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Are diverse ecosystems more valuable? Economic value of biodiversity as result of uncertainty and spatial interactions in ecosystem service provision

Bartosz Bartkowski[a]

[a] Helmholtz Centre for Environmental Research – UFZ, Permoserstraße 15, D-04318 Leipzig, Germany, bartosz.bartkowski@ufz.de

Abstract

Economic valuation mostly focuses on specific ecosystems, species or the services they provide. The diversity within ecosystems is viewed as a valuation object less frequently. In this paper, it is argued that the economic value of biodiversity highlights the relevance of the temporal and spatial dimensions in ecosystem service provision. A framework is presented in which the economic value of biodiversity is the result of uncertainty about the future, regarding both supply of and demand for ecosystem services, and of spatial interactions between ecosystems. Three sources of biodiversity's economic value are distinguished in this context: insurance value, option value and spill-over value. Furthermore, the paper introduces biodiversity-specific methodological challenges (importance of non-market ecosystem goods; uncertainty and subjectivity; complexity and abstractness) which can be used to identify suitable methods for the economic valuation of biodiversity.

Keywords: biodiversity, ecosystem services, economic valuation, insurance value, option value, stated preference methods

1 Introduction

One of the most dramatic and detrimental consequences of the Anthropocene, i.e. the current 'human-dominated[…] geological epoch' (Crutzen, 2002; see also Lewis and Maslin, 2015), is the unprecedentedly fast pace at which biodiversity is being lost due to human activity (Barnosky et al., 2011; Pereira et al., 2012; Steffen et al., 2015). An important facet of this loss is the loss of ecosystem services (ES) (MEA, 2005), which is one of the main reasons why ES research has gained huge influence in conservation and many related discourses in recent years. However, exclusive focus on ES threatens to obscure the complexity of ecosystems and the potential relevance of the *diversity* in them for human well-being (Mainwaring, 2001; Norgaard, 2010). Biodiversity loss can be interpreted in terms of the identity of specific entities, processes and functions lost (ES), as well as in terms of their diversity (biodiversity stricto sensu). The latter perspective is much less pronounced in public debates and research. There exist many different perspectives on the relationship between biodiversity and ES (Jax and Heink, 2015). When it comes to the value of biodiversity, it is often seen as underpinning the provision of ES (via its contribution to ecosystem functions) or linked to cultural ES; sometimes, intrinsic value is attributed to it (Cardinale et al., 2012; Harrison et al., 2014; Mace et al., 2012; Schröter et al., 2014). In this paper, it will be argued that biodiversity has economic value going beyond these considerations.

One of the ways to highlight the seriousness of biodiversity loss is economic valuation (Kumar, 2010). Most valuation studies focus on specific entities – a given ES, a given species etc. Those that make biodiversity their valuation object are more scarce – and have been shown mostly not to capture its complexity (Bartkowski et al., 2015; Farnsworth et al., 2015); the overall picture drawn by available biodiversity valuation studies is rather inconsistent. It seems that there still ‘is […] not yet an established framework for valuing biological variety’ (Nijkamp et al., 2008, p. 218), despite numerous improvements since this remark was made.

This paper aims at making a contribution in the tradition of ecological economics by pointing out that the economic value of biodiversity results above all from its mediation of uncertainty about the future and from spatial interactions between ecosystems in the context of ES provision. It is argued here that biodiversity contributes to human well-being in ways additional to the value of those ES, i.e. that the fact that an ecosystem is more or less biodiverse constitutes value-inducing effects additional to the value of ES. Specifically, biodiversity is the sole ‘ecosystem-side’ carrier of three categories of economic value (of course, these values are also influenced by human activities on the ‘human side’):

- insurance value, which arises when biodiversity can reduce the uncertainty surrounding the provision of ES to risk-averse stakeholders;
- option value, which arises from biodiversity’s being a portfolio of options that reduce the uncertainty surrounding future preferences towards ecosystems;
- spill-over value, which arises from the role of biodiversity in spatial interactions between ecosystems.

Each of these value categories is discussed in more detail below. Furthermore, the thus generated insights into what constitutes the economic value of biodiversity are used to identify valuation methods that are suitable for dealing with this valuation object.

2 Defining biodiversity

Since the term ‘biodiversity’ is often used very vaguely in both public and scientific discussions, all too often as a synonym of ‘nature’, it is essential to clearly define it before we can determine why it is economically valuable and how this value can be approached methodologically.

Despite being so popular, also in scientific discourses, biodiversity has no established definition (Meinard et al., 2014). Different definitions have been used in different contexts, which partly reflects the fact that the concept has evolved over time – for instance, the still highly influential CBD definition (CBD, 1992) does not mention functional diversity, simply because this concept, now considered very important, is of more recent origin. This paper is based on a combination of two definitions from the literature, which is both encompassing so as to account for the multidimensionality of biodiversity, and precise by not including non-biodiversity elements in it.

