as regulation of floods, drought, and in some cases disease; cultural services, such as recreational, spiritual, and other nonmaterial benefits; and supporting services, such as soil formation and nutrient cycling [1]. The same reports emphasised the serious degradation currently experienced by ecosystems in regard to their capability of providing services and the parallel rapid increase in the demand for ecosystem services as populations and standards of living increase. A link with valuation was explicitly made: if ecosystem services were becoming increasingly scarce, it was "*partially due to the lack of valuation because it is impossible to manage what we do not value*" [1], a somewhat self-serving assertion.

However, the concept of ecosystem services has a long history that initiated, after Mooney and Ehrlich [68], with the 1970 Study of Critical Environmental Problems [69], which first used the term '*environmental services*'. Westman [66] was among the first to explicitly refer to the value of '*nature's services*', and finally Ehrlich and others used the term 'ecosystem services' in the early 1980s [67].

Considering the relationship of ecosystem to societies as "services" has become a meaningful qualification, clearly inspired from the services produced by humans. Comparing the issues related to maintaining ecosystems with other dynamics related to human activities might indeed be a dangerous exercise, as focusing on the sole final services that benefit humans can obscure the complexity of ecosystems functioning [70]. Moreover, a major difference between social and ecosystem services lies in intentionality. Unlike human productions and business, ecosystems do not aim at fitting human needs. This is the responsibility of human societies to adapt their organization to ecosystem functioning. And this ability determines to a large extend the social value of "ecosystem services".

3.2.4. Quantification and valuation of ecosystem services

Ecosystem services are the conditions and processes through which natural ecosystems and their biological constituents allow and sustain human life. There are thus many reasons to consider that ecosystems have both utilitarian and intrinsic values. The limited substitutability of Nature induces difficult challenges for any valuation attempt and the quantification of ecosystem services, which are the subject of a continuing debate.

The monetary valuation was probably the main cornerstone that led in the 1980s [4] to cleave the economic approach of society-nature interactions between:

- environmental economists that favour an extension of monetary valuation techniques to non-market natural assets;
- ecological economists that addressed the substitutability of natural capital and preference-based valuation as controversial issues.

This contrast echoes the opposition between the weak and strong conceptions of sustainability [31]. The former assumes a large substitutability that allows a monetary valuation of non-market natural assets, while the latter focuses on the importance of preserving a "critical natural capital" that nevertheless remains difficult to measure [30]. This enduring opposition is known as the "incommensurability debate" [40] and is often considered as the single most controversial issue in Cost-Benefit Analysis (CBA in what follows). Indeed, if no substitution is possible, the very principle of economic valuation fails and the meaning of any valuation no longer holds, except on the basis of the subjective judgments of the subjects involved.

3.3. Ecosystems and human well-being

The abundance or the quality of natural resources does not constitute a guarantee of improved well-being. This paradox constitutes the "resource curse", i.e. the paradox that natural resource-rich countries tend to have lower economic growth and development than less well endowed countries [71,72]. The contribution of ecosystems and biodiversity to human well-being is therefore contingent on the ability of societies to value services. The link between ecosystems and human well-being therefore depends on the potential services that societies know how to obtain from ecosystems, but also on their capability to do without, and to rely on alternative resources (including human creativity).

This complex relation can be represented in three steps:

- identification of ecosystem ecological functions;
- description of the beneficial uses that societies get from these ecosystems;
- analysis of the economic value of these services, according to available alternatives.

In recent publications [50,73] the concept of beneficial use is split between a biophysical description of the service and, secondly, an analysis of how that service benefits to humans. This benefit is finally valued in economic terms (Fig. 1).

An important point here is to understand that there is no simple link or proportionality between the biophysical phenomenon and the social value. Between these two

