Prices for ecosystem accounting

May 2017

Giles Atkinson

Department of Geography and Environment and Grantham Research Institute for Climate Change and Environment, London School of Economics and Political Science

Carl Obst

University of Melbourne and Institute for the Development of Environmental-Economic Accounting (IDEEA)

WAVES

Acknowledgements

The authors wish to thank Jeffrey Vincent and Bram Edens for their valuable input to this paper through discussions, ideas and written comments, as well as a note on valuation in accounting drafted by Jeffrey Vincent. The authors are also extremely grateful to Ed Barbier, Eli Fenichel, Michael Vardon, Alessandra La Notte, Anton Steurer and Rocky Harris for extensive comments and discussions on earlier drafts. The comments of a number of participants at a 2016 WAVES/PTEC workshop are also gratefully acknowledged, especially by Kirk Hamilton, Lars Hein, Pushpam Kumar, Paulo Nunes, Michael Vardon and Kim Zieschang, as well as support and comments from Sofia Ahlroth, Juan-Pablo Casteneda and Glenn-Marie Lange. Any errors are the sole responsibility of the authors.

This paper was prepared by the authors as part of the World Bank-led Wealth Accounting and Valuation of Ecosystem Services global partnership (WAVES). The opinions expressed are the authors' own and do not reflect the view of WAVES or the World Bank.

Table of Contents

Executive summary

Intent of this paper

The intent in pursuing this research is to activate a dialogue among economists and national accountants about the approaches to valuation of ecosystems and ecosystem services. For too long, these two groups of experts have managed to consider issues related to the valuation of non-market environmental stocks and flows in relative isolation. The emergence of the System of Environmental-Economic Accounting - Experimental Ecosystem Accounting (SEEA EEA) in 2012 has brought the question of valuation of these stocks and flows firmly back into the view of national accounts experts.

At the same time, the application of valuation approaches developed in the space of environmental economics has been increasingly called upon to support the valuation of ecosystem services, at both small and large scales. Given the growing interest in both accounting and economic valuation in an environmental context, this paper describes the extent to which ecosystem service values estimated using valuation techniques in environmental economics are consistent with the valuation principles of the System of National Accounts (SNA), which are also applied in the context of ecosystem accounting.

Past dialogue on this topic has led to the overall conclusion that - from the perspective of national accountants - the values generated through most environmental economic techniques are not appropriate for use in accounting. Therefore, to advance the discussion it is necessary to return to the conceptual underpinnings of both economic valuation and national accounting. Indeed, important parts of the paper involve explaining aspects of environmental economics to accountants and explaining the SEEA's ecosystem accounting approach to economists. These explanations are not intended to be exhaustive; for more details on these topics, readers are encouraged to consider additional literature.

With a focus largely on conceptual issues, this paper does not provide specific guidance for compilers in the implementation of valuation techniques. However, it does make progress in advancing the understanding of national accounting requirements and the potential of environmental economics to be applied in that context. It is intended that this progress can underpin the development of practical guidance for compilers in this area.

Not all conceptual issues are pursued in this paper. The focus is on the valuation of flows of ecosystem services as distinct from valuation of the underlying stocks of ecosystem assets. There are close links between these two targets of valuation, but there are also a number of important additional considerations with respect to the valuation of assets that require separate discussion.

Key findings

The framing of ecosystem services

First, reaching a common understanding of the description of the relationships between ecosystem assets, ecosystem services, the associated economic units (businesses, governments and households), and the benefits enjoyed by these units remains a work in progress. When presented in relatively broad terms, there is agreement about the existence and importance of the links between ecosystem services (both market and non-market) and the underlying stocks of ecosystem assets from which they are generated, as well as the use of these services by economic units. It is clear however, through the drafting and discussion process for this paper, that the precise description of these relationships is not agreed upon. At a practical level, this perhaps does not have a significant impact in the short term. However, without reaching a common articulation of these relationships and the associated measurement boundaries, the dialogue and exchange on these topics is confusing. It also makes it difficult for newcomers to the discussion to contribute. Ultimately, it will be important to continue to press towards an agreed description. It is hoped that the discussion in this paper represents an important contribution in this regard.

The purpose of valuation and institutional arrangements

Second, understanding the purpose of valuation is important in ensuring that the discussion of valuation techniques is being considered with the same valuation target in mind. This was a general finding of the SEEA EEA, but this paper provides a stronger conceptual context for this conclusion. The general objective of valuation for accounting purposes is to estimate a price for a flow of ecosystem services that has already taken place. Thus, accounting is retrospective in its outlook and must frame the valuation in the context of a past reference accounting period.

It transpires that this view is not completely incongruent with the economic conception of price. Indeed, any incongruence is often an artefact of a different use of valuation in environmental economics: notably, where the aim is to establish or model an ideal or shadow price that would reflect a situation in which ecosystem services flows were optimally provided at socially desired (rather than actual) levels. To this end, this sort of use typically considers an alternative scenario with associated assumptions concerning institutional arrangements, etc.

Congruence can exist, however, where valuation in environmental economics is used to identify prices for ecosystem service flows associated with current institutional arrangements. The challenge then lies in deciding which institutional arrangements are appropriate for national accounting purposes. At this time, a clear answer to this question cannot be provided. However, the discussion here:

- makes clear that the valuation of ecosystem services for ecosystem accounting will require acceptance of, and assumptions regarding, institutional arrangements;
- explains that making assumptions concerning these arrangements is not incompatible with national accounting but, equally, the assumed arrangements are likely to be different from the type of ideal market arrangements that may be most commonly applied in environmental economic valuation;
- highlights that the economics literature provides a range of alternative models for both the demand and supply side arrangements that may be used to inform a decision for national accounting purposes.

Resolving the treatment of consumer surplus

Third, an important conclusion is that the long-standing reservation of national accountants concerning consumer surplus should be considered resolved. Recalling the retrospective nature of accounting, it is certainly the case that accounting does not record amounts of consumer surplus since these amounts cannot be traded. So, for any given transaction, however effectively a seller can price-discriminate among buyers, the implied or revealed transaction price cannot, by definition, include any consumer surplus for that specific transaction. It is also common for environmental economics valuation techniques to be used to estimate levels of, and changes in, consumer surplus in alternative scenarios (as noted above). National accountants have traditionally used these two points to argue that the values and the valuation techniques themselves are, therefore, inappropriate for accounting.