Stirling (2007) provides a general definition of diversity as the combination of three properties of systems: variety (number of items in a category; the more items, the higher diversity, ceteris paribus), balance (distribution of elements across items in a category; the more even the distribution, the higher diversity, ceteris paribus) and disparity (degree of difference between items in a category; the less similar the items, the higher diversity, ceteris paribus). Translated into ecological terminology, these three properties are richness, relative abundances (evenness) and phylogenetic distance (or a similar measure of dissimilarity).

Maier (2012) defines biodiversity as the multiplicity of kinds in biotic and biota-encompassing categories. This implicitly stresses three things: first, trivially, biodiversity is about biotic (living) elements of ecosystems. Second, it is concerned with the multiplicity of these items, not with their identity (see also Faith, 2017). This is important because in the context of economic valuation biodiversity is often wrongly approached by valuing particular species (Bartkowski et al., 2015). Third, biodiversity is multidimensional and cannot be sensibly reduced to e.g. species diversity (Lyashevska and Farnsworth, 2012).

By combination we acquire the definition of biodiversity that is underlying the present paper:

> Biodiversity is a property of ecosystems; it is the (i) variety, (ii) balance, and (iii) dissimilarity of kinds in biotic or biota-encompassing categories.

3 Sources of biodiversity's economic value: incorporating temporal and spatial considerations in ecosystem valuation

As mentioned in the Introduction, in the literature the value of biodiversity is often framed as: underpinning of ES provision; underlying some cultural ES, particularly those deriving from aesthetic appreciation of ecosystems; and intrinsic value (e.g. Harrison et al., 2014; Mace et al., 2012; Schröter et al., 2014). The first interpretation is only partly relevant from the point of view of economic valuation, namely, when it is linked to the concept of insurance value (see below); otherwise, its inclusion in economic valuation would amount to double-counting (Hamilton, 2013). The second interpretation, too, is only of limited relevance here, as the cultural ES 'supported' by diversity (such as aesthetic appreciation) are constituted by more factors than diversity alone, so it does not appear sensible to distil its relative contribution to them in practice. The third interpretation, while very common, seems to be wrong, as is compellingly argued by McShane (2017), who shows that none of the available interpretations of intrinsic value is compatible with biodiversity.

The basic, textbook perspective on the economic value of ecosystems is as follows: an ecosystem provides goods and services[1] to humans; furthermore, some ecosystems or their elements are valued simply because they exist (existence value[2]). To properly include biodiversity in this picture, one must broaden the perspective by including the temporal and spatial dimensions. Specifically, one must realise that (i) ecosystems are not static (temporal dimension 1); (ii) human preferences are not static as well (temporal dimension 2); and (iii) the provision of ecosystem goods and services does not take place in a vacuum, but is usually embedded in larger networks of interactions (spatial dimension). These considerations are depicted in Figure 1 and discussed in more detail below. Each of the three categories of biodiversity's economic value that are this paper focuses on can be related in a different way to the dimensions of diversity identified by Stirling (2007). This shows that focusing on one dimension is not sufficient to capture the complexity of biodiversity.

[1] Sometimes, a distinction is made between (final) ecosystem services and ecosystem goods (Boyd and Banzhaf, 2007; UK NEA, 2011). For the purposes of the present paper, this distinction is not relevant.

[2] Existence value is sometimes classified as an ES, e.g. in the influential Common International Classification of Ecosystem Services CICES (Haines-Young and Potschin, 2013). This, however, seems to overstretch the inherently instrumental meaning of the term 'service'.