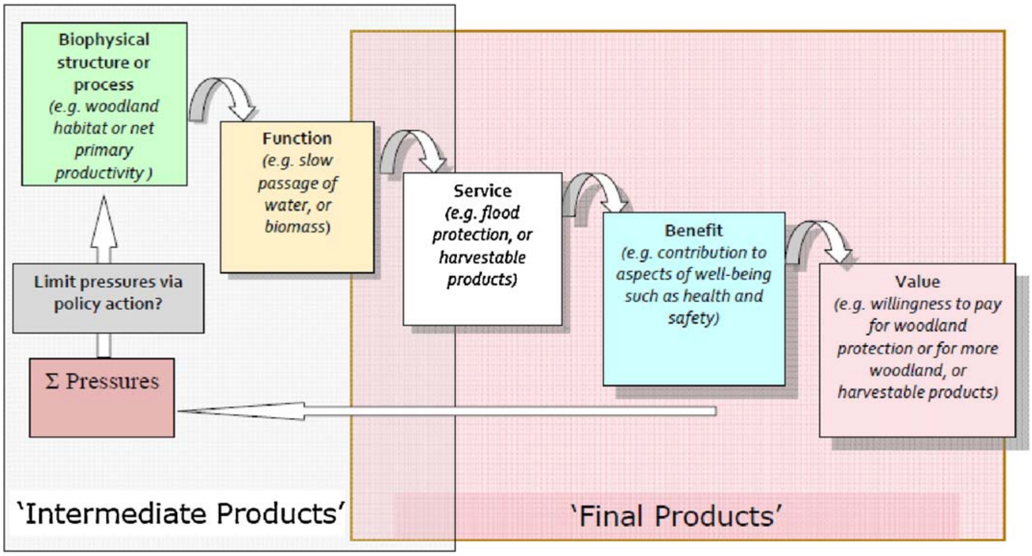

Fig. 1. From ecosystem structure and function to ecosystem services, benefit and value (after [73]).

levels of observation, and analysis, several parameters strongly influence the final results, among which: available technologies, cultural preferences and, as emphasized above, freedom of choice, which determines in fact the final well-being that humans will be able, or not, to draw from the actual ecosystems.

4. Results

Applying CBA to biodiversity issues raises thus so many conceptual and technical difficulties that despite early calls [26,66,74,75] it mostly developed in the last two decades. Many voices have spoken indeed against the possibility or the legitimacy of doing so [9,76,77], or tried to identify the meaningful achievable analysis from less credible attempts [10].

It is not possible to review here the results obtained by the hundreds of studies that have evaluated one or another aspect of biodiversity. This section is thus organized into three selected topics: the economics of endangered species, the valuation of ecosystem services and, finally, a brief discussion of the distinction between general and remarkable or unique biodiversity. We conclude by critically discussing the assimilation of the value of biodiversity with that of ecosystem services.

4.1. The economics of endangered species

There is a large body of studies on the value of species. A large part results from the U.S. Endangered Species Act, in 1973, which led to a budgetary rationalisation point of view [54,78]. The contingent evaluation method is well suited to the evaluation of willingness-to-pay (WTP) for the conservation of endangered species, especially for emblematic species. Constraints on format tend to bias the publications towards methodological issues rather than detailed results. Thus, the results are generally presented in the form of an econometric regression whose explained variable is a household's WTP (usually yearly). The concerned population, which has to be determined in order to calculate the social WTP, to be compared with the policy objective (to preserve the species in the world, the area, or a given specific surface), is, in most cases, not even mentioned.

Most studies concern emblematic species. This qualification does not only relate to ecological characteristics but also integrates the sociocultural context. It may thus vary in space and time. A god illustration is the change in status of predators such as the lynx, the bear or the wolf, formerly driven out, and today "made into heritage", not entirely because of their rarity, already ancient. Limiting our interest to modern times and the Western cultural context, we gathered in Table 2 studies related to threatened vertebrate populations, for which the WTP per household and per year was estimated for various protection measures.

A multiple regression model applied to these data [57] leads to the following figures for willingness to pay: a baseline 11 dollars per year for residents, to which one adds 47 dollars for a mammal species, 33 dollars for a bird, 23 dollars if the person is a visitor rather than a resident, and 42 dollars if a single payment is proposed (which correspond to a reduction in the total value). One should note the proximity paradox according to which residents value heritage assets less than visitors. This model resulted in a willingness to pay which, if extended to all American households, would amount to devoting 1% GDP to protect 2% of the threatened species, which was considered [77] excessive.

In an updated meta-analysis [58] recent studies obtain in general higher willingnesses-to-pay, with the following significant explanatory variables: change in size of the populations, type of species, whether it belongs to the "emblematic megafauna" or not, existence of non-use values; and, also, the year of the study, the type of subject questioned, the survey method, the rate of answers, and

Table 2
Willingness to pay for diverse charismatic vertebrate species (average values in current dollars per household and per year).

