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Review

The Value Landscape in Ecosystem Services: Value, Value Wherefore Art Thou Value?

Adam P. Hejnowicz [1,2,*] and Murray A. Rudd [3]

[1] Department of Biology, University of York, Wentworth Way, York YO10 5DD, UK
[2] Centre for the Evaluation of Complexity Across the Nexus (CECAN), Guildford GU2 7XH, UK
[3] Department of Environmental Sciences, Emory College of Arts and Sciences, 201 Dowman Drive, Atlanta, GA 30322, USA; murray.a.rudd@emory.edu
* Correspondence: adam.hejnowicz@york.ac.uk; Tel.: +44-019-0432-8629

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Abstract: Ecosystem services has risen to become one of the preeminent global policy discourses framing the way we conceive and articulate environment–society relations, integral to the form and function of a number of far-reaching international policies such as the Aichi 2020 Biodiversity Targets and the recently adopted Sustainable Development Goals. Value; its pursuit, definition, quantification, monetization, multiplicity and uncertainty, both in terms of meaning and attribution, is fundamental to the economic foundations of ecosystem services and a core feature driving its inclusion across multiple policy domains such as environmental management and conservation. Distilling current knowledge and developments in this arena are thus highly prescient. In this article, we cast a critical eye over the evidence base and aim to provide a comprehensive synthesis of what values are, why they are important and the methodological approaches employed to elicit them (including their pros and cons and the arguments for and against). We also illustrate the current ecosystem service value landscape, highlight some of the fundamental challenges in discerning and applying values, and outline future research activities. In so doing, we further advance ecosystem valuation discourse, contribute to wider debates linking ecosystem services and sustainability and strengthen connections between ecosystem services and environmental policy.

Keywords: environmental economics; ecological economics; ecosystem services valuation; monetary; non-monetary; uncertainty; discounting; social and shared values

1. Introduction

The environmental landscape is subject to constant change, but, how we perceive, use, exploit and manage "nature" remains one of the fundamental challenges of developing sustainable societies and a flourishing Earth System [1,2]. From economists to conservationists, many have championed the assimilation of economics and ecology as a means to align environmental interests with those of the broader political economy. The purpose of this co-alignment is to "mainstream" nature into general policy-making processes. In recent versions of this process, attempts have been made to delineate the connections between ecosystem goods and services and human-wellbeing [3–7]. However, with reference to the latter development, such fruitful integration remains contingent on the challenges of identifying ecosystem services (ES), attributing values to ES, and resolving and validating the issue of societal dependence on ES all of which have yet to be fully resolved [8,9].

These difficulties are exemplified by the continuing exchanges occurring between environmental and ecological economists regarding the nature of ES, the role of valuation in the implementation of the ES paradigm and the translation of ES into practical decision-making processes and policy applications [8,10,11]. Largely, these debates centre on key differences related to ideas of sustainability, the use of cost–benefit analysis (CBA), monetary valuation and marginal analysis, and the relationship between distributive justice and (economic) efficiency [10,11]. Whilst at first glance these deliberations may seem overly esoteric some argue, for example [11], that they should be considered as enlivening, enriching and informing our understanding of ES rather than regarded as fostering discontent.

Our purpose therefore is to present a codified and synthesized elaboration of these important strands of discourse. In the essay that unfolds, therefore, we first sketch out the current trends and debates in the ecosystem service-value dialectic: where progress has been made (theoretically and methodologically) but also where sticking points remain. Second, following these discussions, we then go on to give a brief account of how valuation has been applied more recently to various terrestrial, coastal and marine ecosystems and their services at global and local scales. Third, we then identify three core issues, two of which have important moral and ethical implications, namely, uncertainty and discounting, and a third, benefits transfer, which although it has normative qualities is more suitably considered for its practical ramifications. Collectively, all three need to be acknowledged and negotiated when applying the value lens to ecosystem services. Finally, we conclude by highlighting future areas of progress.

2. The Nature of Value

2.1. What Is Value?

The concept of value underwrites the process of environmental valuation [12]. However, what does that mean in theory and in practice? Unpacking this statement forces use to grapple with the nature of value, it asks us to examine what environmental valuation is and why it is important, and invites us to wrestle with the difficulties environmental valuation poses. These questions and their answers are central to the ecosystem services paradigm [6,13]. Starting by outlining what environmental valuation is and addressing its connection with value, in a nutshell:

> "Valuation is about assessing trade-offs towards achieving a goal. All decisions that involve trade-offs involve valuation, either implicitly or explicitly [. . .] The value of ecosystem services is therefore the relative contribution of ecosystems to that goal." [14] (p. 153)

This quote makes two clear points. Firstly, that the purpose of valuation is to inform decision-making processes and choices regarding different environmental management and protection options. Secondly, it asserts that values are the mediators of that decision-making, in other words, values act as a necessary bridge linking beliefs to behaviours, or motivations to actions. The second point is neatly captured by [15] (p. 234):

> "Values have been closely associated with worldviews, which describe the basic assumptions and beliefs that influence much of an individual or group's perceptions of the world, their behavior, and their decision-making criteria."

In many respects, this perspective builds on the value-belief-norm (VBN) theory detailed by [16] in relation to the support for social movements. In the elaboration of VBN, the core features are the causal connections made between an individual's values with a set of broad and core beliefs, concerning consequences and responsibility, which inform and co-create a personal set of norms that lead to a mobilisation of action, as [16] (pp. 83–84) make clear:

> "We propose that norm-based actions flow from three factors: acceptance of particular personal values, beliefs that things important to those values are under threat, and beliefs that actions initiated by the individual can help alleviate the threat and restore values [. . .] each social movement seeking a collective good develops its positions based on certain basic human values and that each movement's ideology contains specific beliefs about consequences and responsibilities that, in conjunction with its chosen values, activate personal norms that obligate individuals to support the movement's goals."

It should be rather obvious then that notions of value are broad and rich, with values being "complex, intersubjective, relational and multidimensional" [17]. For instance, as [12] (p. 107) express:

> "When talking about 'value' the term should be specified or be understood as an 'umbrella concept' comprising several incommensurable kinds of value."

Delving beneath this "umbrella" we can distinguish a number of values, from overarching categories such as Ideal values (e.g., notions such as justice and liberty where values relate to non-physical objects or those that are objectively real but are beyond and independent of us and our thinking, wherein what determines their value is the content of goodness imparted on them), and Real/Objective values (e.g., values that emphasise scientific rationalism and relate to real world objects that are endowed with validity through the scientific process, wherein our knowledge and thus understanding of their value is derived from empirical observation and values are given based on an object's properties subject to natural laws) to Subjective values (e.g., values attributed based on individual and social perception of real world objects, as such because they acknowledge that value is socially constructed and subject to specific social norms and value systems they are therefore not fixed nor are they absolute) [12].

An elaboration of Ideal values also captures the notion of transcendental and spiritual values—values that "are fundamental conceptions of the relationships of humans and nature" [18], which are above and beyond any particular contextual situation being concerned with "desirable end states or behaviours" [19] as well as "principles and life goals" [17]. An extension of Subjective values would also include mention of cultural, shared and social values, values that emerge through cultural transmission and contextual history evidencing "shared principles and virtues" as well as demonstrating "values held in common by members of a community" [17,19–21]. Most frequently, it is Subjective values that form the basis of the value typology adopted in environmental valuation: a category which itself can be partitioned into a subset of values each of which that can be expressed in relation to ecosystem goods and services (Table 1) [12,19,22].

Table 1. Ecosystem Service Value Classification, adapted from [7,12,19,23–26].

Value Focus	Value Category	Definition	Value Type	Definition
Nature	Non-Anthropogenic —Intrinsic	Value is "non-derivative" and subjective, arising because it has been attributed value based purely for its own sake (e.g., in the words of [12] either a "non-negotiable transcendental", an "identity value" or an attribution to "moral subjects").	Intrinsic (non-use)	The inherent value of a naturally existing environment or life form irrespective of its market worth.
Good Quality of Life	Anthropocentric —Relational	Based on moral/ethical precepts—held values.	Existence	Value attached to the knowledge that ecosystem services (including biodiversity and environments) exist irrespective of whether they are utilized.
			Bequest	Follows the sustainability criteria of the Bruntland commission, in that it concerns the willingness to pay to maintain the good condition of the environment for present and future generations.
			Altruistic	Value associated with the present generation benefiting from biodiversity and ecosystems.
			Transcendental	Relates to end states and behaviours above and beyond specific situations and contexts.
			Societal and Cultural	Based on common concepts of hared ideals, virtues and principles in relation to meaning and worthiness. Grounded within and developed through a cultural context and lens, related to social institutions and generally shared and held society wide. Includes lower level variations such as communal and group values.
Nature's Contribution to People	Anthropocentric —Instrumental	Value is derived from an object's capacity to achieve a given purpose—to be functional. Instrumental values are not absolute as values can change depending upon on how an object is used in a given context. The use value of an object is therefore subject to moral precepts (e.g., deontological, consequentialist, utilitarian).	Market	The value of a commodity/good or service garnered in an open market. So-called "exchange" value. To be exchanged goods must be regarded as scarce and considered useful. Value is derived from transactions, thus market price reflects utility. Exchange value provides a measure of the utility of a flow of goods from a stock, so-called marginal utility, not the utility of a stock of goods.
			Direct Use Value	The value attached to products and services provided by nature for direct consumptive (e.g., timber and food) or non-consumptive use (e.g., recreation and aesthetic experiences).
			Indirect Use Value	The value attached to indirect utilization of ecosystem services, through the positive externalities that ecosystems provide (e.g., flood protection and carbon sequestration).
	Anthropocentric —Inherent	Value is linked to the utility of particular objects (e.g., species, ecosystems etc.) that derives from a good not being substitutable, having a value for its own sake, but also providing end values.	Intrinsic (use)	Commodity values with little market recognition, but still recognized as having use-value.
			Meta-physical/ Option	Value based on the present willingness to pay for the utilization of a particular asset in the future, current likelihood of using it is highly unlikely.

2.2. Valuation—Some Criticisms: Money Is Not Everything

The process of valuation, and in particular economic valuation (which for the purposes of this article encompasses both monetary valuation (i.e., monetization) and exchange value or market price), has a long history and is not as recent as some have previously claimed [27]. However, despite its historical pedigree, valuing biodiversity and ecosystem services for policy and decision-making purposes remains a contested issue [8,28]. For instance, as [12] (pp. 100–101) clearly argue:

> " . . . the trend of the last 30 years is to value almost everything in terms of money, applying concepts of mainstream neoclassical economics to ecological systems [. . .] Despite the broadness of the debate, it is still disputed what is the niche where monetisation can play a positive role, based on an axiological typology of values, on basic economic theory, and empirical evidence regarding its past performance."