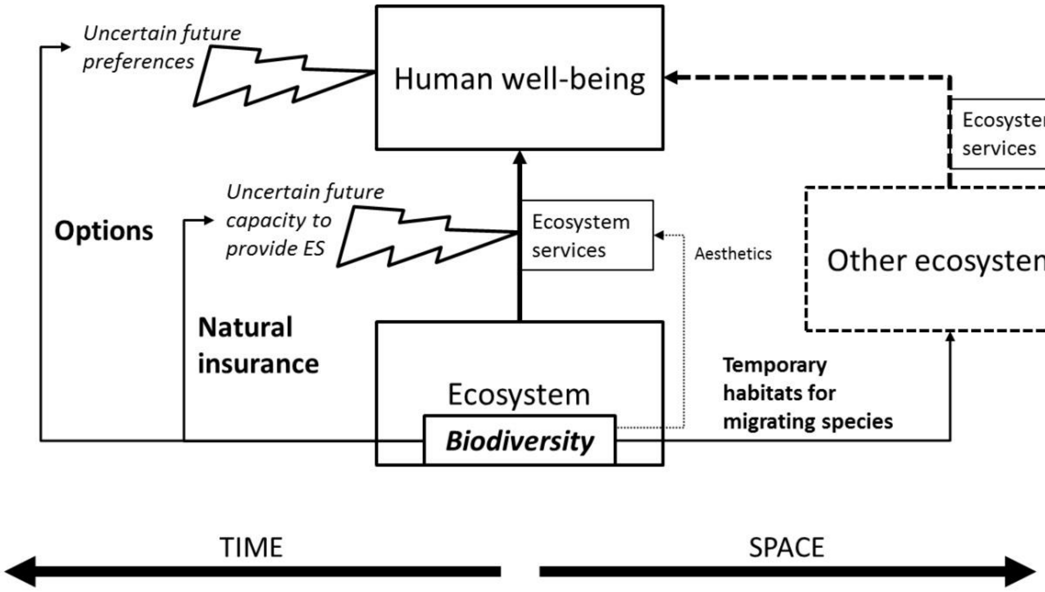

Figure 1: Conceptual framework of biodiversity's economic value. Bold terms indicate biodiversity values.

In what follows, first each of the three sources of biodiversity's economic value will be introduced and discussed in more detail: insurance value and option value in Section 3.1, spill-over value in Section 3.2. In Section 3.3, their compatibility with the total economic value (TEV) framework will be briefly discussed.

3.1 Temporal dimension: ES provision and biodiversity in an uncertain world

Both the supply of and demand for ES can change over time. Supply changes result from changes in the ecosystem itself – ecosystems are dynamic, they evolve constantly. In addition to that, human activities increase the rate of change in ecosystems and make their future even more uncertain (Pereira et al., 2012). Changes in demand result from the dynamic nature of human preferences, changes in tastes, needs, technology etc. In fact, changes in ecosystems can trigger changes in needs/demand, e.g. as response to new pests. The two are connected. Together, this means that (i) a given ecosystem's capacity to provide ES in the future is uncertain and (ii) which ES will be demanded in the future is uncertain, too. Biodiversity is valuable because it can alleviate both sources of uncertainty: by stabilising the ecosystem it provides a 'natural insurance' (Baumgärtner, 2007) against fluctuations in the ecosystem's capacity to provide ES; at the same time, it is a pool of options to accommodate future changes in preferences and thus demand for ES.

3.1.1 Biodiversity and uncertainty of ES supply

There exists a large and long-standing literature on the relationships between biodiversity and ecosystem functioning (BEF). The influence of biodiversity on ecosystem productivity, stability, resilience etc. has been investigated in a large number of both theoretical and experimental studies; there is agreement among most researchers in the field that high levels of biodiversity and ecosystem functioning coincide (Balvanera et al., 2006; Cardinale et al., 2012; Harrison et al., 2014; Isbell et al., 2015).

The central mechanism behind biodiversity's positive influence on ecosystem functioning is *functional redundancy*: the existence of species '[w]ithin the same functional effect type' that, however, exhibit 'different requirements and tolerances' (Díaz and Cabido, 2001, p. 653), *functional effect types* being groups of species that influence ecosystem processes in similar ways. The notion of functional redundancy is closely related to the *insurance hypothesis* (Folke et al., 1996), which amounts to the 'idea that increasing biodiversity insures ecosystems against declines in their functioning caused by environmental fluctuations' (Yachi and Loreau, 1999, p. 1463). This ecological hypothesis can be easily extended by including human preferences and risk-aversion so as to arrive at the concept of the *insurance value* of biodiversity: For something to be considered economic insurance, three conditions must be fulfilled: (i) the provision/supply of some good must be uncertain; (ii) relevant stakeholders must be risk-averse; (iii) there must be a mechanism for lowering the probability of losses/reductions in supply (cf. Baumgärtner and Strunz, 2014). The uncertainty of ES supply was already briefly discussed above; people in general tend to exhibit risk-aversion (Dohmen et al., 2011; Holt and Laury, 2002); and, as shown by the BEF literature, biodiversity has a positive influence on the stability and resilience of ecosystems.

Insurance value is 'a value component in addition to the usual value arguments […] which hold in a world of certainty' (Baumgärtner, 2007, p. 90). Thus, it can be defined as the change in the risk premium of the 'lottery' (i.e. future state of the world) due to a change in biodiversity. Baumgärtner and Strunz (2014) differentiate between two basic forms of insurance: an insurance contract and *self-protection*, the latter amounting to attempts of the interested actor herself to reduce uncertainty on her own. They argue that the insurance function of biodiversity is much closer to this latter notion, as societies can 'insure' against future declines in the provision of ES by deliberately maintaining and increasing biodiversity in ecosystems (see also Pascual et al., 2015). In this sense, biodiversity has been compared to a portfolio (Figge, 2004): Portfolio theory (Markowitz, 1952) shows that in order to minimise the risk of holding financial assets, one should spread this risk by investing one's money in a portfolio of different, uncorrelated assets. A biodiverse ecosystem can be seen as such a portfolio of assets with different proneness to particular disturbances. Redundant species (sensu functional redundancy) decrease the probability of flips in the state of the ecosystem, i.e. they increase its resilience (Baumgärtner and Strunz, 2014; Matsushita et al., 2016).