Group	Species	Place	WTP ($)	Reference
Mammals	Wolf	Sweden	126	[57]
	Grizzly bear	USA	46	Id
	Sea otter	USA	29	Id
	Grey whale	USA	26	Id
	Bighorn Sheep	USA	21	Id
	Caribou	Canada	14–98	[79]
Birds	Northern spotted owl	USA	70	[57]
	Whooping cranes	USA	35	Id
	Red cockaded woodpecker	USA	13	Id
	Bald eagles	USA	24	Id
Reptiles	Sea turtle	USA	13	[57]
Fishes	Pacific salmon	USA	63	[57]
	Cutthroat trout	USA	13	Id
	Atlantic salmon	USA	8	Id
	Squawfish	USA	8	Id
	Stripped shiner	USA	6	Id

the frequency of the payments are also significant variables.

The importance of variables related to design and sampling clearly shows that methodological refinements do not solve all problems with stated preferences methods. In addition, Such approaches often induce a disproportion or even disconnection between the territory to be protected, often small for endangered species, and the size and location of the human population considered as likely to pay, because of the emblematic character of these species and the importance of their option value or non-use value.

The many available studies, often achieved in a cost-benefit analysis perspective (as required for the ESA), do not necessarily bring information that can be used for decision unless there are explicitly aimed at valuing action programs [39,56]. The same comment applies to the fewer studies related to genes or even habitats.

4.2. The economics of ecosystem services

The concept of ecosystem services has received an increasing attention as a way of communicating about the societal dependence on ecological life support systems [6]. A set of studies framed the beneficial use of ecosystems functions as services with the aim of increasing public awareness and policy makers interests in biodiversity conservation [4].

"Ecosystem services", first often examined in ad hoc lists, refer to a set of benefits that are now considered to fall into three distinct economic categories [80]: (i) "goods" (products obtained from ecosystems for direct consumption or as inputs for industry, such as resource harvests, and genetic material); (ii) "services" (recreational and tourism benefits or certain ecological regulatory functions, such as water purification, climate or pollution regulation, erosion control); and (iii) cultural benefits (scientific knowledge, spiritual and religious feelings, heritage...). In a general framework proposed to evaluate the world's ecosystems [7], estimates for 17 categories of services, covering all terrestrial and marine environments, were proposed. The value of coastal environments (including estuaries, coastal wetlands, plant communities and algae fields, coral reefs and continental shelves) represents 43% of the total, even though they only cover 6.3% of the surface of the globe. This weight seems to be related to the role that these environments play in the regulation of nutrient cycles, both terrestrial and marine, whose valuation in monetary units seems however to be particularly tricky.

The total value of services rendered annually was estimated between one and three times the value of the world gross product, for a large part to coastal and littoral ecosystems. Among the many critics this work received, one questioned the meaning of an asset monetary value higher than the global wealth, a result that assumed implicitly a conception of the wealth going far beyond monetary income.

Extending this framework [7] to 23 functions (regulation, habitat, goods and services, information) De Groot et al. [81] gives the value ranges for all the world ecosystems. Their figures range from a few dollars to often several thousand dollars per hectare and per year. This degree of variation results not only from differences in the quality of ecosystems and intensity of their uses, but also in the evaluation method, as different techniques do not capture the same attributes.

The *Millennium Ecosystem Assessment* [1] established of a consensual framework for documenting, analysing, and understanding social-ecological systems, which has had wide influence in the policy and scientific communities. Twenty-two ecosystem services are organized in four major categories: provisioning services, regulating services, cultural services and so-called support services, namely interactions within and between ecosystems that do not directly contribute to human well-being but make the other services possible.

Although it has become a reference, this classification remains a subject of discussion [23,82–84]. The main concerns are: the mixed public goods character (public-private); the difficulties in understanding the spatial and temporal dynamics, the inability to separate some services produced simultaneously by a same ecosystem; the complexity of the interactions between structures, functions and services; the fact that the agents only identify as services those from which they benefit [82].