However, the over-arching logic behind ecosystem service valuation (ESV) seems to be reasonably clear; as [6] (p. 29) neatly synthesises:

> "The idea that ecosystems provide a range of "services" that have value to humans is an important step in characterizing these systems as "natural capital". In order to view ecosystems as a special type of capital asset—a form of "ecological wealth"—then just like any other asset or investment in the economy, ecosystems must be capable of generating current and future flows of income or benefits. It follows that, in principle, ecosystems can be valued just like any other asset in an economy. Regardless of whether or not there exists a market for goods and services produced by ecosystems, their social value must equal the discounted net present value (NPV) of these flows."

Nevertheless, Baveye et al. [27] assert—based on an historical examination of monetary valuation techniques (especially in an environmental context over the last 50 years)—that there remain a number of prominent inadequacies in the dominant monetary valuation paradigm, concluding that alternative ways of accommodating nature into economic decision-making processes are required.

Criticisms of ESV cover a broad array of issues, including: (i) the suitability and validity of valuation typologies and methods [8,28–32]; (ii) the perception of valuation as simplifying ecological complexity [33]; (iii) the lack of psychological and cultural parameters in models generating preference data [34]; (iv) the ability of valuation to aid land-use policy and biodiversity conservation [35,36]; and (v) conflicts of interest and power dynamics in its management application [37].

The first two criticisms are especially significant. Those cautioning against excessive ESV stress the inconsistencies and subjectivities of valuation methods [8,28,29], whilst also highlighting the inherent biases towards monetarisation and the continued lack of interest in non-use values by economists in valuation exercise and the wider literature [8,28,30]:

> "Non-market valuation, and other economic techniques that emphasize exchange values over cultural and ecological values, have been subject to criticism regarding the inability of exchange values to represent the total value of an ecosystem." [38] (p. 78)

The assertion of a continued lack of interest in non-monetary appraisals of ecosystem services is perhaps increasingly open to debate, as there is much movement in this direction, but that this view persists is, for some, indicative of a continued absence of methodological formalization in this area [39]. Indeed this view may be symptomatic of the widespread use of stated preference methods in ESV exercises, which are for some particularly problematical because peoples' preferences are, contrary to standard neoclassical assumptions, neither "pre-formed" or "stable". However, perhaps more fundamentally runs the argument, is the inability of monetary valuation assessments to capture the diversity of values ecosystems have, for example such as intrinsic value, which through the application of a single metric fails to account for the incommensurability (i.e., the non-reducibility to a single common measure because of ranking limitations [40]) of those values [41].

Commensurate with this perspective is the view that the application of economic valuation to the discernment of ideal values such as equality or justice as well as non-instrumental subjective values is inappropriate. This critique has been particularly well vocalised in the case of cultural ecosystem services [42] and spiritual and aesthetic values [18]. For example, as Cooper et al. [18] (p. 225) argue, this value incongruence arises because:

> " ... aesthetic and spiritual values emerge from (and, in turn, shape) discourses that have different ontological conceptions of nature and different axiological conceptions of the value relationships between nature and humans."

Following a similar line of argument, Irvine et al. [21] (p. 187) emphasize the value reductionist turn that diminishes the plurality of expressed values in favour of utility maximizing economic values:

> "To suggest that the shared values underlying [...] plural and integrated conceptions of nature can be quantified by reference to the sum of individual utility is to prompt a reductionist, positivist approach to the study and valuation of nature, the results of which might (mistakenly) be considered to be a "true" or complete reflection of why nature is important."

Making the case that economic valuation has a limited application to environmental resources as a consequence, Spangenberg and Settele [28] (p. 106) state:

> "Economic valuation methods fail in cases where their basic model is in contradiction with the characteristics of the object to be valued. In particular, the calculus is not applicable to stocks of biological resources such as ecosystems and species since the economic definition of stock values (aggregate value of the flows generated by the stock) fails for renewable resources with their potentially unlimited lifetime."

However, it is not entirely obvious from this latter comment why flows from a resource that has generative properties should not be subject to economic valuation. Renewable resources in a theoretically abstract sense may have an unlimited lifetime but they are not fixed either in terms of their stock or their flows, which means the pattern of change they exhibit is amenable to economic valuation. Nevertheless, clearly the central message of these narratives is that values are multiple and that there are many expression systems or "languages" of valuation in addition to monetary conceptions [17,43].

In the same vein, others bemoan attempts to equalize ESs [8] and simplify ecological complexity by reducing valuations to single dimensions [33]. These "reductionist" critiques are highlighted by [44] (p. 254) in their overview of the main criticisms of monetary valuation, where they remark:

> " ... it has been argued that it is simply impossible to value different environmental goods using a single monetary scale. Comparing goods is always done with regard to a specific comparative value (such as beauty, healthiness or economic benefit). Since there is no overall comparative value ('betterness'), converting all goods to a single scale can only be done by favoring one comparative value. Asking people to express what they are willing to pay for environmental goods, is thus inevitably reductionist with regard to the spectrum of values."

Finally, relating a similar observation based on a brief synopsis of economic valuation critiques, Hansjürgens et al. [45] (p. 229) make the point that:

> "Economic valuation seems to fall short on its aspiration: to broaden the scope of values taken into account beyond private gains and costs when deciding upon allocation and distribution of scarce resources."

2.3. Valuation—A Broadening Field (?)

It is fair to say that, like the parent values from which they are borne, ESV methods represent a diverse smorgasbord of instruments (Table S1 Supplementary Material); equally, however, it is easy to argue that they are predominantly fixated on producing quantitative and monetary-oriented valuations of ES—as the critics have observed [4]. While this may reflect the general situation, it is also true to say that in response to these criticisms there have been considerable movements toward expanding the role of qualitative and non-monetary valuation methodologies [46]. For instance, there are increasing attempts towards trying to define the total economic value (TEV) of ecosystems, which according to [47] (p. 188) is defined as:

> " ... the sum of the values of all service flows that natural capital generates both now and into the future—appropriately discounted. These service flows are valued for marginal changes in their provision. TEV encompasses all components of (dis)utility derived from ecosystem services using a common unit of account: money or any market-based unit of measurement that allows comparisons of the benefits of various goods".

This definition encompasses both monetary and non-monetary facets of valuation, as exemplified by The Economics of Ecosystems and Biodiversity (TEEB) (e.g., [7,48]). In addition, recognising that the environment has important moral, ethical and justice elements developments in recent years have also focused on the application of deliberative approaches such as deliberative monetary valuation (DMV) (e.g., [19,41,49–52]).

Deliberative valuation processes are based on the organic emergence of values emanating from social interaction and communication; as such they do not assume that individuals hold fixed and pre-existing values for ES and biodiversity. According to Brondízo et al. [53] (p. 164) deliberative valuation approaches attempt to:

> " ... turn the value elicitation process into a preference-constructing process in order to deal with the issue that people do not hold pre-determined preferences towards the environment and that such preferences should be well informed and deliberately derived."

A view similarly of expressed by Lienhoop et al. [51] (p. 524)

> "Deliberation is a useful means of exploring why and what people value, because it reveals the respondents' motives associated with their preferences [...] Deliberative approaches contribute to a better understanding of the environmental values individuals hold. It goes beyond answering the question of how much something is valued by also looking at why something is valued."

Building on these notions of deliberation Kenter et al. [52] provide an even wider explanatory definition of what constitutes deliberation and deliberative approaches. Initially the author's state that:

> "Deliberation is essentially a process by which something can be considered, evaluated or appraised. Deliberation can be considered as an individual cognitive-reflective process [...] such as a person deliberating over some kind of personal decision, or as a process of social interaction, such as a group of people trying to establish a common point of view." (p. 195)

They then go on to extend from this very basic definitional platform to link the deliberative process with value formation, communal processes of learning and broader concepts of legitimacy contextualised within a societal context that connects judgements and morality in the decision-making process:

> "We have conceived deliberative value formation as a process of social interaction involving the values, worldviews, beliefs and norms of those taking part, where the process involves both knowledge exchange and social learning, and deliberation on the transcendental values of individuals, communities, culture and society." (p. 203)

Highlighting that:

> " ... the aim of the deliberative process is more directly on formation of values through articulation and communication [...] The emphasis on legitimacy of the process of group deliberation, and on communicative rather than instrumental rationality, where reasoned judgement explicitly bridges the moral and contextual in coming to decisions." (p. 204)

From a practical perspective, as [19] (p. 363) note:

> " ... deliberation is a reflexive process in which participants not only discuss information [...] but also set the terms of discussion, debate how questions should be framed and what types of values should be considered [...] They can discuss how values should be weighted and what rights and duties to take into account, including issues surrounding long-term sustainability [...] Participants can also discuss and reflect upon how the outcome of their deliberations should be used."

Nevertheless, even with regards to these somewhat newer developments criticisms remain. Some suggest, for example, that TEV simply sums the main function-based values and therefore fails to account for the total value of an ecosystem [41,54]. In defence of TEV, others counter that it should not be perceived as an accounting device but rather a heuristic designed to enable a broader consideration of value plurality that recognises individuals hold simultaneously multiple values [45] (p. 231):

> "No valuation approach is able to determine all kinds of values in a single value metric that is meaningful for all situations. However, as the TEV framework illustrates, the array of values potentially captured by economic valuation methods is broader than often assumed by non-economists."

Critics of DMV point to the unsubstantiated nature of many of its hypotheses [5]. Even those sympathetic to DMV acknowledge that depending on the mode employed the approach faces a number of theoretical, conceptual and procedural challenges [50]. Others such as [52] also emphasize that the management of the deliberative process is essential if value formation is not to be skewed or undermined:

> "How deliberative processes are managed and facilitated can also substantially influence outcomes. Deliberative inequalities may arise from inequalities in power and communication, and mechanisms are needed to avoid 'dysfunctional consensus', biasing outcomes or exacerbating conflict." (p. 198)

However, even acknowledging some of the technical difficulties underlying DMV Bunse et al. [41] (p. 95) still argue that:

> "DMV can support a better understanding of beliefs, motivations and socio-demographic aspects that influence choices and actions by local people in relation to the environment. Consequently, it can provide a different and innovative approach that does not only facilitate shared understanding of the human-landscape relationships but also fosters collective management of common values."

In arguing for a "choice democratisation" turn in DMV (i.e., a process that supports value pluralism, value articulation and inter-subjective understanding), Lo and Spash [50] (p. 784) agree with this perspective, stating that:

> "As an institution, DMV has the potential to contribute to the social importance given to the act of valuing and any money values articulated. Meaning is assigned to monetary values through a process of cooperative engagement and is part of what is being sought by

> the deliberative institution. There is no need to rigidly envisage the social act of paying as universally fixed or always being a trade-off [. . .] we argue for DMV to be reconceptualised as a mutual agreement resulting from an interactive process involving the contestation of discourses."