However, the reality that clearly emerges from this paper is that, while environmental economics valuation techniques can be used to estimate consumer surplus, in order to do this, they estimate marginal prices and describe demand curves for given goods or services. This is a potential starting point for the estimation of prices for accounting, and it is clear that the techniques of environmental economics cannot - and should not - be dismissed on the grounds that they are used to estimate consumer surplus. National accountants should become far more willing to engage in this important area of work. The practical reward is that this opens a rich empirical record of data on economic prices that may be considered for use in an accounting context.

Using ecosystem service channels

Fourth, in returning to the underlying framework behind the environmental economics valuation techniques, the paper describes the framing of ecosystem services valuation in terms of ecosystem service channels (Freeman *et al*. 2013). The three channels represent the different ways in which economic units (primarily businesses and households) engage with ecosystems. Valuation techniques can be grouped by suitability to valuation of different channels.

This long-standing framing of valuation techniques has been applied in this paper in two ways. From an accounting perspective, the concept of channels between ecosystems and different economic units aligns very well with the concept of the supply and use of ecosystem services as developed in ecosystem accounting. This finding of a common framing in both environmental economics and national accounting is important as it provides a fundamentally strong point of departure for ongoing dialogue, identifying as it does the character of the transaction that is taking place.

In addition, by considering valuation techniques from the perspective of channels, the focus shifts from applying valuation techniques purely on the basis of the type of ecosystem service. Most commonly, at least in accounting applications, the valuation of ecosystem services has first described a particular service and then sought out an appropriate technique for that service. The channels approach, however, suggests a more refined starting point of identifying both the type of service and the user of the service. As a consequence, it is likely that certain techniques may be applied to a wider range of situations than usually considered. The channels framing is not a panacea, but in terms of better ascribing valuation techniques to the range of transactions in ecosystem services that are within scope of accounting, it is an important step forward.

Applying valuation techniques

Finally, based on these conceptual discussions and framings, the following conclusions can be drawn about applying environmental economics valuation techniques for estimating prices for accounting purposes.

- Production, cost and profit function techniques can be considered for use in valuing all types of ecosystem services (provisioning, regulating, cultural) that provide an input to businesses. Conceptually, the ideas behind these methods are well aligned with national accounting valuation principles.
- Hedonic techniques may be applied for specific ecosystem services. The theory behind these methods is well aligned with national accounting valuation principles.
- There is a range of techniques, including defensive expenditures and travel costs, that use information on expenditure, especially by households, as a means to estimate demand for specific ecosystem services. If combined with a suitable estimate of the level of supply, this information can form the basis for valuing various ecosystem services, particularly regulating and cultural services.

- The estimation of stated preferences using contingent valuation or choice experiment techniques can support the derivation of a demand curve for those ecosystem services with clear public good characteristics. Again, determining a corresponding estimate of supply is required for the derivation of prices for accounting purposes.
- The use of cost-based techniques (such as replacement cost and restoration cost) is not strongly supported within the environmental economic community. The primary concern is that the estimation of these costs does not take into consideration the preferences of the users or beneficiaries (or, at least does not provide evidence to reassure about these preferences). The environmental economic literature identifies three requirements before a cost-based valuation should be accepted: (i) whether the costs relate directly to the service being measured; (ii) whether the costs reflect the least cost alternative; and (iii) whether the costs would actually be paid if the ecosystem service were lost. In the evaluation of this last criteria, the need to find cost-effective but meaningful ways of seeking assurance that these approaches do capture the views of beneficiaries, may point to a role for environmental economic techniques.
- The use of information on the relationship between ecosystem services and human health outcomes is problematic from a national accounting perspective. Health outcomes are not valued in the measurement of output in the national accounts, which focus instead on the level of service provided by doctors, nurses, hospitals, etc. Further consideration is therefore required about the extent to which declines in ecosystem services that result in poor health outcomes - and which may then lead to increased health costs - should be captured in a set of accounts aligned with the SNA.

Conclusions and next steps

The research and associated discussion presented in the paper has made some positive steps towards a more common understanding of the valuation requirements for accounting and the potential of existing valuation techniques to be applied. It is clear that this discussion must continue while at the same time, practical application of valuation techniques for accounting purposes must also tested and the feedback used to inform ongoing conceptual discussions.

Using the framing provided in this paper it is planned to pursue two additional directions. First, the description of more specific advice on the use of the methods associated with different channels to the estimation of transaction prices for specific ecosystem services. This work will be directed towards supporting current efforts in ecosystem accounting. Second, the extension of the introductory discussion of the valuation of ecosystem assets provided in this paper. Issues such as the estimation of asset lives, the choice of discount rates and integration with existing national accounts balance sheet values are of particular relevance. The aim in both of these extensions is to utilize the existing expertise and experience across the economic and accounting disciplines to find solutions to clear and current measurement challenges.

1. Introduction

1.1 Opening remarks

The role of natural capital accounting to support assessments of environmental sustainability and improved understanding of the connections between economic activity and the environment is increasingly recognized (World Bank, 2016). At a national level, this recognition is reflected in the development of accounting frameworks that extend the standard System of National Accounts (SNA) that underpins the measurement of economic activity (e.g. GDP) and national wealth (EC et al. 2009). The System of Environmental-Economic Accounting Central Framework, or SEEA CF (UN et al 2014a), was adopted as a statistical standard in 2012 by the United Nations Statistics Commission. Its implementation is being actively undertaken at national and international levels, including through the World Bank Wealth Accounting and Valuation of Ecosystem Services (WAVES) program.

A substantial extension of the SEEA is the application of national accounting principles to the measurement of ecosystems. This is described in the SEEA Experimental Ecosystem Accounting (SEEA EEA) (UN et al 2014b). In broad terms, it presents an accounting framework in which information on ecosystem assets (i.e. stocks defined in terms of spatial area such as forests, wetlands and agricultural land) is combined with information on flows of ecosystem services.[1] The information on ecosystem services can be integrated with information on measures of income, production and consumption from the SNA, and information on ecosystem assets can be combined with data on other assets, including buildings and machinery. Collectively, this information can provide a comprehensive picture of the relationship between economic activity and the environment.