More recently *The Economics of Ecosystems and Biodiversity* (TEEB) [50] proposed a typology of 22 ecosystem services, defined as "the direct and indirect contributions of ecosystems to human well-being". Relatively to the MEA framework [1], it takes apart services and benefits in order to explicitly identify services providing multiple and indirect benefits. It omits supporting services such as nutrient cycling and food chain dynamics, seen as ecological processes. A "habitat" service has been identified as a separate category to emphasise the importance of ecosystems in providing habitat for migratory species (nursery service) and gene-pool (namely for commercial species).

TEEB puts a clear emphasis on the importance of:

- using ecosystem services to link biophysical aspects of ecosystems with human benefits for assessing the trade-offs (ecological, socio-cultural, economic and monetary) involved in the loss of ecosystems and biodiversity;
- making ecosystem assessment spatially and temporally explicit at scales meaningful for policy-making since both ecological functioning and economic values depend on context, space and time;
- using several contrasting scenarios as both the values of ecosystem services and the costs of actions are best measured as a function of changes among alternative options;
- including all ecosystem services provided by different conversion and management options; staying aware of the cost side of the equation, as an exclusive focus on benefits ignores important societal costs such as missed opportunities;
- integrating an analysis of risks and uncertainties, acknowledging the limitations of knowledge on the impacts of human actions on ecosystems and their services and on their importance to human well-being.

Apart from the last recommendation, that sacrifice to the ideology of transparency, but may be difficult to meet, these recommendations appear of real interest when faced to the existing studies. In a pure economist's perspective, the determination of the biophysical basis of the services is not generally required. But it is here of importance, once acknowledged that some of the services might be poorly perceived or understood by individuals. The integration of the biophysical basis plays as a safety belt against the risk of too short a checklist.

4.3. General and unique biodiversities

In conservation policies, the distinction between general and unique biodiversity is widely used to legitimate specific protection measures for unique or extraordinary elements of biodiversity and ecosystems. This distinction is not independent of human judgement: what is exceptional nature? Beautiful landscape, endangered species, remnants of disappearing ecosystems?

In a large meta-analysis of wetland valuation [85], the mean value of a "biodiversity" characteristic was more than one thousand times its median (US $ 17,000 versus 15 per ha and per year). The simplest explanation is that some results concerned exceptional ecosystems with unique biological diversity and were then highly valued by individuals, compared to most other sites.

Valuing unique assets is always difficult, in particular when the asset is considered a heritage. The analyst is then faced with a series of additional challenges: how to consider substitutability, how to handle the social-ecological dynamics of the asset, which confidence give to the non-use values?

The economic concept of substitutability goes far beyond the technical notion of replacing an object by an equivalent object, if not in the form, at least in its function. This approach would not in fact be satisfactory for unique assets (which object could replace the Mona Lisa if destroyed?). The economic substitution must be understood as a possibility of compensation in terms of final services, or even of well-being. The destruction of the Mona Lisa would be a great misfortune, but it seems unlikely that it would cause great changes to the world. For each of us, even this great loss would probably be compensated in one way or another. It would be quite different if we were talking of the destruction of all existing artwork. In that case, the world as we know it would be radically and permanently changed, and there is probably no way to evaluate this change.

Damage to ecosystem potentially implies repair mechanisms that take time. As a consequence, ecosystem dynamics is a central issue for linking social issues and biodiversity conservation. In economic valuations, time is usually taken into account through "discounting", which allows effects occurring at different times in the future to be compared to current expanses by multiplying each future, say, euro by a discount factor to convert it into a common currency of equivalent present euro. The discounting is then generally built like a simple composite interest calculus, based on an annual discount rate. The choice of the discount rate is of particular importance for long-term projects as, and then, even tiny changes in the discount rate can drastically modify the results of the valuation. These questions have become especially acute in the economics of climate change, but ecosystems and biodiversity might raise similar crucial questions. In a few words ([39] for an extensive presentation):

- there are strong arguments in favour of a lower discounting rate for natural assets than for manufactured goods by at least 1%, due to different evolution of their anticipated future prices;
- the uniqueness of these assets creates option values that must be added to their preservation value;
- if these assets are seen as irreplaceable (a matter of judgement) then they should be evaluated as exhaustible resources (the so-called "Hotelling rule" applies).