Two specific interpretations of insurance value are possible: first, biodiversity can be argued to promote *acute stability* in the sense of resilience or resistance of the biodiverse ecosystem against exogenous shocks, e.g. storms (Thompson et al., 2009) or climatic events such as droughts (Isbell et al., 2015). Second, when biodiversity positively influences the temporal stability of an ecosystem, this can be valuable if coupled with intergenerational equity concerns. People may appreciate the fact that a relatively biodiverse ecosystem is more likely to be available to future generations, on top of its availability to current people themselves – a notion closely related to the TEV category of bequest value. However, this temporal stability is not to be understood in the sense of a non-changing state but rather the more general 'capacity to produce well-being' (Anand and Sen, 2000, p. 2035).

Regarding the different dimensions of diversity (Stirling, 2007), insurance value obviously results from variety and disparity, in line with the idea of functional redundancy; but balance seems important as well – a 'functionally redundant' element of an ecosystem does not contribute much to its stability if it is very rare and thus easily lost.

3.1.2 Biodiversity and uncertainty of ES demand

On top of the uncertainty of ES provision, another uncertain factor is which ecosystem elements will be demanded as ES in the future. In this context, biodiversity can be viewed as *container of future ES* or *carrier of options,* from which option value results (Weisbrod, 1964). Since future is uncertain, it may be wise, according to this interpretation, to keep components of ecosystems intact (thus maintaining their diversity), even if we do not have use for them now. This is closely related to the Noah's Ark metaphor, first introduced by Weitzman (1998), which frames biodiversity conservation as the search for an optimal combination of dissimilar natural entities (see also Nehring and Puppe, 2002; Weikard, 2002). Obviously enough, the two perspectives – insurance and options – are inherently interlinked; however, they depend on different types of uncertainty (supply vs. demand), which makes the differentiation sensible.

The view of biodiversity as carrier of option value stems from the recognition that a biodiverse ecosystem, which contains many different species and genomes, can best accommodate unanticipated future desires (preferences). As in the case of insurance value, this can be coupled with considerations of intergenerational equity. In fact, in the case of option value, this notion is arguably more central: high levels of biodiversity now mean many different options for our descendants (cf. Birnbacher, 2014), who may want to extract from ecosystems technological blueprints, substances and genes which we currently have no use for.[3] Biodiversity can be viewed as a 'legacy library,' i.e. a pool of (genetic) information bequeathed to our descendants (Goeschl and Swanson, 2007; Weitzman, 1998). Under this perspective, biodiverse ecosystems are potential sources of basically three categories of future benefits: genetic knowledge (relevant especially for agriculture), models or blueprints for new technologies (a classic example being aircraft, which is an attempt to mimic birds) and substances for future use in the chemical and pharmaceutical industries (Myers, 1997).

Option value is arguably particularly dependent on variety and disparity, in line with the focus of the Noah's Ark literature, which is essentially concerned with the preservation of future options. In this case, balance seems relatively less important – for instance, given the advancements of science and technology, in the extreme case only one specimen of a plant species is sufficient to derive from it useful substances or genetic material.

3.2 Spatial dimension: ES provision and biodiversity-mediated interactions between ecosystems

As shown above, an important part of biodiversity's economic value is the result of uncertainty about the future, regarding both ES supply and demand. Another source of its value has its origin in the recognition that ecosystems are not isolated from each other, but interlinked in many different ways. These interlinkages result, among other things, in what can be called the *spill-over value* of biodiversity.

A biodiverse ecosystem can be expected to be diverse in (micro-)habitats. Some of these (micro-)habitats can be essential for migratory species (e.g. salmonids, cranes, geese), whose main habitats lie outside the investigated ecosystem, but for which this ecosystem is one (potential) station in their migratory life-cycle. An example of such ecosystems are the dehesas in the Spanish region of Extremadura, where numerous species of migratory birds from Northern Europe spend winters (Diáz et al., 1997). This is possible because of the high habitat diversity of these agro-silvo-pastoral ecosystems. Thus, biodiversity in such ecosystems has spill-over effects on other ecosystems. The idea behind biodiversity's spill-

[3] This interpretation of option value of biodiversity is a part-response to the criticism of neoclassical environmental economics expressed by Scholtes (2010), whose concept of *environmental dominance* emphasises that our current use of ecosystems has repercussions for the freedom of choice of future generations. Preserving future options would be one possible approach to alleviate our environmental dominance.

over value is related to the *maintenance of life cycles of migratory species* or *nursery service* in the TEEB classification (Elmqvist et al., 2010; Liquete et al., 2016).