A significant measurement challenge for SEEA EEA is in the area of monetary valuation of ecosystems services. Environmental economics has made substantial progress in providing valuation techniques that have been increasingly applied to ecosystem service valuation (e.g. Freeman et al. 2013; Champ et al. 2016). On the face of it, initiatives for valuing ecosystem services for national accounting purposes are well situated to take advantage of this progress. Whether or not this happens depends, in no small part, on whether the integration of those ecosystem service values with national accounting frameworks is combining apples and oranges.

Specifically, our focus is on when "monetary prices" to be attached to the quantities supplied by ecosystems (i.e. the ecosystem services) can be interpreted as prices suitable for use in national accounting as prescribed in the SNA (EC, et al, 2009). In the SEEA EEA (UN et al 2014b), the prices suitable for accounting are referred to as "exchange values." However, in this paper, we simply use the term "price" in order to avoid confusion with how the terms "exchange" and "value" may be understood in economics.

UN et al (2014b) highlight some important conceptual requirements for consistency with such prices currently recorded in the SNA. It also speculates that not all valuation techniques developed in environmental economics satisfy those conceptual requirements. Unfortunately, the SEEA EEA leaves the discussion at that point and only notes the need for further research and discussion to investigate precisely which valuation approaches would be appropriate for national accounting purposes. This current paper picks up from where that discussion leaves off, although in doing so we recognize an existing body relevant to this endeavor.[2]

[1] Including, for example, flows of timber, fish, water, nutrients, pollination, water purification, air filtration, soil retention and recreational opportunities.

[2] Important contributions by Boyd and Banzhof (2007) and Boyd (2007) underline both the progress made in this literature as well as the additional challenge of (SNA) consistency for accounting

The rest of this paper is organized as follows: First, we continue this introduction by defining what we mean by price for accounting purposes, as well as further scoping out the reasons for the focus of our paper on accounting for the monetary value of ecosystem services (rather than ecosystem assets). In Section 2, we set this discussion in the context of progress about how ecosystem services have thus far been placed within the SEEA framework. In Section 3, we discuss how identifying the economic channels (familiar in the environmental economics literature) whereby ecosystem services contribute to economic activity and human wellbeing can augment that progress, particularly as a way of understanding the relevant prices. Section 4 directs that discussion further towards practical valuation techniques and reflects on how these approaches, commonly used in environmental economics, might be suitable as a way to empirically estimate prices for ecosystem accounting. Section 5 concludes and discusses the hierarchy of challenges to be confronted when using such techniques in an accounting context.

1.2 Defining prices in accounting and economics

The valuation principles of the SNA define the prices required for national accounting as those that represent the "… amounts of money that willing buyers pay to acquire something from willing sellers …" (EC et al (2009), para. 3.119, p50). It is an understatement that there are challenges in applying this definition to the valuation of the numerous goods and services supplied by ecosystems, and indeed for other non-market goods and services (e.g. defense, education, and health services). Critically, the implied institutional arrangements governing different transactions will vary. The SNA definition arguably fits arrangements, such as markets (of varying design), where there are observable prices for transactions made voluntarily. By contrast, the situations in which economic units like producers and households are supplied with and use ecosystem goods and services are undoubtedly diverse, but are largely characterized by arrangements where supply and use are unpriced and potentially non-voluntary.

Nevertheless, at least in accounting terms, there is still a transaction, albeit implicit (or in national accounting terms "imputed"), that arbitrates this supply and use of ecosystem goods and services. The question is the extent to which these implicit transactions differ from transactions in "standard" markets, and hence whether any deviation means that prices implied by the transaction (perhaps estimated by techniques of environmental valuation) are inconsistent with those envisaged in the SNA.

One starting point for thinking about this is anticipated in the SEEA EEA and subsequent contributions.[3] One instance is in the definition of buyers and sellers (see e.g. Edens and Hein, 2013; Obst et al. 2013). The "buyers" are those parties who benefit from (i.e. use or consume) the goods and services that ecosystems provide (e.g. farmers, water supply companies, tourists). The "seller," by contrast, is harder to definitively identify, although a potentially useful approach is to consider that the "ecosystem" itself is a useful (albeit new) institutional unit in

---

applications. Further, and more recently, discussion on this has included Day (2013) and Vincent (2015). They focus on whether the economic foundations and application methods within the contemporary "environmental valuation toolkit" are consistent with national accounting valuation principles and practice. All of this builds on a number of earlier discussions which acknowledge this same challenge, including Nordhaus (2006), Abraham and Mackie (2006), as well as Vanoli (1996), Blades (1989) and Perkin and Peskin (1978). Also relevant is work on wealth accounting, both in terms of its grounding in the theory of links between income, saving and wealth – extended to account for (what is happening) to underlying natural assets (e.g. Hamilton and Clemens, 1999; Dasgupta and Mäler, 2000; Arrow *et al*. 2012) - as well as practical valuation (e.g. Barbier, 2014; Hamilton and Atkinson, 2006).

[3] Vincent (2015) discusses a number of distinct (non-environmental) exceptions within the SNA, which are required to cover a range of non-market and similar transactions within the scope of the measures of production and income defined in the SNA; e.g. imputed rent for owner-occupied dwellings.

this respect.[4] What this means is that the notion of a transaction price reflects what buyers would pay for services produced by an ecosystem and what the seller (the ecosystem itself) would accept.