If there has been a general incoherence in deliberative approaches that has prevented their wider uptake and systematic use in ESV, then encouraging progress has been made towards developing a more formalised and rigorous theoretical approach to guide deliberative processes, negotiate potential barriers and interpret their outcomes [52]. In the development of their deliberative value formation (DVF) model, Kenter et al. [52] emphasize that it is "informed by social-psychological theory" with the capacity to identify both "positive" and "negative" outputs of the deliberation process as well as "key factors that influence outcomes". Explaining the wider significance of the DVF model [52] (p. 204) state that:

> "The DVF can provide a clearer theoretical backbone justifying particular orchestrated interventions [. . .] The DVF can be applied as a foundation for characterizing, designing, facilitating, and analysing a very wide range of deliberative methods and [. . .] Deliberative processes designed on the basis of the DVF can also help in understanding and encouraging learning across decision-making contexts and institutional processes of appraisal."

Further recent progress in deliberative approaches and DMV has extended the range of value articulating processes applied to facilitate the expression of individual and group values, whereby DMV has been allied to participatory mapping, systems modelling and psychometric methods [55], alongside more deliberative-interpretive approaches like story-telling [56], ethnography [57] and arts-led dialogues [58]. Combinatorial approaches such as these have the advantage of enhancing the strengths whilst simultaneously reducing the weaknesses of individually applied monetary and non-monetary approaches [56].

All the same, these more innovative and plural valuation approaches still remain subordinate to the dominant mainstream ESV discourse. However, and in spite of the substantial criticisms levied against ESV, more mainstream applications of environmental valuation are still important. For example, proponents continue to praise its capability to manage trade-offs between ESs and alternative management regimes [4]. In relation to this specific point, it is important to bear in mind that although the relevant ESs need to be accounted for valuing bundles of ES does not mean attempting to value everything; rather, it means valuing the marginal changes associated with management alternatives—even though at the margins these value changes can be significant and thus have important economic valuation impacts [22]. Others voices contend that mainstream ESV can be used to assess the different "capital" contributions to human-wellbeing over time, and that it is an essential element in the design of institutional and market-based instruments such as payments for ecosystem services [47].

Increasingly, ESV forms part of the evidence base that aids and informs policy and decision-making processes [4,47,59]. Particularly in times of austerity, an important function attributed to ESV is as a tool to identify where limited conservation funds, which are often derived from public monies, may be best targeted to achieve the most credible gains [59]. Finally, in more general terms, it has been pointed out that ESV is useful as a kind of marketing device highlighting the relevancy of ES to society [60], with the potential to influence policy and planning [41] whilst also making a wider contribution to the sustainability agenda [22]. This supposition, embodied in the TEEB process (Box 1), rests on the premise that as "economics" represents the dominant normative language of politics, articulating the economic valuation of ecosystems is more likely to feedback onto society to better regulate and inform human-nature relationships and decision-making [61]. For example, according to [7]:

> "The invisibility of many of nature's services to the economy results in widespread neglect of →natural capital, leading to decisions that degrade →ecosystem services and

> →biodiversity. The destruction of nature has now reached levels where serious social and economic costs are being felt and will be felt at an accelerating pace if we continue with 'business as usual'." (p. 25)

Box 1. The Economics of Ecosystems and Biodiversity: Progress and development.

Purpose and Innovation: TEEB was established in 2007 at the Potsdam G8(+5) meeting in order to evaluate the economic consequences of continued biodiversity loss (at all scales); make the economic case for continued conservation efforts, and supply policy makers with the tools to make effective decisions [7,62]. TEEB propagated a major re-think regarding the current economic paradigm, whilst acknowledging the need for an economic framework and approach to understand and manage biodiversity loss and ecosystem services degradation [7,62]. More latterly, as [63] highlight TEEB can be seen to be a vehicle for driving the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011–2020, particularly with regards to local and national accounting plans. In this respect, although TEEB was not originally conceived of as a national accounting strategy it nevertheless provides a useful framework, a suite of valuation methodologies and a reservoir of information to enable national accounting of ecosystem services [63].
Outcomes and Impacts: The importance of TEEB lies in its wider goal of highlighting the economic aspects of biodiversity, emphasizing the increasing economic burden created by continued biodiversity loss through its impact on ecosystems and their supply of goods and service, and furthermore, expounding the necessity for an interdisciplinary and international cooperative enterprise [62]. The TEEB initiative is a three phase programme, with Phase 1 (completed in 2008) and Phase 2 (completed in 2011) leading to the current Phase 3 of the programme, which is focused on "facilitation" and "implementation" in relation to specific ecosystem/biome assessments and valuations, the mainstreaming of TEEB into other related initiatives (e.g., green economy) and tools (e.g., natural capital accounting), and supporting country-level TEEB assessments [63].
Critiques: There have been a number of criticisms levied against the TEEB initiative over the course of its duration, some of these have questioned the validity and legitimacy of the valuation approaches it has adopted to assess ecosystem services, and in particular, the emphasis placed on monetary valuation—what some refer to as the increasing "financialization of the environment" [63,64]. Along similar lines, others have argued that TEEB is a driver of neoliberalist capitalism that functions to translate the "natural" into market realities and the "virtual" [65]. Finally, some claim that the focus of TEEB has been too overly concerned with conceptualizing ecosystems and biodiversity in terms of natural capital, with the consequence being that it has ignored other forms of ecosystems and genetic diversity that are produced or co-produced by and with humans [66]. Furthermore, Tisdell [66] also argues that TEEB does not sufficiently highlight the fact that not all natural ecosystems and genetic material may be beneficial human assets, and in this regard may actually act as economic liabilities. Nevertheless, there remains a general consensus that TEEB continues to represent an important step on the journey to a wider acceptance and recognition that the ecosystem service's story does require an economic narrative, but one that is sympathetic to and acknowledges the complexities and critiques widely aired in academic and policy circles [62].

2.4. Valuations—We Still Have Some Way To Go

In some quarters these more positive views of environmental valuation have been given short shrift [12]. Critical reflections on ESV have also drawn attention to the fact that the values valuation exercises generate are neither neutral nor independent of their institutional and social context. In other words, they are not "value free" as it were, but instead evolve out of complex social processes or "value articulating institutions" to use Vatn's [13] phrase that frame their orientation [43] (p. 100):

> " . . . monetary valuations are not isolated phenomena of methodological interest, but part of broader commodification processes, which involve symbolic, institutional, intellectual, discursive, and technological changes that reshape the ways humans conceive and relate to nature."

Taking the construction of value a stage further and with reference to the whole process of valuation, Jacobs et al. [31] (p. 215) argue that:

> "The choice of the types of values to elicit or the value language to use, the selection of social actors to engage in the process, the decision of which methodological tools and measurement units to use, or even the choice of which ecosystem services or benefits to

include, are steps of the assessment that determine the construction of values and, therefore, the outcome of the assessment."

Focusing on "framings", or the context in which points of view are construed, arguments that suggest monetary valuation implies notions of commodification and privatization, many of which preface some of the criticisms we have already discussed, are for some both entirely misguided and misjudged fundamentally misrepresenting the purpose of valuation exercises and their inclusion of monetary estimates. For example, De Groot et al. [59] in their global analysis of ecosystem service valuation estimates state that:

> "We also want to make clear that expressing the value of ecosystem services in monetary units does not suggest that the values should be used as a basis for establishing prices and does not mean that they should be treated as private commodities that can be traded in private markets. Most ecosystem services are public goods that cannot (or should not) be privatized. Their value in monetary terms is an estimate of their benefits to society—benefits that would be lost if they were destroyed or gained if they were restored. Thus, monetary valuations of the importance of ecosystem services to society can serve as a powerful and arguably essential communication tool to inform better, more balanced decisions regarding trade-offs involved in land use options and resource use. Ecosystem service valuations are best seen as complementary to conventional decision-making frameworks, in which the positive and negative externalities of the use or loss of many environmental goods and services are still not, or insufficiently acknowledged. Monetary valuation can help to make these externalities visible and complement the insights on the role and importance of nature gleaned via other quantitative and qualitative measures." (p. 57)

Similarly, Constanza et al. [14] (p. 154) contend that:

> "It is a misconception to assume that valuing ecosystem services in monetary units is the same as privatizing them or commodifying them for trade in private markets. Most ecosystem services are public goods (non-rival and non-excludable) or common pool resources (rival but non-excludable), which means that privatization and conventional markets work poorly, if at all. In addition, the non-market values estimated for these ecosystem services often relate more to use or non-use values rather than exchange values. Nevertheless, knowing the value of ecosystem services is helpful for their effective management, which in some cases can include economic incentives, such as those used in successful systems of payment for these services. In addition, it is important to note that valuation is unavoidable. We already value ecosystems and their services every time we make a decision involving trade-offs concerning them. The problem is that the valuation is implicit in the decision and hidden from view."

The reality is likely to lie somewhere between these two positions, and the research seems to back this up. Recent work on commodification has suggested that there are "degrees" of commodification, so that rather than being a binary phenomenon as normally presented commodification is actually more complex, and that it would be better characterized as a dynamic continuum [67]. Hence, according to Hahn et al. [67] commodification in this context has the following meaning:

> "Commodification of biodiversity and ES means, broadly speaking, the expansion of market trade in to previously non-marketed areas of the environment. This is often described as a process related to the idea of commensurability underlying monetary valuation." (p. 75)

However, in contrast to the consensus opinion that commodification proceeds by a sequential series of stages the authors also argue that:

> " ... these stages need not be consecutive and the process is not necessarily unidirectional or irreversible [...] hence we use degrees rather than stages. Based on Muradian et al. (2010:1206), we define the degree of commodification as the extent to which the value of biodiversity or an ecosystem service has become a tradable commodity." (p. 75)

For others though it is a question of language [44]. From this perspective the concern is less to do with the possibility of real (and perhaps inappropriate) commodification and more to do with the potential consequences of how the language of economic valuation can promote a "commodification in discourse". Here the issue is how a strand of discourse, by gaining widespread ascendency, essentially becomes (and is viewed as) the only conversation in-town: edging-out other equally valid forms of discussion and infusing the narrative in such a way that it potentially reproduces the same moral ambiguities as real commodification [44].

Quite naturally, the question of when and under what circumstances economic valuation is appropriate gains currency. For example, Kallis et al. [43] offer four selection criteria for consideration, namely: "environmental improvement"; "distributive justice and equity"; "maintenance of plural value articulating institutions" and "confronting commodification under neo-liberalism"; wherein, if selected monetary valuation should be able to demonstrate how each criterion is met. Harking from a similar ethos, Spangenberg and Settele [12] (p. 107) make the case that within limited and specified parameters economic valuation can be "defendable", by which they mean that economic valuation should have the following characteristics:

> "To be relevant to decision-making on biodiversity, ecosystems and the services they co-produce economic valuation must be purpose specific e.g., market-based prices for real or hypothetical transactions can be aggregated to calculate damage cost, avoidance cost, restoration cost etc. [...] They must also be case-specific, as the results are based on the subjective value attribution of (often local) stakeholders, without a universal market value as a reference. [...] To be effective, the valuation method chosen must be relevant, referring to budget relevant cost [...] or to the opinions and preferences of the decision-makers' constituencies. They ought to be adequate for the decision to be made and the object to be valued [...] To be credible in the longer-term results have to be cautiously interpreted; all methods make assumptions that have to be reflected and [...] spelt out."