Under the assumption that the relevant migratory species contribute to human well-being (by providing ES or having existence value), the contribution of a biodiverse ecosystem to their life cycles can be argued to increase the overall value of this ecosystem. It is important to distinguish here between the importance of *specific* habitats for *specific* migratory species and the *multiplicity* of habitats for *different* migratory species. The former, while important e.g. from a conservation point of view (see e.g. Liquete et al., 2016; López-Hoffman et al., 2010), is not attributable to biodiversity. In a certain sense, this multiplicity of habitats might be called 'efficient,' as it is possible to support a number of migratory species within one single ecosystem, thus minimising the area needed for their support (of course, within the confines of overall carrying capacity). Note that this 'efficiency' is a value-inducing effect only when it is linked to spill-overs to other ecosystems. Of course, a diverse ecosystem is also home to a number of potentially useful local species, thus contributing to the provision of a large bundle of ES. However, this 'within-efficiency' or multifunctionality is unlikely to have additional value beyond the sum of the values of the involved ES. Furthermore, the thus induced diversity of species using the diverse (micro-)habitats is itself part of the ecosystem's biodiversity, so interpreting it as contributing to the latter's economic value would be circular.

Spill-over value may well be criticised as an instance of double counting. This is certainly true in the context of environmental-economic accounting and large-scale cost-benefit analyses, in which the ecosystem(s) of the migratory species' origin are included as well. However, these are not the only, not even the main purposes of economic valuation (cf. Costanza et al., 2014). For example, for communication of the importance of intact, biodiverse ecosystems to the public and policy makers, spill-over value's importance consists in showing that ecosystem services, which provide direct benefits to humans and thus have use value, are embedded in a larger, highly complex dynamic system and should not be viewed atomistically or in a static way. More generally, when the purpose is to demonstrate the economic value of a specific ecosystem, spill-overs to other ecosystems are a relevant component of this value.

It appears that spill-over value is related especially to variety and disparity within an ecosystem – for many different species to dwell, many different (micro-)habitats are needed. However, as minimally small habitats are only of limited usefulness in this context, balance plays a role as well.

3.3 Biodiversity in the TEV framework

The TEV framework in its most common form consists of three main value categories: use values, non-use values and option value (e.g. Pascual et al., 2010, fig. 5.3). In earlier publications, if insurance value was included in TEV, it happened as a category additional to the 'output value' of an ecosystem, which corresponded there to the usual TEV (e.g. Pascual et al., 2015). Spill-over value has been absent to date.

How can biodiversity's contribution to the economic value of an ecosystem be properly included in the TEV framework? To do that, TEV has to be restructured and extended – two dimensions have to be added. An extension along a temporal axis helps to include insurance value (and make better place for option value, which usually has an unclarified role somewhere between use and non-use values in many versions of the framework), while spill-over value necessitates the addition of a spatial dimension. Both extensions are depicted in Figure 2. To integrate the two dimensions, two additional levels are added to the usual TEV scheme: first, *local values* and *external values* are distinguished (spatial dimension); second, we have *certain-world values* and *uncertain-world values* (temporal dimension). In Figure 2, values attributable to biodiversity are highlighted in darker grey.