It is accepted that further discussion of this proposed identification of the seller is required. This is especially true regarding the relationship between these new ecosystem units and their ownership and management by the current suite of economic units, namely corporations, governments and households. For example, an alternative construction would see the owner of an ecosystem asset, e.g. a farmer in the case of agricultural land, as the seller. There is a related concern from an economic perspective that envisaging the ecosystem as the seller may imply that ecosystems have preferences. Ultimately, what works in a national accounting framework also needs to have a sensible economic interpretation if it is to be useful more broadly.[5]

Notwithstanding these concerns, this paper uses the framing of the ecosystem as the seller in transactions in ecosystem services. The approach was presented as an option in SEEA EEA (UN et al, 2014b) and, in principle, it reflects an extension of the national accounting treatment of owner-occupied dwellings. These dwellings are considered separate producing units whose output, imputed rent, is sold to the households living in the dwellings. The ecosystem-as-seller approach also solves the attribution challenge in the normal situation where multiple ecosystem services are generated from a single ecosystem asset and used by more than one economic unit, i.e. not only by the economic owner of the ecosystem. This mismatch between service flows and ownership is not considered in standard national accounting. It is noted, too, that the link to ownership by economic units can be made in a subsequent accounting step beyond an initial framing of ecosystems as distinct units.

Finally, it should be made clear that the key findings of this paper are not affected by the treatment of ecosystems as units for accounting purposes. Although the presentation of some tables would vary if a different approach was used, it would still be the case that, for valuation purposes, a transaction in ecosystem services would be identified for accounting purposes and both a seller and a buyer would need to be defined.

1.3 Our focus: Valuing ecosystem services

In the framework of the SEEA EEA, ecosystem services[6] are seen as *flows of production* (and hence income in a national accounting context) that are supplied by the underlying ecosystem assets or *capital* (e.g. forest, wetland, agricultural land). Figure 1 below shows the links. This fuller framework (encompassing income and capital perspectives) is important given that a critical application of ecosystem accounting is to shed light on what is happening to ecosystem assets, and whether, as a result of national development paths more generally, the use of ecosystem assets is sustainable. The literature on wealth accounting, in particular, identifies a

[4] Proposals for additional "quasi" institutional units to reflect the connections between the economy and the environment are longstanding in SEEA discussions. See, for example, Harrison (1995) and Vanoli (1995).

[5] This might involve, for example, adding (a conceivably realistic but generalizable) institutional substance to the "ecosystem as seller" metaphor. For example, the ecosystem and its services could be assumed to be held in trust, along with other endowments, for future generations. We are grateful to Eli Fenichel for suggesting this interpretation. Given the focus of this paper, in this vein, our question is what price should arbitrate a transaction for current ecosystem services between "buyers" (the current generation consuming these services) and the "sellers" (the future generations, which hold these resources as one component of their portfolio). This emphasis on current and future, however, also suggests the importance of thinking explicitly about how the underlying ecosystem asset is managed, and how capital services from the asset should be valued. This wealth accounting is then crucial but largely beyond the scope of the current paper, as we explain elsewhere.

[6] This term itself refers to both tangible goods as well as intangible services, which are provided by ecosystems.

clear role for ecosystem services valuation to estimate (the change in) asset values (including via ecosystem degradation) and constructing measures of *adjusted net income* and *adjusted net saving* (e.g. World Bank, 2006; Barbier, 2011, 2014; Arrow et al. 2012).

The SEEA EEA (UN et al, 2014b) provided the first framing from a national accounting perspective for the integration of information on ecosystem services and ecosystem assets. This framing is described further below, to provide a general understanding of the logic and motivation for the valuation of ecosystem services. It is recognized, however, that the precise description of the relationships between ecosystem assets, ecosystem services and the associated production, consumption and balance sheet information in the standard national accounts is subject to ongoing discussion. It is not the aim of this paper to advance this discussion. At the same time, it is clear from the research and discussion of this paper that a more precise and commonly agreed framing is required to support discussion and exchange on this issue.

Our emphasis, in what follows, is on the valuation of *flows of ecosystem services*, rather than the stock of underlying assets. While, on the face of it, this appears to narrow the relevance of our discussion, we adopt this focus in order to concentrate on defining the prices with which these flows can be valued.[7] Our discussion remains relevant to questions about valuing underlying (ecological) assets because, just as the prices of ecosystem services are not observed, neither are the prices of ecosystem assets.[8] As a result, the valuation of ecosystem assets will rely on much the same valuation methods as for the former and, in large part, will be equal to the capitalized value of flows of future ecosystem services.

However, we note that, as shown in Fenichel and Abbott (2014), accounting for the value of an ecosystem asset (or renewable natural capital more broadly) requires estimation of a range of parameters, of which the value of the flow of ecosystem services is just one ingredient. First, when the asset is renewable (or regenerates), the ongoing resource productivity must be considered in discounting the (future) value of the asset.[9] Secondly, there is a capital or holding gain, which Irwin *et al.* (2016) term as a "scarcity effect" arising from holding the last or marginal unit of the asset.

Thus, accounting for ecosystem asset values, as well as degradation or enhancement of these assets, raises additional and important concerns.[10] The intention is to consider these in a separate and additional paper and, as such, we do not explore these issues in what follows, although we acknowledge that such issues are often never far from the surface of our discussion. This allows us to concentrate on our specific objective: the extent to which ecosystem service values estimated using valuation techniques in environmental economics are consistent with

[7] Knowing the value of current flows of ecosystem services in ecosystem accounts could also be useful information for other reasons. Linked to income and production accounts, for example, this could support better understanding of the extent to which ecosystem services currently support the economy, and in what ways. In principle, such information could also be used to augment a measure of current (gross) production such as GDP. In other cases, this might involve re-attributing elements that currently comprise GDP (e.g. identifying ecosystem service values which are implicitly already in the national accounts, and explicitly re-assigning them to a new "institutional producer": the ecosystem asset).

[8] Partial observed valuations for some ecosystem assets will exist, for example, in terms of observed prices for land, but these values will not capture the full suite of ecosystem services produced by that ecosystem asset. For a more complete discussion of this issue, see UN et al 2014b, Chapter 6.

[9] That is, asset price, $p = \frac{W_S + \dot{p}}{r - \dot{s}}$, where W_S is the value of the marginal unit (current) service flow from the asset and r is the discount rate. One additional term, in the denominator, is $\dot{s}$, which refers to (net) resource productivity and is therefore used to calculate an effective discount rate. A further term, in the numerator, $\dot{p}$ refers to the "scarcity effect" of holding the last unit of the asset. From this perspective, our focus in this paper is on W_S only.