Evaluating unique assets gives logically a larger weight to non-use values than to more common ecosystems or habitats. However, non-use values raise many problems, both conceptual (are they economic values?) and methodological (how to get reliable information on their "importance", how to define the population concerned; etc.). Evaluations of unique biodiversity assets will seldom produce robust results. Stated preferences methods provide results, but many analysts would agree that such results must be replaced in a deliberative framework that allows all stakeholders to express their views.

In a recent French report aimed at producing "reference values" for public socio-economic assessment of the impact of human activities on ecosystems [39], the latter considerations indeed led to skip the case of "remarkable" biodiversity; "reference values" for unique assets were in fact considered as a contradiction.

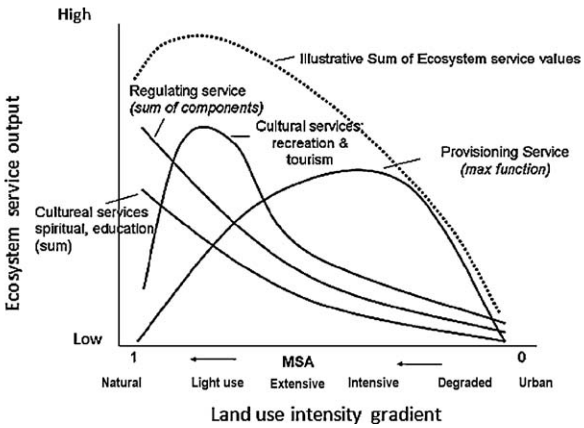

Fig. 2. A general perspective on ecosystem services and human transformation of nature (from [8]).

4.4. Valuing ecosystem services or biological diversity

Recently, Norgaard [86] expressed his concern that assimilating the diversity of the living world to a provider of services, although an "eye-opening metaphor", may hide the complexity of the ecological processes that render these services available to human beings. This concern encompasses several of the above remarks: intrinsic vs. utilitarian values, bias related to incomplete information and understanding of ecosystem functioning, etc. But this concern may also reflect actual differences between the biodiversity and ecosystem services. This separation is self-evident in certain meta-analysis [85] in which the "biodiversity" appears as a particular argument among other ecosystem services.

Although it is repeatedly stated that diversity is a characteristic of ecosystems that increases their ability to provide services, this assertion is true only in general, and in each case, the precise relationship between biodiversity and ecosystem services must be analyzed. In some cases, such as certain human diseases whose prevalence is reinforced by the proximity of ecosystems such as forests or wetlands, an increase in diversity can result in a degradation of services. Productive activities in artificialized environments such as agriculture [86], forestry or aquaculture, although inducing massive losses of diversity, must continually find equilibria that involve a minimum level of control against weeds, pests, etc. More generally, it must be accepted that the dependence of ecosystem services upon biodiversity widely varies with the nature of the service.

Fig. 2 shows that if the regulating services are fairly systematically promoted by diversity, provision services instead pass through a maximum when diversity is managed appropriately [8]. The case of cultural services has led these authors to distinguish between scientific and spiritual services that are maximal in wild nature, and recreation or tourism which benefit from certain facilities.

5. Discussion

"The total value of biodiversity is infinite so having a debate about what is the total value of nature is actually pointless because we can't exist without it." (Robert Scholes, ecologist).

The legitimacy of evaluating biodiversity remains at stake. Behind these criticisms, there may be some misunderstanding of what economic evaluation really means. The issue is not to put an economic value on nature, which would indeed be pointless, but to translate the value of losses from the destruction of some ecosystems in terms that allow a comparison with other societal issues. Scholes' assertion is actually based on confusion between the economic value of the whole biosphere, which is obviously meaningless, and the sum of all economic reasons of conserving or preserving a particular ecosystem. Even the latter, more limited purpose is hardly achievable in absolute terms, in the absence of a precise context of what threatens this ecosystem and how [87]. To go further in this direction, we will briefly review what should not be done and what should be tried, before discussing the contexts needed for meaningful evaluations of ecosystems.

5.1. Values of the services vs. preservation cost: looking for efficiency

Confronted to the many uncertainties and controversies in the economic valuation of ecosystem, an alternative often proposed, rather than evaluating the cost of the destruction or degradation consists of estimating the preservation or restoration costs.

This seemingly very comforting solution is actually a false good idea. Apparently, one is shifting from an assessment based on preferences too difficult to assess to a more reliable cost of technical supply. In reality, this approach provides a measure of cost that might be irrational, because much higher than the value of lost services. Following this fallacy, the analyst has lost the very principle of economic valuation: the search for efficiency.