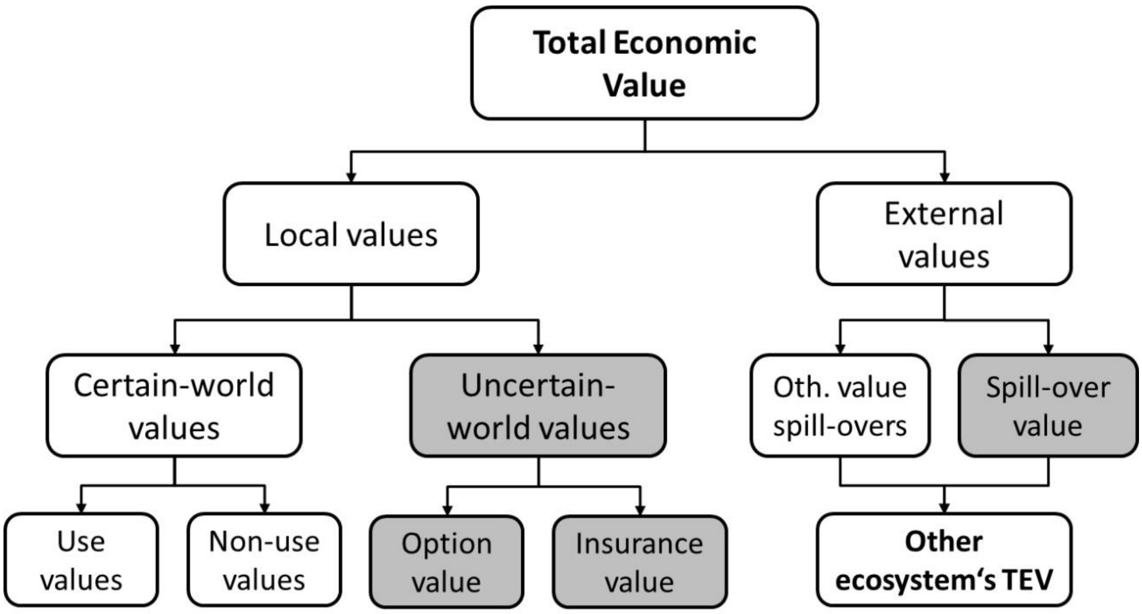

Figure 2: TEV framework with insurance value of biodiversity. Biodiversity-related values are in darker grey boxes with white font.

Usually, the TEV has no notion of inter-ecosystem value spill-overs – the notions of altruistic value and existence value only take preference-based effects between locations (since they are based on the idea that the *valuer* is located elsewhere than the *object of value*). External values, on the other hand, amount to contributions of one ecosystem to the value of another, where it can be distinguished between biodiversity-related spill-over value and other, non-biodiversity related value spill-overs (see Section 3.2).

The temporal dimension is rooted in the idea that uncertainty 'creates' value – both insurance and option value derive from the fact that there is irreducible uncertainty about the future. Without this uncertainty, these values would be non-existent. The basic idea of the extension presented in Figure 2 is related to Pascual et al.'s (2015), the difference being that here, option value and insurance value are put together under the heading of *uncertain-world values*, i.e. values which result from uncertainty about the future, whereas use and non-use values are *certain-world values*. From what was said above, it is obvious that biodiversity's contribution to the TEV of an ecosystem is mainly via uncertain-world values – both of the latter's components can be directly attributed to biodiversity.

4 Choice of valuation methods: some orientation for biodiversity valuation studies

In previous sections, we have identified how the economic value of biodiversity results from (i) uncertainty about the future provision of ES (insurance value), (ii) uncertainty about the future demand for ES (option value) and (iii) interactions between different ES-providing ecosystems (spill-over value). The next important question is how this value is to be estimated. This section offers some tentative suggestions in this direction.

First, it is important to make clear how the three sources of biodiversity's economic value can be measured or linked to quantitative or qualitative attributes of ecosystem change. In the case of insurance value, this already has been done (e.g. Finger and Buchmann, 2015). The most obvious way of expressing the insurance effect of biodiversity is to link changes in biodiversity with the probability of flips in the state of the ecosystem. This can be done on the basis of ecological models (Grace et al., 2016) or prior observations of the ecosystem in question, which can help to both express a given ecosystem change in terms of a biodiversity change and link this to a change in the probability of a flip (resilience). Option value is a different matter – it is about the probability of making 'useful discoveries' in the ecosystem in question, depending on its biodiversity level. This probability can hardly be based on models or observations, as it is essentially based on inherently unknown future preferences. Therefore, this probability is inherently subjective and cannot be linked to objective measures, with important consequences for the choice of suitable valuation methods (see below). Spill-over potential can be expressed as the number of (potential) visitors (i.e. migrating species) or of suitable habitats for such visitors that an ecosystem offers. Here, too, there is ample room for interdisciplinary exchange, as ecological knowledge and, e.g., niche models can help formulate this attribute.

What methods can be used, then, to assess the economic value of biodiversity in a given ecosystem? To give orientation in this regard, it is helpful to formulate criteria that these methods should fulfil in order to be suitable for biodiversity valuation. In fact, biodiversity poses a number of specific challenges for valuation. These are: (i) the non-market nature of components of biodiversity value (especially in the case of insurance value); (ii) high levels of uncertainty involved in the relationship between biodiversity and human well-being and, related to this, the multidimensionality of the concept; and (iii) its abstractness and complexity. These can be used as criteria for identification of suitable valuation methods. Table 1 offers a tentative evaluation of three large classes of valuation methods – production function methods, revealed preference methods and stated preference methods – in terms of these challenges/criteria. Note that the evaluation is based on the informed opinion of the author of this paper and on standard literature on economic valuation methods (e.g. Mäler and Vincent, 2005), unless otherwise indicated.

Table 1: Suitability of valuation methods for valuing biodiversity

Assessment based on standard literature (e.g. Mäler and Vincent, 2005). If a specific method within a class is particularly well suited to tackle a given challenge, it is named in brackets (the evaluation applies then to this method only). Explanations see main text. '++' – well suited, '+' – suitable with limitations, '-' – not suited. BP: bioprospecting, HP: hedonic pricing; CE: discrete choice experiments; DMV: deliberative monetary valuation.