[10] There could be additional complications, including the effects of overuse of the ecosystem asset on the asset life and ecosystem capacity.

SNA valuation principles. A point that can be made now though is that ecosystem asset prices also need to demonstrate this consistency and our current discussion is relevant to that endeavor.

2. Ecosystem services in the SEEA ecosystem accounting model

The conceptual framework used in this paper to integrate ecosystem services into the national accounts is taken from the SEEA EEA (UN et al 2014b). The SEEA EEA provides a framework that applies national accounting principles to the organization and integration of information on ecosystem services and ecosystem assets. The basic definitions and relationships for ecosystem services and ecosystem assets in an accounting context are detailed below in Section 2.1. Section 2.2 provides a description of the key accounts that are compiled in monetary terms for ecosystem accounting – namely, the ecosystem services supply and use account and the ecosystem monetary asset account.

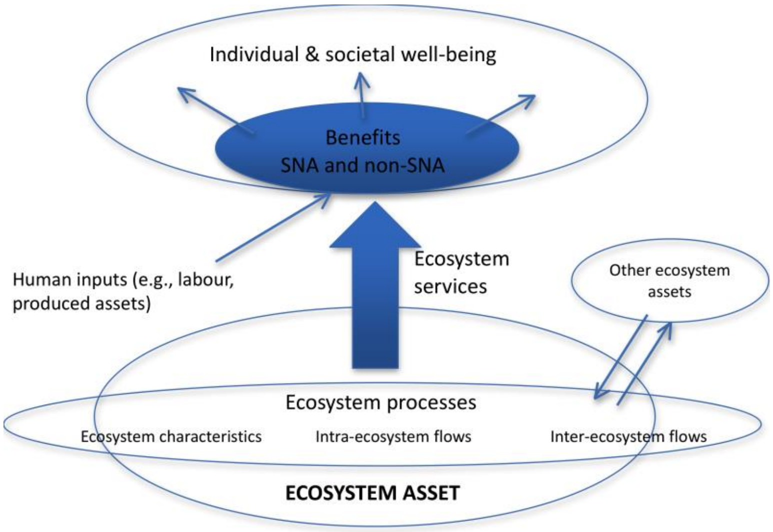
A key feature of the definitions and measurement boundaries developed in the SEEA EEA for ecosystem accounting is that they are designed to facilitate direct integration of the resulting estimates with the estimates of the standard national accounts, including aggregates such as gross domestic product (GDP) and national wealth. This design feature implies some particular outcomes for the estimation of ecosystem accounts and the valuation of ecosystem services, including the use of SNA valuation concepts. These implications and related assumptions are discussed in Section 2.3. They provide the measurement context against which the valuation techniques described in Section 3 can be assessed.

2.1 Introduction to ecosystem accounting in the SEEA EEA

The SEEA EEA was developed through 2011 and 2012 to provide an approach to the measurement and integration of environmental degradation within the standard economic accounts. The definition and measurement of degradation has been an area of discussion and contention within national accounting circles for more than 20 years. The work on SEEA EEA was able to take advantage of the more recent developments in the measurement of ecosystem services, such as presented in the Millennium Ecosystem Assessment (MA, 2005); the original TEEB study (TEEB, 2010); and work on inclusive wealth accounting (UNU-IHDP, 2012), among many others. The SEEA EEA represents a synthesis of approaches to the measurement of ecosystems, but one which is specifically adapted to enable integration with standard national accounting concepts, principles and measurement boundaries.

The full ecosystem accounting framework is described at length in SEEA EEA Chapter 2, and readers are referred to that document for a detailed description. For the purposes of discussion here, Figure 1 provides a depiction of the general model.

Figure 1: General ecosystem accounting framework (SEEA EEA Figure 2.2)



Source: UN et al, 2014b

Five key features of the ecosystem accounting model are noted:

<u>(i) The delineation of ecosystem assets.</u> Ecosystem accounting is focused on accounting for ecosystem assets, each delineated by a spatial area. By way of example, an ecosystem asset may be a rice farming area or a forest area, with the understanding that each ecosystem asset should consist of a similar vegetation type and cover at a specific spatial location. From a measurement perspective, defining the spatial boundaries of ecosystem assets is fundamental, since without such boundaries it is not possible to consistently and comprehensively measure the extent, condition and changes in extent and condition of the assets over time, or to appropriately attribute flows of ecosystem services.

For the purposes of integrating ecosystem information about the defined ecosystem assets with standard economic accounting and production analysis, it is useful to consider each asset as a type of quasi-producing unit (an ecological "factory") that operates in addition to the standard economic units like industries and households. [11] From this perspective, the different characteristics that are considered in the delineation of ecosystem assets (e.g. vegetation cover) can be considered analogous to the characteristics that are considered in classifying different economic units and grouping them into industries.

<u>(ii) Measuring the condition of ecosystem assets.</u> Each ecosystem asset (e.g. a rice farm or forest) has numerous characteristics (climate, soil, vegetation, species diversity, etc.) and undertakes various ecosystem processes. The integrity and functioning of the asset is measured by its condition. It is the decline in overall condition, in biophysical terms, that underpins the measurement of ecosystem degradation. For accounting purposes, ecosystem degradation is defined consistently with the depreciation of produced assets. As yet, there is no standardized view on precisely which characteristics of condition should be monitored for each ecosystem type in order to provide an appropriate assessment of the overall condition (current state) and the change in condition of an ecosystem asset. Accounts for ecosystem condition and ecosystem extent (i.e. the area of the ecosystem asset) are described in the SEEA EEA. These accounts are compiled in biophysical terms only.

[11] As noted in Section 1.2, treating ecosystem assets as distinct units is subject to ongoing discussion.

(iii) Measuring the flow of ecosystem services. Based on the ecosystem asset's location, condition, and how it is used (e.g. for rice production, timber production, recreation), a basket (or combination) of various ecosystem services will be supplied by an ecosystem asset. From an accounting perspective, the ecosystem services supplied are matched to corresponding consumption of users/beneficiaries, i.e. economic units including businesses, households and governments. Thus, an ecosystem services supply and use account can be compiled (see Section 2.2). The coverage of ecosystem services includes provisioning services (e.g. food, fiber, water), regulating services (e.g. air filtration, water flow regulation, carbon sequestration) and cultural services (e.g. tourism, spiritual connections) (see also Section 2.3).