And specifically, in instances where:

> " ... valuation would be helpful to distinguish the cost of options if and only if the different economic cost and benefits are the decisive criterion to choose one of several options for which no overriding priority has been identified based on other types of values—value pluralism, in particular in economics, is an essential element of democracy and requires each agent to reflect her role, interests and positions." (p. 107)

A similar claim is made by the pro ESV camp [5]; namely, that economic valuation in particular has necessary and important heuristic functions in contexts where multiple trade-offs exist between different management regimes choices [5].

Misapplication can also arise from confusion. For instance, Davidson [68] considers that the problem of inappropriate economic valuation resides with the conflated relationship between ecosystem services, intrinsic value and existence value. The argument advanced by [68] revolves around the issue of compatibility, and specifically, that intrinsic value and existence value are mutually exclusive, and that whilst existence value may be compatible with any ES applying the same logic to intrinsic value remains conceptually (philosophically) flawed. Nevertheless, as Davidson [68] is at pains to point out, intrinsic value, as benefits to nature, may still be captured economically although this depends upon the moral stance one takes. The easiest way of thinking about this is that if one adopts a deontological position, that is, behaviours based on the concern for the moral status of other agents or beings (i.e., intrinsic value) then decisions made with regards to that moral status will always be preferred over any other set of preference options. As such, from a deontological perspective intrinsic value is incompatible with economic valuation as by definition other alternatives must have the potential of being favoured. However, from a consequentialist perspective the concern shifts from agents to their actions, wherein morality resides not so much with agents themselves but rather the outcomes of their actions, in this way intrinsic value is perceived as that relating to "states of affairs", and as states of affairs are relative then agents may demonstrate different preference options meaning in this case that economic valuation is entirely commensurate with intrinsic value [68].

Pricing is another thorny issue in ESV. As some of those interviewed by Bauler et al. [69] expressed, the boundary between economic value (more broadly) and market price (more specifically) is easily blurred when monetary valuation enters the fray, with the logic soon being advocated that environmental finance markets are the universal panacea to environmental problems. For Parks and Gowdy [34], part of the problem has been the dominant use of shadow pricing to calculate the social price of environmental goods. Shadow prices are used when market values differ from the "ideal" or "socially efficient" set of prices. However, the assumptions underlying their calculation are somewhat dubious and restrictive, particularly because shadow prices for environmental externalities are not "socially observable". A second problem they identify is the application of welfare theory to environmental valuation via CBA. This is problematic primarily because welfare economics bases its consideration of human welfare at the aggregate scale based on the assumptions of micro-economic theories of human behaviour (which are at best simplistic) and the operations of competitive markets. These assume, for example, that markets can operate in a way that resources can be allocated in an optimal manner such that no individual is left worse off, and that in such cases redistribution of resources can be achieved without affecting prices [70].

Following from the above, in the eyes of Parks and Gowdy [34] CBA suffers two central flaws: Firstly, its value theory foundations and secondly the dubious nature of the numbers it generates. The authors highlight a litany of common problems ensuing from these weaknesses including: (i) the generation of economic values that underestimate the "true" value of ecosystems and fail to capture aspects of sustainability or distributive fairness; (ii) the production of price values that reflect the dominant structural power narratives of the day; (iii) value monism (i.e., a lack of value pluralism); (iv) a misguided addiction to assessing marginal values; and (v) in more general terms its fundamental utilitarianism which can be at odds with the ethics of many individuals [34].

These issues have the potential to create an additional set of problems; specifically, the idea that monetary valuation, as an extrinsic motivator (i.e., a force that motivates people to act for purely instrumental reasons primarily in relation to the prospect of an exogenous gain), and by extension the incentive programmes that are often designed based on valuation exercises, can displace peoples' intrinsic motivations (i.e., pro-social and pro-nature motivations based on pure enjoyment and satisfaction) for conserving biodiversity and ecosystem services leading to an overall decrease in the "demand and support for environmental protection" [44,71]. This so-called "crowding-out" effect (i.e., where monetary valuation, discourse, regulations and incentives displaces peoples' intrinsic motivations for environmental action as a consequence of reduced satisfaction, control aversion or frame shifting) has been identified, but so too, albeit to a lesser extent, has a "crowding-in" effect (i.e., where monetary valuation, regulations and incentives reinforce peoples' intrinsic motivations to engage in environmental protection through internal satisfaction, social standing, or positive attitudes and trust) [71].

Dissenters of the "standard" ESV approach advocate value pluralism arguing against a one-size-fits-all framework [8,30,53]. For example, Parks and Gowdy [34] have recently called for researchers to expend far more effort in pursuing social valuation, describing it as the next "frontier" in ESV. Echoing this sentiment, Dendoncker et al. [22] have advocated for a tripartite valuation system jointly focused on assessing ecological, social and monetary dimensions, whilst pressing for greater use of non-monetary social valuation approaches, a view fervently endorsed by Spash and Aslaksen [72] who demand that the social ecological aspects of ecosystems need to be explored far more richly and extensively. These clarion calls have started to bear fruit. For instance, Kenter et al. [73] have recently developed a shared and social values approach to the appreciation of ecosystem services, where shared values refer to the:

> " ... guiding principles and normative values that are shared by groups or communities or to refer to cultural values more generally [...] the conception of shared values as implicit, communal or public values, and of shared values as values that are brought forward through deliberative social processes" (pp. 87–88)

And social values are those that relate:

> " ... to the values of a particular community or the cultural values and norms of society at large, but can also be used to refer to the public interest, values for public goods, 'altruistic' values and feigned altruistic values, the values that people hold in social situations, contribution to welfare or well-being, the willingness-to-pay (WTP) of a group, the aggregated WTP of individuals, or values derived through a social process [...] or as non-monetary place-based values." (p. 88)

The authors also identify a set of values they term shared social values, a malleable class of values that can appropriate a diversity of meanings for example:

> "'shared social' was used to indicate group deliberated values reflecting that societal context [...] Shared social values were regarded as the outcome of processes of effective social interaction, open dialogue and social learning. From this perspective, shared social values were closely allied to shared meanings ... " (p. 88)

Overall the authors note that:

> "Seven distinct but interrelated and non-mutually exclusive types of shared and social value have been identified (namely: transcendental, cultural/societal, communal, group, deliberated and other-regarding values, and value to society), and the relationship between individual and shared values conceived of as a dynamic interplay, where values can be considered at multiple levels (individual, community, society)." (Bracketed wording is the author's insertion)

Making clear why this development is important the authors say:

> "In general, the elicitation of shared and social values goes beyond the narrow elicitation of individual monetary valuations to incorporate common notions of social goods and cultural importance through social processes that can incorporate a broad set of individual and shared meanings and concerns." (p. 96)

Expanding further on this perspective, [17] has recently argued that one of the virtues of focusing on shared and social value approaches is that they are able to explore the interrelationships between value plurality and connections to individual and communal senses of "place", "identity" and "interpretation", and consequently concretize what are in ecosystem service valuation processes often "abstract and generalised services, benefits and costs." More than that, value expression and exploration can lead to understanding, consensus building and compromise opening up "new democratic spaces" [19] (p. 362):

> "By recognising and making explicit transcendental, societal and communal values [...] we can bring more understanding to what we share and what differentiates and divides us [...] and it may be possible to arrive at a more widely accepted consensus or compromise."

Examination of the ontological basis of shared and social values has suggested that they are not simply preformed (i.e., merely awaiting elicitation through a valuation process), albeit they may have a latent sub-conscious component; but rather, these "contextual" values form and emerge, are expressed, through social processes and dialogue out of which they co-evolve [21]. The implication being that individual preferences are part of a wider "meta-narrative" of social values, and thus are also open to change, divergence and convergence [19,21]. To some extent this is reminiscent of Vatn's [13] exposition of the institutional configuration of values referred to earlier. The assertion that "shared values do not necessarily exist a priori" [21] is important, because the identification of values as forming through the twin processes of co-production and social learning provides a conduit to link valuation and policy making, activities which are often strangely divorced from one another [17].

Additional exploration of social and shared values has also revealed the importance of transcendental values as a central, but largely neglected, component of ecosystem service valuations whose expression, through more deliberative methodological approaches, can have a significant bearing on the management of ecosystems and their services [17,18,74]. The focus on transcendental values has also shown that the observer-participant convention, which underpins most valuation exercises, can work against capturing these values as the observer necessarily affects the valuation process, as [17] (p. 180) explains:

> " . . . challenges common approaches in ecosystem service valuation (e.g., contingent valuation and cost-benefit analysis, but also public participation GIS) of 'measuring' or 'capturing' values through individual observations, and also challenges that it is possibly to objectively sum these to social values."

Developments in accessing shared and social values co-aligns with the growing interest in integrative valuation approaches, the purpose of which is to combine "ecological, socio-cultural and economic valuation tools", engage in "self-critical reflection", establish a "common practice" and "promote the inclusion of diverse values" [31,32]. For example, as Pandeya et al. [32] (p. 251) make plain:

> "The integration of different valuation approaches, especially quantitative measurements of services production, distribution and consumption, should be closely aligned with social and economic valuation approaches."

The principal reason for this being that:

> "Only an integrated approach makes it possible to explore the linkages of the functioning of various ecosystems and their values in terms of biophysical generation, socio-economic and human well-being." (p. 256)

This direction of travel is also fostered at the international scale through the conceptual framework adopted by the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), which in its construction embraces "different disciplines and knowledge systems" and "highlights commonalities between diverse value sets" [23,75]. Indeed, the IPBES conceptual framework places a much greater emphasis on the strategic integration of social and ecological spheres, with its focus on "Mother Earth and Systems of Life" that underpin nature's benefits including "Nature's gifts" which in turn input into a "Good quality of life". The latter being a multi-valent and multi-dimensional notion predicated on the fulfilment of human life, both in a material and non-material sense, which links directly to meta-physical concepts of "balance", "harmony" and "Mother Earth" [23,75]. In this regard the value framing of IPBES provides a more holistic vision in its formulation than that presented by TEEB, which is significant given the status of IPBES as an inter-governmental initiative sanctioned by the United Nations [23].