	Production function	Revealed preferences	Stated preferences
Non-market aspects	-	++	++
Uncertainty			
- subjectivity	+ (BP)	-	+
- two-level	+	++ (HP)	++ (CE)
Abstractness	-	-	++ (DMV)

Ad (i): The first challenging biodiversity characteristic for the identification of suitable valuation methods is related especially to insurance value. This value results from the influence biodiversity is supposed to have on ecosystem stability and resilience, thus 'insuring' the delivery of ecosystem goods and services. It was argued in the literature that biodiversity's economic value can be estimated by means of production function and related methods (Farnsworth et al., 2015), and related approaches specifically targeting the insurance value of biodiversity have been developed and applied (Baumgärtner, 2007; Finger and Buchmann, 2015). However, such approaches can only provide estimates of the insurance value of biodiversity towards marketed ecosystem goods, effectively excluding all others. This would result in a serious underestimation in many cases. Conversely, revealed preference methods and stated preference methods are better suited to deal with this issue. Assuming that stakeholders know about the insuring effect of biodiversity (on this, see below), they can be assumed to express their appreciation of this insurance of locally enjoyable non-marketed ecosystem services by moving into the vicinity of ecosystems exhibiting high levels of biodiversity. This could be potentially captured by means of hedonic pricing analysis. However, the insurance of globally or supra-locally relevant ecosystem services (such as carbon sequestration) is unlikely to have influence upon choices of place of living. Here, stated preference methods have the advantage of not being dependent on any actual market behaviour.[4]

Ad (ii): Biodiversity's economic value is inherently linked to issues of uncertainty about the future, which offers another criterion for choosing methods suitable for the estimation of this value. First, in the case of option value, but also for insurance value, relevant probability distributions are not necessarily known. As a result of this, the economic value of biodiversity is based on inherently subjective judgements of stakeholders – judgements which, in many cases, cannot be linked to any observed behaviour in (surrogate) markets other than, possibly, markets for bioprospecting (Cox and King, 2013). This is an argument in favour of stated preference methods (though bioprospecting contracts could be used as a proxy in some cases). Second, it is not *entirely* clear if and how biodiversity has an influence on ecosystem functioning: the exact relationship between biodiversity and ecosystem functioning (in terms of stability, resilience or other related measures) is uncertain (Harrison et al., 2014). In the context of economic valuation, this amounts to a *two-level uncertainty*: first, it is uncertain whether a given land-use change will in fact result in a specific change in biodiversity – this type of uncertainty is common in valuation studies in general and there exist approaches to deal with it (e.g. Lundhede et al., 2015; Torres et al., 2017); second, it is uncertain whether and how the change in biodiversity will affect ecosystem functioning, which is not easily comparable to the situation regarding other environmental goods. For instance, when the economic value of an endangered species is to be estimated, respondents in stated preference surveys are asked for their willingness-to-pay for a change between two states of the world: the status quo and a world in which the abundance of the species in question is significantly

[4] Note that at the same time this is often considered the main limitation of stated preference methods: they are based on hypothetical decisions of stakeholders and thus prone to a number of psychological biases and to strategic behaviour.

raised. This can then be directly compared with the costs of a suitable protection programme. Conversely, since biodiversity is the property of an ecosystem, changes in it cannot be sensibly valued in isolation – rather, they can only be valued as a result of a specific land-use change. Then, the above-mentioned two-level uncertainty emerges. This uncertainty has also to be handled when biodiversity's economic value is to be estimated; furthermore, it is closely related to the fact that biodiversity and its value are multidimensional and different parts of it are differently affected by uncertainty – for instance, option value is more affected by the subjectivity issue, while insurance value is affected by two-level uncertainty. Discrete choice experiments (CE) offer an opportunity to handle these issues. This valuation method makes it possible to assess the valuation weights people attach to different attributes of a good (e.g. the influence of biodiversity on ecosystem functioning), instead of simply valuing the good as such, as done e.g. in conventional contingent valuation (CV) studies. Due to the type of econometric models CE is based on, it is inevitable anyway that what is valued are not 'realistic' scenarios but more or less arbitrary combinations of attribute levels – while potentially problematic due to the hypothetical nature of the choices participants are asked to make, this means that uncertainty can be handled comparatively well in CE studies. Also, uncertainty can be included more explicitly in CE surveys (viz., as a qualitative or quantitative attribute) and it was argued that it is important in stated preference surveys to '(1) assess, whenever relevant, respondents' prior belief in policy outcome uncertainties and ([2]) incorporate when possible the degree of uncertainty into the valuation exercise, even if only in qualitative terms' (Lundhede et al., 2015, p. 314). Moreover, by combination of a number of biodiversity attributes with other ecosystem characteristics, it is possible to account for both the multidimensionality of biodiversity – that it is at the same time 'insurance,' the carrier of future options, a provider of temporary habitats – and the fact that the concept is meaningless when detached from an actual ecosystem. However, other methods can also produce weights of different factors/attributes of value. Particularly, hedonic pricing (HP) and some types of production function methods (PF) allow for distinguishing between the relative contributions of different factors to the overall value of an environmental good. None of them, however, can provide an answer to the problem of subjectivity that can at least partially be accounted for in stated preference studies. Moreover, while they can capture biodiversity as one attribute among many, and possibly also identify the relative contributions of the different dimensions of biodiversity, they cannot distinguish between the different value sources of biodiversity, as those cannot be pinned down to single measurable dimensions of biodiversity (see above).