Nevertheless, this approach can be sometimes adequate. If the definition of objective appears out of reach of any economic analysis, as it is definitely the case in many situations, the search for efficiency should lead to achieve the goal determined on other bases at lower cost, and analysing the costs of preservation, conservation, restoration or replacement, whichever is deemed possible.

Ideally, economists may wish to put their analysis in a CBA framework, the only one to provide a measure of efficiency, but this would require being able to estimate all the costs, market and non-market, associated with every possible situation to determine what would be the best situation. At the optimum, the marginal value of services and the marginal costs of conservation would be equal. Such calculations are generally just unrealistic.

5.2. Evaluating potential

Most existing evaluation relate to services actually rendered by ecosystems here and now. If the objective is to assess whether the expected profits from the destruction of these environments will be greater than that of the lost ecosystem services, one must be careful to compare two trajectories of the same nature, and not the reality of ecosystems that may have suffered other damage, with the uncertain promises of idealized projects. Given the optimism of developers about their projects, there is no reason to value biodiversity according to the present state of ecosystem services, but rather in their expected state at the relevant time horizon under favourable management.

As good practices in evaluation are to measure the differences between contrasting scenarios, it is of utmost importance to take into account values of ecosystem services, which would be effective in a favourable scenario. The word "favourable" should not be construed as referring to a pristine wilderness that will not exist anymore, but as the result of changes in real ecosystems at a specific horizon, assuming that reasonable choices were made.

5.3. Valuation as a guide for decision making

On the one hand some economists and ecologists are convinced that economic analysis is an adequate framework for improving decisions involving conservation aspects [88]. On the other hand, other ecologists or policy analysts consider this task as unrealistic and misleading [89,90]. It appears therefore legitimate to ask: "*Can the concept of ecosystem service be practically applied to improve natural resource management decision?*" [91].

5.3.1. Decision without explicit valuation

It may appear somewhat surprising to read so many warnings about the unreliability of economic evaluations, particularly of ecosystem services, whereas, in real decision making, particularly in France, economic evaluation appears to have little influence on the final choices. The question therefore remains somewhat theoretical, or refers to foreign contexts. It is of course complicated by the fact that agents-citizens-voters have, in this case, a biased perception of the real issues.

The situation of a policy maker who has to make a choice in an area where people have wrong beliefs, can be considered as a simple extrapolation of a situation in which there is no reliable or recognized assessment, with three typical situations [92]:

- dictatorship, when the decision is made according to the sole preferences of the Prince, or of the interests he may serve;
- populism, when the decision is made according to the preferences of people, or of the best organized lobby, even though the policy-maker knows that their beliefs are wrong;
- paternalism, when decision relies on expert knowledge to serve the real interests of people, even if they do not realize the dangers they are protected in this way, and they can be tempted to fight this decision.

Obviously, these three situations do not compare favourably with an explicit valuation allowing the policy-maker to make choices according to the actual interests of the population. It is admitted here that these interests are not easily identifiable, and much less quantifiable or economically assessable. Not even trying is probably worse.

5.3.2. Valuing ecosystems for better decision making

Since ecosystem services are not fully captured in commercial markets or adequately quantified in terms comparable with economic services and manufactured products, they are often given too little weight in policy decisions. There is then a need, like for many assets involving public good aspects, to implement public policies based on efficiency considerations. In this perspective, the evaluation of ecosystems as a means of improving information for decision making has been repeatedly proposed [33,39,88,93,94]. Most works exploring technical and informational difficulties aim at defining cost-efficient, least-cost, or efficient conservation policies [95–102]. Apparently, no published study aims at characterizing an optimal policy of conservation for legitimating the objectives of conservation relatively to other social goals.

This latter objective, which would be the most consistent with the purpose of economic analysis, is probably unrealistic given the quality of results. Most studies in this direction did not go further than declarations of intent. The quality and incompleteness of information, notwithstanding possible conceptual difficulties, cannot a priori do better than the construction of indicators of values that can be incorporated into the economic assessment of the projects that affect biodiversity.

Several authors have nevertheless stated that it would be possible to go further, and considered that valuation might be a first step toward a "commodification" of Nature.