The focus in the SEEA EEA is on final ecosystem services following the approach taken in TEEB (2010) and Banzhaf and Boyd (2012), among others. Thus, ecosystem services are considered the ecosystems' *contributions* to the production of benefits. In this context, benefits include: (a) SNA benefits - goods and services recorded within the production boundary of the SNA (e.g. crops, livestock, timber furniture); and (b) non-SNA benefits - additional services outside of the current SNA production boundary, for example public benefits from the environment, clean air that results from air filtration services, or flood protection that results from water regulation services.

In general discussion, the distinction made in the SEEA EEA between ecosystem services and associated benefits may be seen as unimportant and, indeed, the MA defined ecosystem services as equal to benefits. However, in both an accounting and valuation context, the distinction is essential, as emphasized in Banzhaf and Boyd (2012) and as recognized in valuation work in the UK (NCA, 2011), where the term "ecosystem goods" was used to refer to the concept of benefits applied here. The distinction is relevant for two reasons. First, concerning accounting, making the distinction between ecosystem services and benefits allows many ecosystem services to be recorded as inputs to existing production functions (e.g. the input of pollination services to fruit production) which would not otherwise be recorded. If only the benefit of providing fruit is identified, the dependence on ecosystem services is not highlighted. Secondly, concerning valuation, in many cases, especially in relation to provisioning services, it is essential to recognize the distinction between the observed price of a marketed benefit, such as rice, and the value of the contribution of the ecosystem.

In principle then, by estimating the monetary value of all ecosystem services supplied by an ecosystem asset, and then estimating the associated net present value of future flows of this basket of services, the value of the ecosystem asset itself is derived. The value of ecosystem degradation will be related to the change in the value of the ecosystem asset over an accounting period, noting that the value of the asset may change for reasons other than a decline in condition, e.g. through changes in land use. A loss in condition may not be due to human activity, for example in the case of storm damage, and hence would be excluded from ecosystem degradation for accounting purposes.[12]

(iv) Relating ecosystem services to standard measures of economic activity. This has remained a matter of ongoing contention, although it does not directly affect approaches to valuation. The broad logic is that the supply of all ecosystem services is outside the current production boundary of the SNA, as they are considered natural processes (see EC et al (2009), para 6.24). At the same time, as noted above, many ecosystem services contribute to the production of goods and services that are included in the SNA production boundary, for example the contribution of pollination services to apple production. In this case, if the standard production boundary was expanded to include ecosystem services, the net effect on GDP of recording the

[12] In national accounting, degradation - like the depreciation of manufactured assets - is considered a cost against income from production, and hence only the change in asset value that is attributable to the production activity should be deducted. Other changes in value are recorded in the accounts but not as a deduction from income.

supply of ecosystem services is zero, since the ecosystem services are considered outputs of the ecosystem asset and inputs to existing production. It is by recognizing ecosystem services as both outputs (of ecosystem assets) and inputs (to economic units) that double counting is avoided. This treatment is exactly analogous to the treatment of outputs and inputs through the standard supply chains recorded in the national accounts.

As noted above, the SEEA EEA also includes the supply of ecosystem services that are not inputs to current SNA production of goods and services. For example, the air filtration services of plants. It is the inclusion of this additional output, and the associated value added, that directly increases measures of GDP if the standard production boundary of the national accounts were to be expanded

Further, although not described in the SEEA EEA, the ecosystem accounting framework can be extended to consider flows of intermediate ecosystem services which are essentially transactions between ecosystem assets. These can be recorded as supply by one ecosystem asset, balanced by use in another ecosystem asset. Generally, there would not be a requirement to record all of these flows, but there may be interest in doing so in some cases (e.g. the habitat services provided by inland streams for migrating salmon which are subsequently caught at sea). Recording both supply and use allows a balanced recording without needing to pre-emptively assume a focus on only final ecosystem services.

(v) The use of prices. The ecosystem accounting framework just described reflects relationships between stocks and flows that exist without regard for the unit of measurement (although we have referred to monetary values on a number of occasions so far). Thus, in concept, accounting relationships can be reported in physical terms (for example, the stocks and changes in stocks of timber resources can be recorded in a standard asset accounting format) and in monetary units. In theory, for any given stock or flow there will be a relationship between the physical and monetary measures reflected in the measurement of price. In cases where prices and associated monetary values cannot be observed, then measurement in monetary terms requires the use of various valuation techniques since, in general, prices for ecosystem services and assets are not directly observed in markets.

Given that non-market situations arise in a number of contexts, the SNA has developed a range of methods for valuing transactions where prices are not observed. In short, the SNA recommends the use of the following methods, in order of preference: (i) valuation according to market prices of equivalent items; and (ii) valuation according to the cost of production. These methods are routinely applied in national accounting to ensure that all transactions within the scope of the production boundary are assigned the most appropriate value possible. SEEA EEA, Section 5.4 provides a longer summary of the relevant parts of the SNA.

As described elsewhere in this paper, economists have developed many valuation techniques to support analysis of environmental issues, including the valuation of ecosystem services. (See extended discussion in Section 4.) In effect, the genesis of interest for national accountants working in this same space, rests on whether surety can be provided that those techniques yield values which can also be interpreted as prices for national accounting purposes, i.e. the price at which a buyer and a seller would complete a transaction.

2.2 Ecosystem accounts

Recording transactions in ecosystem services

The starting point for structuring accounts for ecosystem services is the identification of transactions between accounting "units." In the standard national accounts, the units include the set of economic actors, businesses, governments and households that may be variously grouped into industries (agriculture, manufacturing, retail, etc.) or institutional sectors (corporations, general government, households, etc.). Each individual actor is considered an economic/institutional unit for accounting purposes and, with respect to production, consumption and investment, is considered to undertake these activities by engaging in mutually beneficial transactions with other units.

Building on the earlier discussion about the treatment of ecosystem assets as distinct units, these are effectively new "industries" or activities that are supplying previously unrecorded services. The key in the design is that both the supply of the new products (i.e. the ecosystem services) and the use of these services by various consumers must be recorded.