Ad (iii): A particularly challenging issue in the context of economic valuation of biodiversity is that people are rather unfamiliar with this abstract good, as shown in a number of different studies and polls in different countries (Bakhtiari et al., 2014; Buijs et al., 2008; DEFRA, 2007; UEBT, 2013). They cannot be expected to have pre-defined preferences for this special good. As a consequence, valuation methods which are based on observed choices of people, i.e. revealed preference methods, have a serious disadvantage – for biodiversity to influence people's choices such as where to live (HP) or which area to visit during vacations (travel cost method) it must be assumed that those people are aware of the importance of biodiversity. This is a bold assumption. Therefore, stated preference methods, which usually involve the provision of information about an environmental good before the willingness-to-pay for it is elicited, appear more suitable for biodiversity. Of course, production function methods, being supply-oriented, do not depend on the knowledge of consumers. However, they suffer from other limitations, especially their inability to capture the insuring effect of biodiversity on non-marketed ecosystem services (see above); therefore, the case for stated preference methods in biodiversity valuation appears particularly strong. Furthermore, it can be argued that biodiversity is even 'worse' than so-called *experience goods* (e.g. Czajkowski et al., 2015), which pose a challenge to economic valuation because consumers learn about their preferences towards these goods in the act of consuming them. Biodiversity can be seen as an even more extreme case, as there is no obvious way of 'consuming' it, so other ways of learning about one's preferences are necessary (Lienhoop and Völker, 2016). In addition, ecosystems in general are complex and it takes years of full-time scientific training to understand them properly. Biodiversity is an particularly complex and abstract concept (Meinard and Grill, 2011). Lack of knowledge of/experience with biodiversity and the concept's abstractness not only suggest that revealed preference methods may not be helpful (since they can only be used to derive preferences people hold for things they know are valuable), but even that conventional stated preference methods may not be sufficient. Here, deliberative monetary valuation (DMV) could be a viable option, as this approach has been developed to tackle such limitations involving limited knowledge and familiarity with environmental goods (Lienhoop and Völker, 2016; MacMillan et al., 2006; Sandorf et al., 2016).

If we combine the insights provided by the analysis of the methodological challenges biodiversity poses for economic valuation, a method suitable in this context should: account for non-market effects, handle subjectivity, uncertainty and multidimensionality, and not be dependent on pre-defined preferences. According to the analysis offered above, deliberative choice experiments, i.e. a combination of CE and DMV, fulfil these criteria comparatively well. Of course, both exhibit limitations of their own (see Bunse et al., 2015; Lienhoop et al., 2015; Rakotonarivo et al., 2016), therefore the analysis offered here is only meant to stimulate further thinking and sensitise valuation practitioners to the challenges posed by biodiversity.

5 Conclusions

In this paper, a novel perspective on the economic value of biodiversity has been offered. Biodiversity's economic value has been framed as resulting from the temporal and spatial dimensions of ES provision. While the economic value of biodiversity is inherently dependent on the ES provided by an ecosystem, the fact that this ecosystem is more or less biodiverse constitutes value-inducing effects additional to the value of those ES. The reasons for that are uncertainty about the future (insurance value and option value) and interactions between ecosystems (spill-over value). On the basis of these insights, the paper formulated three biodiversity-specific methodological challenges, which can be used to identify valuation methods suitable for this particular valuation object.

Especially the latter issue, i.e. the choice of valuation methods suitable for biodiversity, should be understood as a proposal, not a definitive recommendation. There is ample need for further research on this, including applications of the ideas presented here in actual valuation studies. Also, the relevance of this paper's findings for biodiversity governance is an important issue which was beyond its scope. For instance, it is unclear whether and how biodiversity values could be included in systems of environmental-economic accounting (UNEP-WCMC, 2015). Last but not least, it is an open question how biodiversity fits the emerging concepts of social, cultural and relational values and how these are relevant for the economic perspective on ecosystem value (Chan et al., 2016; Kenter, 2016).

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