The recent publication by [76] demonstrates that IPBES's pluralistic value construction is configured around the concept of "nature's contribution to people", which is based on the idea that these are the values that provide the link between what we refer to as "nature" and the sense that human-wellbeing concerns "a good quality of life". In this paper the authors indicate that the IPBES approach presents a broader and more fluidic sense of what "values" are compared to previous frameworks like the Millennium Ecosystem Assessment and even TEEB. Indeed, they show that the emphasis in the IPBES notion of value is on the expression and capturing of a plurality and diversity of world views and value systems acknowledging that these may be both complementary as well as conflictual, and moreover, that within a decision-making arena different types of values may need to be promoted in different ways and to differing extents. The authors also provide a practical-based approach for eliciting, capturing and assessing values based on a five-step process, beginning with stating the specific purpose of the valuation assessment in order to provide the correct framing in which values are to be understood. The second step refers to scoping, which essentially boils down to setting the terms of the valuation approach—where should the focus of valuation be, what values are most relevant, how are they going to be elicited, captured and synthesized. This then flows logically onto the undertaking of the valuation, central to which is the elicitation of as wide a spectrum of values across the core value domains of the biophysical, economic, socio-cultural, health-based and holistic-indigenous as possible. Step four is all about bringing these heterogeneous values together, of "integrating" and "bridging" values, particularly those values that may be irreconcilable or incommensurable. Here the authors argue for participatory processes to navigate these difficulties especially those posed by the problems of power asymmetries between various stakeholders. The last step concerns the communication and dissemination of the valuation to decision-makers and the public.

Integrated valuation approaches are also seen as an appropriate vehicle for the inclusion of legal sciences, the combination of which is regarded as essential for accommodating and negotiating the various environmental and social justice dimensions and repercussions of natural resource use. For example, the process of integrated valuation has been suggested to aid in the definition of what constitutes the "ecological acceptability of the impacts of projects, plans or programs", or "set the threshold of illegal ecological damage" or indeed "contribute to achieve an efficient and fair ecological tax reform" [77].

2.5. Valuation—Moving Forwards

Clearly, progress is being made but there is still much to do and still room for improvement in how ESV is approached and used, particularly for non-marketed ecosystem services [78]. However, and in all probability, a pluralistic approach to ESV is most likely to deliver more valuable and realistic information concerning biodiversity and ecosystem goods and services as a means to inform environmental management and policy decisions [12].

Ultimately, when we think about valuation—valuing biodiversity and ecosystem services—we need to be clear why we are doing it, and what it is we are trying to achieve. We ought not to be axiomatically opposed, on the grounds of idealism, over the integration of economics and biodiversity, but rather, be pragmatic enough to understand the benefits that such an integration can offer in helping to improve the way we manage our interactions with nature, as Charles Perrings [78] (pp. 78–79) remarks in his book *Our Uncommon Heritage*:

> " ... the concept of ecosystem services has nothing to do with market ideologies. Nor does it imply the commodification of nature. Some ecosystems services that are important today are certainly provided through markets. Many foods, fuels and fibers are in this category. Other services will surely be provided through markets in the future [...] But there are many ecosystem services that are not now, and never will be, provided through markets. What the concept of ecosystem services does is to give us a way of characterizing the interests people have in their environment. Whether an ecosystem service can be provided through the market depends on its properties, and not the fact that it is important to people [...] By distinguishing between the price and value of marketed ecosystem services, it explains where markets are likely to succeed in signalling the importance of biodiversity

> and where they are likely to fail. By identifying the value of services for which no price exists, it indicates what we lose when we allow those services to erode."

A view similarly shared by [59] (p. 60):

> "Values in monetary units will never in themselves provide easy answers to difficult decisions, and should always be seen as additional information, complementing quantitative and qualitative assessments, to help decision makers by giving approximations of the value of ecosystem services involved in the trade-off analysis. However, even if we do not have a 'precise' value for, for example, water purification we can assess broadly how valuable it is as an ecosystem service relative to other services, or the costs of the absence of that service, in a particular decision making situation."

3. The Value of Nature

3.1. Recasting Old Debates

In their ground-breaking but highly controversial Nature paper, [79] suggested that the global economic value of ecosystem services, to the world economy, was worth (on average) US$33 trillion year^{-1}; more specifically the authors stated:

> "We estimated that at the current margin, ecosystems provide at least US$33 trillion dollars' worth of services annually. The majority of the value of services we could identify is currently outside the market system, in services such as gas regulation (US$1.3 trillion year^{-1}), disturbance regulation (US$1.8 trillion year^{-1}), waste treatment (US$2.3 trillion year^{-1}) and nutrient cycling (US$17 trillion year^{-1}). About 63% of the estimated value is contributed by marine systems (US$20.9 trillion year^{-1}). Most of this comes from coastal systems (US$10.6 trillion year^{-1}). About 38% of the estimated value comes from terrestrial systems, mainly from forests (US$4.7 trillion year^{-1}) and wetlands (US$4.9 trillion year^{-1})."

At the time, perhaps not unsurprisingly, the paper garnered a wide amount of press coverage as well as a substantial torrent of criticism, especially from mainstream economists such as [80,81]. Their reaction to the article questioned not only the underlying methodologies used to arrive at headline grabbing figures such as "US$33 trillion dollars", but also the intellectual foundation and practical purpose (i.e., policy benefits) of the work. For example, Michael Toman a prominent economist, who is himself not unsympathetic to the idea of "valuing" nature's services, remarked in a *Special Issue of Ecological Economics*:

> "Leaving aside [. . .] technical quarrels about the estimates in the paper, the fundamental problem is that there is little that can usefully be done with a serious underestimate of infinity. The paper asserts in its first paragraph that it is seeking to estimate the 'marginal' value of ecosystem services, but the now-famous figure of $33 trillion/year does not reflect such an incremental calculation. Instead, what has been done is to estimate total social surplus by taking selected average values per unit (e.g., hectare) and multiplying by all the units in the biosphere [. . .] So long as priorities must be set among competing claims for ecosystem protection and/or amelioration, it is necessary to understand how specific changes in different ecosystem states are affecting social interests and values [. . .] A simple point aggregation of 'everything', or a comparison of this aggregate with something like GDP (which is problematic on other grounds in any event), give no insights into either the directions of current changes in ecosystems and their services or the relative urgency of different changes." [80] (p. 58)

For those involved in the original article there remains a sense in which those earlier criticisms continue, and continue to "misrepresent", or at least miss the point, of what they were attempting to demonstrate, which according to Constanza et al. [14] (p. 157) is to communicate:

> " . . . the relative contribution of natural capital now, with the current balance of asset types. Some of this contribution is already included in GDP, embedded in the contribution of natural capital to marketed goods and services. However, much of it is not captured in GDP because it is embedded in services that are not marketed or not fully captured in marketed products and services. Our estimate shows that these services (i.e., storm protection, climate regulation, etc.) are much larger in relative magnitude right now than the sum of marketed goods and services (GDP)."

However, even if we were to agree with the critics and admit that the article suffered from a series of significant economic flaws, putting those to one side for a moment, and with an eye to the bigger picture, the substantial contribution [79] made was not, in fact, the "showy" big dollar estimates widely reported in the news; but, the globally significant and hitherto largely ignored, hidden and woefully undervalued input the biosphere makes in sustaining the human enterprise. Less profound perhaps, but by no means less important, was the article's secondary effects of which two are of particular note: First, the widespread debate it promoted led to the development of better and more diverse valuation methodologies, and second, it paved the way, indeed it cried out for, similar types of analyses to be conducted in the future; and, over the intervening years ES valuations across all scales and ecosystem types have multiplied sharply [59]. Table S2 in Supplementary Material makes this point, for example, by displaying a compilation of global value estimates for 22 ecosystem services across 12 biomes drawn from recent valuation syntheses.

In a recent reappraisal of their 1997 study, though this time with the benefit of more up-to-date ES values and land-use change projections, [14] reported an estimated global value of ES in 2011of US$125 trillion year^{-1} or US$145 trillion year^{-1} (when considering changes in ES estimates and not biomes): an amount virtually twice the value of global gross domestic product (GDP) and much of it contributed by ocean, coastal and wetland systems. Worryingly, the study also illustrated the dire consequences of the continued exploitation of natural resources and perturbations of the geosphere-biosphere system since 1997, with high levels of ES losses resulting from land-use change impacts on ecosystem service provision and flows equivalent to US$4.3–20.2 trillion year^{-1} [14].

Though these values may seem wildly astronomical, in reality, they are neither extreme nor fanciful. For instance, in their global assessment of "synthetic green GDP" (i.e., the aggregated monetary and non-monetary ecosystem service values for each nation) for the year 2009 [82] produced a similarly large figure of US$149.61 trillion (in actual fact this is probably a conservative estimate). Most of this (approximately 75% or US$112 trillion year^{-1}) was provided by marine ecosystems, particularly by coastal ecosystems (US$85.7 trillion year^{-1}), and although terrestrial systems supplied just a quarter of the ecosystem service values much of this was derived from forest ecosystems (US$16.3 trillion year^{-1}) (Table S3 Supplementary Material) [82].

Finally, terrestrial and marine mapping also established Russia, Southeast Asia, Central and South America, Northern and Western Europe and central Africa to have the highest ecosystem service values, indeed as Li and Fang [82] (p. 303) remark:

> "The twenty countries with the largest ESVs represent almost 71.9% (US$ 95.8 trillion) of the total worldwide ESVs (excluding the ESV for the "Open Ocean" biome). The countries with the largest ESVs tended to have large areas (including both the terrestrial and marine areas, especially the marine areas)."

3.2. Values and Scale

It is quite noticeable that many of the ecosystem service values used to derive global estimates largely focus on provisioning and regulating services (66%), and frequently those services provided by wetland (46%), tropical forest (14%) and coral reef (14%) systems: the reason for this seems to be that this is where most value data points are found, as is evident from Table S2 [59]. Further evidence of bias towards provisioning and regulating services is provided by a meta-analysis of the value of wetlands to agricultural landscapes, in which only regulating services were considered; chiefly, flood control, water supply and nutrient recycling [83]. Added to that, the majority of the studies included in the meta-regression analysis conducted by [84] commonly expressed value estimates for three main ecosystem services, namely: food production (188 studies); recreation (153 studies) and habitat–biodiversity (140 studies). In addition, a recent global benefit transfer analysis [74] indicated that most studies and value estimates were related to food provision, recreation, provision of raw materials, maintenance of genetic diversity, climate regulation, water provision and extreme events prevention. The analysis also highlighted a significant bias in the geographical distribution of where valuation assessments were conducted [85].

It therefore seems strange that in global analyses, quite often, little distinction is made between socio-political and economic settings in the aggregation of value estimates; yet, factors such as these can be particularly important in determining the values placed on ecosystem services. For example, covariates such as "social", "socio-economic", "economic", "economic sectors", "life domains of human well-being", and "agricultural subsidies" have been identified as influencing, to varying degrees, monetary value transferability [85]. Furthermore, for instance, the broader social-cultural and political context of developing countries has been suggested to affect how wetlands and their services are perceived and hence valued [84].