5.4. Valuation as a prerequisite for institution building?

Economic valuation can indeed be considered as a step toward institutional innovation, such as Payment for Ecosystem Service (PES) schemes [16] and possibly of new property rights.

5.4.1. Designing policy instruments

Schemes of Payment for ecosystem services (PES) have mostly appeared in Latin America, namely Costa Rica [103], as a practical way to raise money for conservation. They have further sometimes be seen a universal policy instrument [104].

There is, indeed, no direct link between the value of ecosystems and the prices the PES mechanisms can create as an incentive for ecosystem services preservation or enhancement. As in the case of cost-efficient policies, the price in a PES mechanism is supposed to reflect the opportunity costs of the farmers or any other social category that become beneficiary of such a mechanism in exchange of fulfilling some ecological target or implementing some constraint in terms of ecosystem use.

There is a gap between the optimistic liberal approach that dominates the design of PES in the economic literature and what can be practically implemented [105]. According to their analysis, PES must, on the contrary, be analysed taking into account complexities related to uncertainty, distributional issues, social embeddedness, and power relations in order to understand the variety of contexts and institutional settings in which PES operate. Even if the reality of PES is usually very far from an efficient market, implementing PES schemes implies to some extent designing new property rights.

5.4.2. Designing new property rights?

Can it be both possible and appropriate to go beyond the implementation of incentives policy instruments and to use economic valuation for defining new property rights? This way was followed by several authors [106–109], who explore the potential and pitfalls of managing biodiversity by bundling it with marketable assets like agricultural products, pharmaceutical bio-prospecting contracts or eco-tourism.

New property rights potentially are expected to emerge when benefits in appropriation are greater than transaction costs for their implementation [110]. New property rights may even create new responsibilities and appropriate incentives. However, some basic principles shape their potential. Demsetz clearly distinguishes between the goods and the related rights that "*When a transaction is concluded in the marketplace, two bundles of property rights are exchanged. A bundle of rights often attaches to a physical commodity or service, but it is the value of the rights that determines the value of what is exchanged*" [110]. Faced with the complexity and uncertainty attached to biodiversity and ecosystem functioning, it seems unlikely that a comprehensive system of rights should never be able to cover all issues. Even if efficiency gains can be expected from the definition of new rights expanding the social management of the benefits that humans obtain from ecosystems, some aspect of these benefits will not be supported appropriately by these mechanisms, and public policies relying on a broader and shared understanding of issues will remain necessary.

5.5. Final words

"In the last 30 years or so, valuation of environmental change and services has become one of the most significant and fastest evolving areas of research in environmental and ecological economics" [21]. Many non-specialists might have believed that this field was mostly developed since this statement in 2003. This massive interest can be related to the motivation to build a better and more comprehensive informational base for the policy formulation and decision making process.

Indeed, valuation is not an end in itself, but rather a conceptual and methodological framework for organizing information as a guide for decision making. It is "*one tool in the much larger politic of decision making. Wielded together with financial instruments and institutional arrangements that allow individuals to capture the value of ecosystem assets, however, the process of valuation can lead to profoundly favourable effects*" [3].

Is the valuation of ecosystem services actually able to bear a relevant "internalisation" of the non-market benefits of conservation? The answer is unfortunately no, not because of some weakness of the conceptual framework, but rather of practical information and, perhaps, of valuation techniques, struggling with poorly motivated preferences to achieve price-equivalent consistent with the common monetary metric. Alternative approaches to build a value concept on objective information, such as energy-equivalent or ecological footprint, have not really succeeded to produce a usable framework that links conceptually empirical observations with normative social objectives.

The political will to continue developing a conceptual and methodological framework that has not established its capacity to handle the complexity of the natures-societies interaction can certainly be related to the growing evidence that we are living in a world of increasing scarcity [111] in which choices among competing uses of ecosystems might become more and more unavoidable. And referring to general principles, such as the equity argument that has been shown to be used for self-serving objectives [112], is hardly more convincing. Explicit analysis method may become a necessity to legitimate brutal choices.

Finally, the choice is not between valuing or not valuing, it is between valuing with explicit and contestable methods and valuing implicitly. But we must remember that biodiversity and ecosystem services valuation would remain meaningless if it does not aim at making better practical choices and actions.

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