This can be seen in the supply and use table (Table 1) that shows stylized entries in the case of an apple grower who "purchases" pollination services from a neighboring forest ecosystem asset. Compared to a supply and use table in the standard national accounts, the changes are: (i) the inclusion of a new producing unit, the forest, as an additional column; and (ii) the inclusion of an additional row for the new product, the pollination services. This extended supply and use table was not present in the SEEA EEA but represents an application of the extension of the standard SNA production boundary that was inherent in the SEEA EEA. The extension was first proposed in Obst et al (2015), described further in Obst and Eigenraam (2016), and is included in the SEEA EEA Technical Recommendations (UNSD, 2017).

Note that the accounting balance required in this table is that, for each row of supply, there is a matching row for use, where the total for each pair of rows is the same. Since this table is in physical units, there is no meaningful aggregation across products but the accounting identity of supply equaling use is still maintained for each product.

Table 1: Physical supply and use table for selected products and ecosystem services (physical units)

	Apple farmer	Other industries	Ecosystem asset: Forest	Households	Total
Supply table:					
Apples	4 tonnes				4 tonnes
Apple products		2 tonnes			2 tonnes
Fertilizer		80 units			80 units
Other intermediate inputs		150 units			150 units
Ecosystem services: Pollination			80 units		80 units
Use table:					
Apples		4 tonnes			4 tonnes
Apple products				2 tonnes	2 tonnes
Fertilizer	80 units				80 units
Other intermediate inputs	150 units				150 units
Ecosystem services: Pollination	80 units				80 units

The potential to extend this stylized example should also be clear. Thus, additional ecosystem services supplied by the ecosystem asset could be recorded, for example carbon sequestration services, observing that in this case a different consumer would be identified (likely the government on behalf of society generally).[13] Further, additional ecosystem assets could be included, for example a river from which other industries extract water for use in production. The final choice of account design for a supply and use table for ecosystem accounting will

[13] This treatment would be analogous to the treatment of the consumption of national defense services and other collectively consumed public goods in the SNA.

therefore depend on the chosen scope of ecosystem services and types of ecosystem assets within the overall geographic scope of the account.[14]

Ecosystem services supply and use table in monetary terms

Using Table 1 as a foundation for recording transactions in ecosystem services, the link to the standard supply and use tables in monetary terms is shown in Table 2. Compilation of this account requires the estimation of prices to assign to the flows of ecosystem services recorded in quantitative terms in Table 1. Since all entries concerning ecosystem services and other products are recorded using the same monetary units, it is possible to derive aggregate estimates of total supply and total use and related accounting derivations of value added. Measures of wages and salaries can be incorporated as well, to derive estimates of gross operating surplus (GOS).[15] Note that this is a stylized example and the estimated prices and values should be considered purely indicative.

Table 2: Monetary supply and use table incorporating ecosystem services (currency units)

	Apple farmer	Other industries	Ecosystem asset: Forest	Household final consumption	Total
Supply table					
Apples	800				800
Apple products		2000			2000
Fertilizer		200			200
Other intermediate inputs		150			150
Ecosystem services: Pollination			200		200
Total output (1)	800	2350	200		3350
Use table					
Apples		800			800
Apple products				2000	2000
Fertilizer	200				200
Other intermediate inputs	150				150
Ecosystem services: Pollination	200				200
Total input (2)	550	800	0	2000	3350
Gross value added (3=1-2)	250	1550	200	N/A	2000

A notable extension to Table 2 would be the derivation of income measures (e.g. GOS) that are adjusted for both the cost of using up produced assets (depreciation) and ecosystem assets (degradation). (Where non-renewable resources are used up, the depletion of these resources could also be deducted.)

It is also important to note some effects of expanding the scope of the traditional supply and use table to incorporate ecosystem services. First, in this instance, since the output of ecosystem services is fully consumed by the apple farmer (as input to the harvest of apples), then the system as a whole sees no change in the total gross value added (i.e. gross domestic product)

[14] As for standard supply and use tables, the rest of the world can be incorporated, hence allowing for recording of imports and exports of ecosystem services as appropriate.

[15] The entries in monetary terms are based on a set of assumed prices for the output of apples and the various produced inputs. The price of the ecosystem service of pollination has been derived implicitly as the unit resource rent for the apple farmer, i.e. revenue from apple sales less all production costs, including the user cost of produced capital. This assumes no use of other ecosystem services or other forms of non-produced capital. While clearly simplistic, the assumption is sufficient for the purposes required here in showing the design of the supply and use table.

across all activities. That is, the increase in output recorded in the system through the recognition of pollination flows is fully offset by the increase in intermediate costs of these flows recorded, as paid by the farmer. The common concern of double counting as a result of recording ecosystem services is therefore resolved in this approach. Note that, in practice, there may be flows relating to changes in the underlying asset base, for example improvements in the soil underlying the apple orchard, but the recording of these flows is separate from the flows of ecosystem services described here.

Second, as introduced earlier in this section, underpinning this presentation is the assumption that the ecosystem asset is a type of production unit that is distinct from other economic units, specifically from the apple farmer. It should be noted that, if the ecosystem asset were considered as fully owned by the apple farmer, the two columns (apple farmer and ecosystem asset: forest) could be merged and the resulting gross value added of the two units would be equivalent to that obtained using a standard recording.

3. Ecosystem services: Channels from economics to the national accounts

Initial clues for practical accounting for ecosystem values can be found by reflecting on how ecosystem services that are supplied by an underlying ecosystem asset (e.g. forest, wetland, agricultural land) ultimately provide benefits to people and businesses. This is what Freeman et al. (2013) term "The economic channel through which wellbeing is affected" (p13).[16] These channels are manifold (e.g. Brown *et al*. 2007, Freeman et al 2013) but broadly speaking can be summarized in three ways.

ES#1: First, there are ecosystem services which are used as inputs to economic production (i.e. become part of intermediate consumption). Examples include soil nutrients and pollination, which are inputs to agricultural production. Water regulation and water purification services are inputs to those economic (producing) units which need a supply of clean water as an input, usually alongside other factors of production.