One step down from global ES estimates is the pan-regional scale. These include, for example, valuation syntheses of the economic value of marine goods and services in the Wider Caribbean Region (WCR) [86]. Syntheses such as these are quite important because they helpfully include valuations for ecosystem services associated with reef, pelagic and continental shelf ecosystems, as well as highlighting where there has been both a concentration and dearth of valuation activity. Indications are that reef systems have been the primary focus of valuation exercises, particularly in relation to recreation and tourism within marine protected areas, whilst at the same time the continental shelf ecosystem has garnered relatively little attention. The reason for this seems to be, as Schuhmann and Mahon [86] explain, because:

> " ... the economic value of coral reefs for recreation and tourism and coastal protection is considerable and [...] while the valuation of reefs for fishing suggests that many reef-dependent fisheries comprise only minor components of national income and most fishers can be characterized as marginally profitable at best, it is clear that small-scale fishers in the WCR are highly dependent on reefs for livelihoods and food security." (pp. 59, 62)

However, the consequence of this means that there are large valuation gaps across different parts of the WCR marine environment, with the result being an asymmetry in the focus and concern of valuation assessments, for example, a proliferation of studies on the economic valuation of "easy to measure" reef-based goods and services [86].

Whilst analyses estimating the global value of ecosystem services supplied by the world's major biomes are important and provide a measure of what is happening at a planetary scale, a global direction of travel as it were, for the most part we do not experience or value ecosystem services in this way and to that extent these global value aggregations, viewed in this very specific way, carry little inherent meaning. It is at smaller national and regional geographic scales where meaning gains ascendancy. Against this backdrop, national assessments of the economics of ecosystem services and biodiversity as well as green accounting exercises have increased in recent years, as [63] (p. 39) relay:

> "Inspired by the results and recognition of the global TEEB study and its potential to impact on economic as well as environmental policies, a number of countries became interested to carryout national studies on the economics of biodiversity and ecosystem services. The focus and scope of country initiatives varies substantially, depending on countries' specific initial situation, intentions and aims, the initiator of the study (governmental, scientific or civil society organisations), available professional research capacity, approaches chosen, data availability and financial resources. Final, interim, or upcoming outputs range

> from spatially-restricted biome-specific case studies to comprehensive assessments and valuations that may cover an entire country and a multitude of ecosystem services, or reflect on specific issues (climate change, trade chains etc.)."

In the UK, for example, the National Ecosystem Assessment (NEA) presented the first consolidated analysis of the changing ecosystem service landscape ascribing social, health and monetary values to a broad diversity of services [87,88]. The first NEA report released in 2011 painted an all too familiar picture of ecosystem decline, indicating that across eight aquatic and terrestrial habitats roughly 30% of the ecosystem services provided by these systems had waned, whilst others were either reduced or severely degraded such as the case of marine fisheries. Often these changes negatively impacted on biodiversity, particularly changes associated with food and energy production, infrastructure development and public consumption patterns [87]. A follow-up report produced in 2014, apart from consolidating many of the initial findings described in 2011, offered important policy and management recommendations (based on mainstreaming ESV) to inform and improve the future sustainability of the UK's natural capital base [88]. Subsequently, a number of European countries (e.g., Denmark, Germany, Netherlands and Norway) as well as non-European countries (e.g., Bhutan, China, Ecuador and India) have followed suit in establishing and undertaking similar style assessments of their natural capital base [63].

3.3. Green Accounting and Green GDP

The development of a system of natural capital accounts, frequently referred to as green accounting, represents a complementary process to TEEB-style country assessments and appends itself to notions of sustainable economic development [89]. Advocacy for natural capital accounting systems has been growing over the last few years, for example, as Schaefer et al. [90] (p. 7384) detail:

> "Nations throughout the world are recognizing the value of natural capital and are taking steps to account for and conserve it [. . .] Globally, business and financial institutions are examining the implications of natural capital accounting. More than 40 financial institutions have signed the Natural Capital Declaration, an initiative to integrate natural capital considerations into loans, equity, fixed income, and insurance products, as well as in accounting, disclosure and reporting frameworks."

Examples of accounting frameworks include the World Bank's Wealth Accounting and Valuation of Ecosystem Services (WAVES) initiative as well as its Global Partnership for Ecosystem and Ecosystem Services Valuation, and the Inter-America Development Bank's Biodiversity and Ecosystem Services Programme [89,90]. Another particularly important accounting project, one that will grow in importance over the next few years, is the European Union's (EU) Knowledge Innovation Project—Integrated System for Natural Capital and ecosystem services Accounting (KIP-INCA). This project, which is a multi-collaborative enterprise between Eurostat, DG Environment (ENV), DG Research and Innovation (RTD), DG Joint Research Centre (JRC) and the European Environment Agency (EEA), stems from the 7th Environment Action Programme and the EU's Biodiversity Strategy to 2020. The purpose of KIP-INCA is to create a knowledge platform that joins-up and connects various projects and databases to provide an integrated and geo-referenced accounting system of ecosystem services at the EU level. Specifically, bringing together both biophysical and economic data on ecosystems (extent, function, condition, service provision and use, asset accounts and capacity accounts) in a coherent and systematic manner, but also, in a way that can be aggregated and disaggregated at the pertinent scale for the purposes of improving the coordination and sensitivity of natural capital policy decision-making [91].

It is important to point out that green accounting is not a welfare-based approach, rather it is a means by which measures of ecosystem services and ecosystem assets can be formalised into an account system in a spatially explicit monetary and physical manner [92].

Advocates of green accounting, for example Hein et al. [92], even acknowledging certain inherent limitations, argue that it supports environmental sustainability by affording a number of important benefits, including: (i) the standardisation of definitions for key concepts; (ii) cross-comparisons between environmental and national account outputs; and (iii) robust modelling of environmental assets in an integrated and spatially explicit manner that enables accurate assessment of changes in, and judgements concerning the sustainability of, ecosystem assets and services over time. Collectively, these have important consequences for landscape management, planning and strategies designed to encourage the provision of environmental goods [81].

Similarly, the last few years have also witnessed developments in so-called "green GDP"; these analyses make an explicit link between ecosystem services and national income [82]. Taking Bhutan, as an example, Kubiszewski et al. [93] estimated the country-wide value of ES to human-wellbeing to be US$15.5 billion year^{-1}, a figure almost four times greater than national GDP and roughly equal to US$15,400 per capita. What is also interesting is that the authors established that over half (approximately 53%) of the ES provided by Bhutan benefitted people outside the country. Nonetheless, Li and Fang [82] make the point that a lot of green GDP estimates are not well formulated and are often reliant on shaky and ad-hoc accounting data, and so by using spatially explicit mapping approaches for ESV and GDP they argue that their (global) analysis provides a much more comprehensive assessment of the connections between socio-economic and ecological systems. In fact, their headline figure suggests that global ESV is more than double global GDP, as [82] (p. 302) remark:

> "The world GDP (PPP) in 2009 was approximately US$71.75 trillion (for 225 countries or regions), resulting in a total ESV to GDP ratio of approximately 2.09 to 1".

The authors were also able to show that by and large economic development had negative consequences for ecosystems, and that countries with the greatest "economic aggregate" had the lowest ESV index. Nevertheless, this pattern was not always observed [82].

3.4. A Focus on Ecosystems and Bundled Ecosystem Services

Adopting an ecosystems-eye view of value estimates, with respect to forest, coastal and marine ecosystem services research indicates significant spatial, contextual and geographic differences as well as variations in socio-cultural and economic realities, all of which affect service valuations. For instance, the value of forest carbon storage is reportedly worth US$378 ha^{-1} in Paraguay yet as much as US$1,500 ha^{-1} in Borneo [94], whilst averaged figures for saltmarshes and mangroves are as little as US$30.50 ha^{-1}year^{-1} [95,96]. Similarly, the value of forest ecotourism ranges from approximately US$20 to US$140 per person, with lower values for Ugandan forests compared to Costa Rican forests [83]. Forest ecosystem service values in China demonstrate similar levels of heterogeneity between particular ecosystem services, for example, values for hydrological services range from US$12–4938 ha^{-1}, carbon storage from US$4–4422 ha^{-1}, soil conservation from US$3–1302 ha^{-1} and nutrient cycling from US$56–505 ha^{-1} [97]. Likewise in marine ecosystems, the coastal protection services offered by nearshore coral reefs in India are valued at US$174 ha^{-1}year^{-1}, whilst similar coastal protection services afforded by saltmarshes in the USA and mangroves in Thailand are worth about 50 times as much, US$8236 ha^{-1}year^{-1} and US$8966–10,821 ha^{-1} respectively [95,96]. Fisheries maintenance values are also diverse, for example, estimates for nearshore coral reefs in the Philippines range from US$15–45,000 km^{2}year^{-1}, yet for mangroves in Thailand the values are much narrower and smaller ranging from US$708–987 ha^{-1} [95]. These reports also argue for much needed valuation assessments of forest health and hydrological services as well as more detailed assessments of the ESs provided by seagrass beds, sand dunes and beaches [94–96].

Finally, historically speaking, economists have tended to focus on single service valuations of ecosystems, however, recognizing this to be overly simplistic more recent efforts have started to consider the broader bundles of ESs provided by ecosystems and landscapes, thereby capturing multiple ecosystem service values [11,98,99]. Recent examples include the valuation of ecosystem service bundles provided by the Oku Aizu forest reserve in Japan [100], the Bapahai Wetland in China [101], eelgrass ecosystems in Sweden [102], and the multiple non-use values of lesser known aquatic species in Ontario, Canada [103]. The movement towards the environmental valuation of ES bundles co-aligns with trends for integrated valuations of ecosystem services, both as a means of accessing and increasing the value plurality associated with ecosystem services but also with the objectives of fostering better management practices and policies [32,104,105].

The take-home message from this brief coverage of recent valuation appraisals of ES is that the valuation literature is broadening: developing from a background of mainly single ES driven valuations towards a more inclusive set of assessments of ecosystem service bundles (across scales and ecosystem types), alongside a drive to connect ecosystem service valuations with human-wellbeing (socio-economic factors), natural capital accounting and green GDP. It is important to realise that the values we have presented are not hard and fast estimates, certain and unchanging, absolute in their capturing of the flow of ecosystem services, instead they are decision-making aids, as [47] (p. 187) spell out these values are:

> " . . . a reflection of what we, as a society, are willing to trade-off to conserve these natural resources [. . .] and these values provide information that can guide policy making."

4. Problems Come in Threes

The two proceeding sections have discussed the central role of environmental valuation in delivering and underpinning the ecosystem services paradigm. They have described the debates and developments in how valuation methodologies are chosen and applied, as well as how they are able to capture, increasingly so, a broad array of non-monetary values alongside the more traditional, and still dominant, monetary valuation assessments of ecosystem services. In addition we have highlighted (albeit briefly) the range of valuation assessments that have taken place in recent years, primarily to emphasize their commonality as a standard research and policy tool, thereby also demonstrating that their use regularly extends across scales, biomes and ecosystem types. At each point we have alluded to the fact that what often characterizes the debates and controversies surrounding environmental valuation is the specific assumptions that valuations make, what they are able to capture (or not) and the degree of confidence we can have that elicited values accurately reflect reality. This section seeks to take on this latter issue by concentrating on three areas that go to the heart of the matter, namely: uncertainty, discounting and benefit transfer.

4.1. Uncertainty

Uncertainty looms large in policy, in decision-making, in choices about future actions and consequences, in research and the conveyance of information [106,107]. These are often connected to a broader repertoire of uncertainties sometimes described as "deep uncertainty" and linked to so-called "Wicked Problems" [107]. Uncertainty is, however, a central property of complex systems, such as coupled social-ecological systems [108,109]. However, in the context of environmental valuation, what do we mean by uncertainty? Specifically, we mean two things: first, doubt over the probabilities attached to the outcomes of decision-making processes, and second, doubt regarding the possible outcomes that may ensue from taking particular decisions [47].

In particular [47] flag three sources of valuation uncertainty, namely: supply uncertainty (i.e., in the provision of ES, so-called "biophysical uncertainty"); preference uncertainty (i.e., the elicitation of individual values) and technical uncertainty (i.e., the ability to accurately measure values). Preference and technical uncertainty are dual aspects of the "process" of monetary valuation, and have elsewhere been termed "structural uncertainty" and "parametric uncertainty" [110]. According to Boithias et al. [110] structural uncertainty refers to:

> " . . . the structure of the valuation process (i.e., selection of services, benefits, and valuation metrics)" (p. 684)

Whereas parametric uncertainty relates to:

> " . . . the uncertainty in the parameters used in each of the valuation metrics (i.e., valuation methods)." (p. 684)

Similarly, supply uncertainty relates to what [108] identify, in relation to biodiversity, as uncertainties concerning "data" and "proxies", while preference and technical uncertainty variously links to what they define as uncertainties in "concepts", "policy and management" and "normative goals".

Honing in on supply uncertainty, the degree of doubt regarding biophysical uncertainty is dictated by the extent of our knowledge ("epistemic uncertainty") regarding the relationships between ecosystem services and biodiversity, management actions and the provision of ecosystem services and; ultimately, their transformation into human-wellbeing: although the evidence base is increasingly more comprehensive about these connections it is still far from robust [47,108,110]. The main challenges underpinning supply uncertainty have been classified as comprising a triumvirate of issues, specifically relating to: (i) the difficulties involved in disentangling the relationships between ES generation and ecosystem functioning (e.g., spatial heterogeneity that is the supply of ecosystem services is not generally on a uniform per hectare basis); (ii) the requirement that, for valuation purposes, ESs be regarded as independent when in reality they are interrelated and co-produced; and, finally, (iii) the difficulty of pinpointing, and accounting for, ES thresholds [54,61,111].

When we talk about preference uncertainty essentially we are referring to the capricious nature of people's preferences—that individuals do not hold (or have) a fixed set of preferences for the amount they would be willing to pay for particular ecosystem services: obtaining consistent and reliable valuable estimates then is like dealing with shifting sands, they are forever moving and hard to pin down [47,106] This is because, as Haila and Henle [108] (p. 35) express:

> " . . . uncertainty is inherently contextual, making sense of uncertainty in specific situations requires that we take into account several aspects of cognitive work and social reality."

This has obvious and important ramifications for conducting valuations. Regularly used valuation methods, such as contingent valuation, have attempted to identify peoples' uncertainties upfront by allowing individuals to express a value range rather than a specific value. Although adopting a value range approach is regarded as highly promising, the problem of what value range ought to be chosen to elicit the most "truthful" responses remains [47]. Clearly, valuation metrics and the type of metric used to elicit particular information about a specific service or services are crucially important, as Boithias et al. [110] (p. 684) remark:

> "The choice of valuation metric has been reported to be relevant for the valuation, as different valuation metrics might be based on the same set of economic assumptions but approach the ecosystem services from different perspectives, with results varying widely depending on the choice of valuation metric rather than on the object under analysis."

Finally, technical uncertainty relates to the reliability of stated preference values and the degree of "truthfulness" they represent. Extending this further and drawing on the definition of parametric uncertainty, technical uncertainty is therefore also associated with uncertainties in the valuation metrics included in market prices for example [110]. Consequently, the drive for accuracy in valuation methods represents a constant battle against the odds, particularly for revealed preference and price-based approaches, where data availability and inability to capture non-use values are problematic [47].

4.2. Discounting

Directly linked to uncertainty and intimately related to the concept of sustainability, and like sustainability hard to pin down, discounting neatly encapsulates one of the core features and difficulties inherent to sustainability discourse, namely, our relationship and responsibility with and to future generations, as [112] (p. 350) explain:

> "The concept of discounting is central to economics, since it allows effects occurring at different future times to be compared by converting each future dollar into a common currency of equivalent present dollars. Because of this centrality, the choice of an appropriate discount rate is one of the most critical issues in economics. It is an especially acute issue for projects involving long time horizons because in such situations the results of cost–benefit analysis (CBA) can be incredibly sensitive to even tiny changes in the discount rate."

Discounting, in general as well as in relation to the environment, has been discussed extensively elsewhere, for example [113–115], we therefore do not provide an expansive theoretical coverage here; instead, we highlight some of the core challenges associated with discounting environmental assets and services. The primary concern in providing valuation estimates is how these will be used in policy-making and management contexts to influence the continued provision of ecosystem services into the future. In other words, how can valuations be applied to inform our choices and underline our responsibility to use and conserve natural resources in a manner that is consistent with sustaining present generations, whilst at the same time ensuring future societies will be in a position to flourish?

> "Evaluating the impacts of present activities on those living in the future is one of the most critical areas of uncertainty in environmental policy. The debate surrounding discounting is not only important to the numerical valuation of the costs and benefits of environmental policies (social benefits/costs and optimal path calculations), it is also central to designing policies that are incentive compatible with observed human behaviour and evolved neurological structures and pathways." [116] (p. S94)

As the quote above implies, discounting is a highly contested area of (environmental) economics, primarily because the rate adopted can produce two strongly contrasting outcomes: one that is highly conservative and favours fewer restrictions on the present use and consumption of natural resources for the purpose of maximizing current human welfare and a second, more radical stance, that calls for substantial curtailments in present natural resource use—generally through aggressive environmental policies—in order to sustain human welfare in the future [116,117].

The continuing challenge presented by discounting remains its standard neo-classical economic foundations which generally conceive of individuals as rational and utility maximizing in their behaviour and; moreover, characterizes their decision-making and actions as being underpinned by complete and stable preferences as well as perfect information regarding the choices available to them. Thinking has, thankfully, started to repeal this orthodoxy and progress beyond the confines of these flawed caricatures of human decision-making. For example, insights from behavioural, neuro and evolutionary economics (e.g., [34,115,116,118–121]) are starting to provide a much richer picture of peoples' internal cognitive decision-making processes, emphasizing its complexity and fuzziness, and some of these insights have been especially revealing demonstrating that people, for example, quite readily display loss and risk aversion. In the case of loss aversion, because people feel losses more than equivalent gains they place a higher value on a loss compared to a gain of the same magnitude [118]. This, in part, helps to explain why quite often WTP and willingness to accept (WTA) values can be so very different [117]. On the other hand, in the case of risk aversion peoples' concern is with regards to the probability of obtaining some future reward or "pay-off" in light of the uncertainty surrounding how the future will unfold, this means that if people perceive future events to be highly uncertain they will tend to stick with what they know rather than making substantial changes to their day-to-day behaviours [117]. These developments have also highlighted that people have a tendency towards hyperbolic and inconsistent discounting. What does this mean? In the case of hyperbolic discounting, that discount rates are no longer straight line phenomena but decline and flatten over time meaning that future benefits of present action can be woefully underestimated. In contrast, inconsistent discounting refers to the fact that people can display different discounting behaviours for different outcomes this, however, dramatically increases the chances of producing conflicting discount rates [117]. Finally, these new understandings have indicated that discount rates themselves have to acknowledge both uncertainty and price issues. Why? Because a highly uncertain future can mean a drastic alteration in discount rates as people refocus their concern on "safer" assets likely to guarantee a future level of economic welfare [106]. Also, estimating the rate of change in prices for non-consumption goods (in the standard sense), like biodiversity for example, is not straightforward such that situations could arise where environmental damages could offset a positive discount rate [117].

Based on these insights Gowdy et al. [117] reach the stark conclusion that there exists no set of adequate economic-only guidelines for selecting a particular discount rate. In their view, whatever forms discount rates take, that choice, is a normative one—a matter of ethics and a moral act. The authors go on to argue that a variety of discount rates ought to be applied, including zero and negative values, though they are careful to emphasize that this needs to be set within the context of the particular conditions of the valuation exercise. This position is also supported by [61]. Overall, a higher discount rate is considered likely to produce poorer future outcomes for ecosystems and biodiversity, particularly on a project by project basis. Conversely, Gowdy et al. [117] also acknowledge the possibility that a lower discount rate, applied across the entire economy, by encouraging greater levels of investment and stimulating economic growth may result in environmental damage.

Picking up on this thread, in their review of the literature regarding the appropriateness and application of dual discount rates to manufactured consumption goods and environmental (impacts) services (as a means to account for the divergence between the growth in global GDP alongside the decline in global ecosystem services) [122] (p. 274) comment that:

> "From this analysis it has emerged that dual-rate discounting is warranted if relative scarcities between different goods are changing over time, yet, future consumption is valued in constant relative prices or future prices for environmental goods are unavailable. Differing discount rates then serve to account for changing relative scarcities between the different goods. In contrast, if future consumption is valued in prices that change over time to properly reflect changing relative scarcities, then a uniform discount rate (reflecting pure time preference only) is appropriate."

Against this background, Baumgärtner et al. [122] performed an assessment of 10 ecosystem services across a number of different countries to estimate the differences between discount rates for ecosystem services and manufactured consumption goods, finding that:

> " ... ecosystem services in all countries should be discounted at rates that are significantly lower than the ones for manufactured consumption goods. On global average, ecosystem services should be discounted at a rate that is 0.9 ± 0.3%-points lower than the one for manufactured consumption goods. The difference is larger in less developed countries and smaller in more developed countries. This result supports and substantiates the suggestion that public cost-benefit-analyses should use country-specific dual discount rates—one for manufactured consumption goods and one for ecosystem services." (p. 273)

Ultimately, producing a discount rate is about expectations of future human welfare and wealth. Therefore how much should be consumed now and how much should be left for future generations to consume are predominately moral judgements. Such decisions need to carefully balance the likely potential impacts on natural capital of business-as-usual approaches to consumption, which is fuelling global increases in GDP, with the potential negative consequences for doing so on long-term economic growth and human welfare in circumstances in which the natural capital base has become irrevocably eroded. However, as [116] (p. S102) acknowledge:

> "Especially for long-term threats like climate change and biodiversity losses, environmental valuations to be discounted suffer from our current lack of knowledge, high uncertainty and our weaknesses to act as regent of future generations' needs."

Thus, the authors call for a social valuation approach to discounting, ultimately arguing that:

> "Types of behaviour conducive to cooperation, doing with fewer material possessions, and recognizing the necessity of shared sacrifice, are also part of the human experience and these behaviours should certainly be taken into account in any intergenerational policy decisions." [116] (p. S102)

4.3. Benefit Transfer

Over the last 20 years or so, benefit transfer (BT) has become an increasingly popular valuation and policy tool, primarily because it is seen as relatively cheap and easy—big pluses in an era where the costs and time associated with undertaking primary valuation studies are regarded as [123–125]:

> "Benefit transfer is increasingly being used to meet the demand for increased information on nonmarket ecosystem service values in a manner relevant to the time frame and budget within which decisions often have to be made." [125] (p. 2)

Benefit transfer describes the process whereby monetary environmental values pertaining to particularly ecosystem services at a specific locale or "study site" are transferred to a different but relatively similar "policy site" [40,60,123–125]. The point has been made that, if carefully crafted, BT valuations can provide good approximations to areas that have not been previously studied [125]. However, issuing a word of caution, Johnston and Rosenberger [124] note that there is considerable confusion and controversy in the academic literature regarding the overall effectiveness of BT, as well as over what the "optimal" BT methods to employ are. These disputes also relate to a long-standing divergence between how academics and policy-makers perceive BT, with the former often appraising it from an idealist perspective (i.e., primary valuation studies are preferential) and the latter taking a more pragmatic stance (i.e., what works best in the "real" world). Debates such as these, though they may seem anodyne, are actually quite significant because the values BT valuations condone can have important policy and management implications for biodiversity conservation and the provision of ES: persistent issues concerning valuation transfer practices should not therefore be ignored but instead acknowledged and addressed [124,125]:

> "Otherwise, if violation of the basic principles and methodological requirements for valuing ecosystem services through benefit transfer remains widespread, this may ultimately undermine the integration of ecosystem service values into policymaking." [125] (p. 2)

A significant proportion of BT debates concern the types of BT that are or should be employed, and four broad categories of BT approaches are recognized: (i) unit BT (where values for an ecosystem service at the policy site are a product of an averaged monetary value for ES at the study site multiplied by the estimated quantity of ES at the policy site); (ii) adjusted BT (similar to unit BT but the calculation of values also includes differences in beneficiary characteristics such as income, prices, and population between the study site and the policy site); (iii) value or demand function transfer (these use a value function derived from valuation methods such as hedonic pricing or choice modelling at a study site alongside value parameters for the policy site to transfer values); and (iv) meta-analytic function transfer (where values are derived from several valuation studies alongside value parameters for the policy site) [47,60,125].

To varying degrees these BT modes are challenged by a number of issues, and [47] outline eight in particular: (i) transfer errors (these arise when the values transferred differ from the actual values of the ecosystem at the policy site either because of "measurement errors" or "generalization errors". Available evidence seems to indicate that meta-analytic transfer functions suffer from fewer generalization-associated errors [47,124]); (ii) aggregation (here the challenge is accurately accounting for supply and demand in order to assess the total value of a service without producing spurious results. On the demand side this means knowing who the beneficiaries are and adequately capturing their WTP for ESs. In relation to supply, this means estimating the values for actual service delivery rather than potential service supply. Also, the dangers of double-counting have to be avoided [47,111,124]); (iii) spatial scale (can affect BT in three main ways: as a determinant of ES provision and the location of beneficiaries; as an element in determining the proximity and availability of substitute or complementary ES for beneficiaries, and its impact on distance decay and discounting [47,111]); (iv) variations in ecosystem properties and context (the values attached to ESs will be affected by ecosystem type and condition, the geographic and socio-economic characteristics of beneficiaries and the context in terms of other available sites or services [47,125]); (v) non-constant marginal values (that is to say, ecosystem service values may have diminishing or increasing returns to scale perhaps depending on fundamental ecological processes or spatial-related relationships. At the very least both the size and change in size of the ecosystem must be factored in to transfer value determination [47,124]); (vi) distance decay and spatial discounting (distance decay refers to the pattern of decreasing ES values witnessed as a consequence of the distance beneficiaries are away from the supply of ES, which is also related to the type of service being valued. Spatial discounting relates to the "weightings" applied to values according to the distances ecosystem services are from beneficiaries. Failing to account for distance decay effects is likely to produce an overestimation of total ES values [47,124]); (vii) equity weighting (proposes to account for the different level of dependence poorer households and communities have on ES compared to wealthier households and communities [47]); and (viii) primary valuation availability (without primary evaluation data (on ecosystems, ecosystem services and socio-economic and socio-cultural conditions and characteristics) the capacity of BT to produce realistic values is questionable conditions [47,124]). Many of these issues are also discussed in [85,124,125].

How would we sum-up the current BT landscape? Overall, meta-analytic functions are regarded as the most robust and advanced form of BT with respect to dealing with the challenges outlined above. For example, in a recent article, Schmidt et al. [85] employed a meta-analytic approach to develop global value transfer functions based on the monetary evaluation of ecosystem services drawn from a global data set of 194 cases studies and 839 monetary ES estimates. This allowed the authors to provide the first global scale "quantification of uncertainties and transferability of monetary valuations." Using this approach the authors were able to demonstrate that their models (value transfer functions) for 12 ES (i.e., food provision, waste treatment, climate regulation, recreation service, raw material provision, habitat service, soil fertility regulation, erosion regulation, maintenance of genetic diversity, extreme events prevention, provision of medicinal resources, and water provision) described from 18% to 44% of the variation in monetary values. The confidence regarding the extrapolation of these value transfer functions was regarded as reliable (low to medium levels of uncertainty) for 70% to 91% of the Earth's terrestrial surface. The article also established that the ecological, social and economic context, alongside the policy setting, scale of valuation and valuation methodology used were the primary covariates contributing to value transfer uncertainties [85]. However, meta-analytic functions are also the most complex and time consuming modes of BT. Nevertheless, recent modelling developments have helped to improve function transfer estimates, and moreover, the development of web-based resources looks set to continue to improve BT methods going forwards, by enabling best practice exchange and the provision of accessible primary valuation databases [125].

5. Conclusions: Future Research

Drawing together the evidence we have laid out over the preceding Sections 2–4, it is clear that progress in ecosystem services valuation has been substantial and many insights have been gained through endeavours such as TEEB, IPBES and associated processes. For example, as [61] relate these collaborative and transdisciplinary research and policy assessments have demonstrated the importance of using integrated knowledges and methodologies to undertake economic valuations. Nevertheless, there are still many areas of ESV that need to be improved. For instance, as they go on to emphasize, ESV needs to be conducted at relevant policy scales that acknowledge the context and temporal dependent nature of ecosystem processes and human values. In this sense, they argue it is essential that the socio-cultural milieu that pervades and informs value articulating institutions are recognized by those individuals involved in economic assessments [61].

It is clear therefore that there are a number of significant avenues to pursue to further progress the development of more realistic, credible and useful environmental valuations, and from the evidence-base (e.g., [11,17,19,31,32,59,61,71,72,121,123,126,127]), it seems reasonably apparent that actions need to be taken in the following areas:

(1) Improving data availability, reliability and heterogeneity (e.g., increase the number of ecosystem services and estimates per biome as well as value estimates per biome), with a need to focus on micro-macro system level relations and accounting for data scarcity issues at decision-making scales;

(2) Providing more consistent and coherent terminology and methods across studies to enable thorough in-depth systematic reviews and meta-analysis assessments;

(3) Focusing more heavily on valuing and accounting for supporting and cultural services as well as neglected biomes such as deserts and Polar Regions;

(4) Furthering the development of tools for cross-scale valuation, particularly focusing on heterogeneities in individual and social preferences concerning environmental services that have representation across scales;

(5) Expanding valuation methodologies to integrate non-use and use-values, developing more integrated valuation approaches concentrating on the inclusion of stakeholder constituencies (including the public—perhaps with a citizen science focus) in valuation design and knowledge production as well as assessing the wider social (societal level) impact of integrated valuation cases;

(6) Focusing on mainstreaming social valuation methods (e.g., deliberative approaches) as part of standard ESV assessments and further investigating how different elicitation processes construct and frame values alongside expanding the evidence base to illustrate the importance of shared and social values across sectors and spheres. In particular, attention needs to be paid towards the differing ontological, axiological and epistemological basis of value pluralism and how these are accommodated in and by valuation methodologies;

(7) Co-linear with points 4 through 6, a greater focus and attention should be paid to addressing the underlying basis of peoples' choices, decisions and ultimately behaviours (i.e., their choice architecture especially in relation to uncertainty);

(8) Improving the integration and incorporation of environmental and social justice dimensions within valuation typologies, frameworks and methodologies;

(9) Refining valuation techniques to account for: marginality, double counting and benefit transfer; selection bias of value estimates; the explicitness of their value assumptions; aggregation of monetary values and deliberatively derived shared and social values; the spatial explicitness of ES provision and distribution, ecosystem disservices and threshold effects in ecosystem states; differences in local socio-economic conditions and the scale at which services are provided to beneficiaries;

(10) Finding ways to integrate and scale-up micro-economic outcomes to connect with a broader macro-economic framework for ecosystem accounting; and

(11) Developing inter- and cross-sectoral analysis of the individual impacts of policies for ecosystem management.

Moving ahead on the multiple fronts highlighted will ensure that future ecosystem valuation developments will be integrated and holistic, that avenues will be explored to reconcile monetary and non-monetary methods, and that a new "value space" will be opened-up bringing to the fore, specifically within policy decision-making domains, the depth, extent and richness of value attributes that are truly reflective of ecosystems and their services. These developments will help to guarantee that, in the future, in contrast to recent assessments [128], ESV is not only central to the evidence-base informing environmental policymaking but also fosters an inclusive sustainability and human-wellbeing ethos.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/9/5/850/s1, Table S1: Corpus of Valuation Methodologies, adapted from [4,5,41,46,47,60,73,126], Table S2: Maximum value estimates for 22 ecosystem services across 13 biomes (in Int.$/ha/year, 2007 price levels (2009 price levels for [82]))*, Table S3: Summary of global ES flows, adapted from [82].

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