ES#2: Second, ecosystem services can act as joint inputs to household final consumption.[17] That is, there is use of ecosystem services in combination with (or as a substitute for) expenditure on produced goods and services in providing a "product" for consumption. In such cases, an ecosystem service and the market goods/services are complementary (or substitute) inputs, and because of this expenditure on the latter, can provide a guide to the value of the former. Examples include (final) ecosystem services which, in combination with travel expenditures, are used to produce recreation benefits. An example where an ecosystem service is a substitute for market expenditure is air purification services, which can substitute for the purchase of a produced good which filters air.[18]

---

[16] These "channels" could be considered when building or extending the common representation of ecosystem services in the cascade model that shows the linkages between ecosystem functions and processes, ecosystem services, and the benefits ultimately received.
[17] In environmental economics this is typically referred to as "household production." We refer to "consumption" here as it is the conventional terminology in national accounting. Household production in the SNA incorporates, for example, subsistence production of crops, which would be included in ES#1.
[18] Firms may also undertake this sort of defensive expenditures, that is, purchase substitute goods to defend against an environmental burden that exists in the absence of some ecosystem service. The value of this service might then be approximated by estimating how the cost of producing the current output changes as a result of a small change in its provisions. Given that this refers to the production side of the economy, this is a pathway under ES#1 rather than ES#2, which is defined here as referring to household consumption.

ES#3: Thirdly, ecosystem services can be inputs that directly contribute to household wellbeing. That is, there is no existing economic production or household consumption where these services are inputs. These services are consumed directly in generating benefits, that is, directly from ecosystem assets without any other (produced) inputs. Examples here are naturally rather abstract, but include those services that are valued for reasons of what is usually termed "non-use" or "passive-use."

All of these channels are well-rehearsed in the literature on categorizing ecosystem services in environmental economics. The ambition, then, is to apply this understanding in answering our question about prices for ecosystem accounting. There are parallels between these categories and national accounting. Thus, in accounting, ecosystem services can be seen as "outputs" of ecosystem assets which, in turn, act as inputs to existing (economic) production processes, as in the case of ES#1, or to final (household) consumption as in ES#2 and ES#3. In terms of adding substance to these parallels, an important consideration is the effect on measures of GDP from each channel. This clearly will depend on how the ecosystem services are used. If they are used as inputs into current production, then the impact on GDP is zero. That is, the increased output is completely offset by an increase in inputs. This will include those services in channel ES#1. By contrast, if the ecosystem services are inputs to household consumption, there will be an increase in GDP equal to the output (and consumption) of these ecosystem services - that is, ES#3 and some, but not all, of ES#2 (see Section 4 and Table 4 for a fuller illustration of this).

The overall message is that, by considering each transaction between buyer (producer or household) and seller (ecosystem), it becomes possible to work towards full integration of the value of these transactions with the entries currently recorded in the national accounts. Whether this optimism is justified depends on exploring further a number of related issues, perhaps best illustrated by specific ecosystem services alongside the specific valuation techniques for those services.

3.1 Ecosystem services supply & use account and valuation channels

Using Table 2 as a starting point, Table 3 represents the idea of grouping valuation techniques via "channels" in a supply and use context. The rows reflect the different types of ecosystem services that can be recorded as additional products in a supply and use table. Table 2 above incorporated only one ecosystem service, but extension is possible to cover a full range of services in an account.

Classification systems for (final) ecosystem services typically distinguish between provisioning services, regulating services, and cultural services (henceforth, PRC). Ecosystem accounting has been no exception in utilizing classifications along these lines (e.g. the use of the CICES in the SEEA EEA).[19] However, to define channels, it is the economic unit that uses the ecosystem service, or put differently, the way in which the ecosystem service is used, that is also fundamental. Thus, it should not necessarily be expected that a single type of service within PRC (e.g. a type of regulating service) always maps onto a single economic channel (e.g. ES#1).

[19] Since the release of the SEEA EEA, discussion has continued on the development of ecosystem service classifications for ecosystem accounting. The discussion now encompasses the CICES and two classification systems developed in the US: FEGS-CS and NESCS. Each approach applies a different perspective to classification. The application of the principles discussed here is not affected by the choice of classification, but the implementation of valuation techniques will need to ensure alignment between measurement in physical and monetary terms.

Table 3: Channels of ecosystem services by type of ecosystem service and economic unit

	Industry				Government	Household
	Agriculture	**Forestry**	**Water supply**	**Other**		
Ecosystem services:						
Provisioning services	ES#1	ES#1	ES#1	ES#1	ES#1	ES#1
Regulating services	ES#1	ES#1	ES#1	ES#1	ES#2	ES#2
Cultural services	ES#1	ES#1	ES#1	ES#1	ES#2	ES#2 & #3

While generalizations appear difficult to defend, a few observations are possible, and Table 3 suggests some indications. Self-evidently, many of those ecosystem services used by industry could be valued using techniques suitable for ES#1 type flows, which are relevant where the ecosystem services are inputs to current production by economic units, particularly for primary producers, water supply, and tourism-related industries.

ES#1 techniques will also be relevant in cases of own-account or subsistence production that involves the use of ecosystem services by households. From a national accounting standpoint, the harvesting of biological resources (fish, wood, fruit, etc.) by households is considered within the standard production boundary of the SNA, whether or not the harvested goods are subsequently sold or retained for own consumption. This includes situations of subsistence farming but also, for example, backyard production of fruit and vegetables. Thus, for national accounting purposes, there is no conceptual difference between large-scale and small-scale production of goods.

In other cases, ecosystem services used by households could be valued either via channels ES#2 and ES#3, depending on the nature of use. For example, while cultural services might be thought of candidates for ES#3, some services such as recreation might be consumed by households alongside, or as a result of, market expenditures (and hence, ES#2).

The key message from Table 3 is that different valuation channels may be relevant for a single ecosystem service depending on the context, in particular the user of the ecosystem service. For example, pollination services may be considered an input to agricultural production and hence the focus of ES#1 type methods. Alternatively, pollination may be a relevant ecosystem service in understanding people's cultural enjoyment of the landscape. In this case ES#2 type methods (or even ES#3) would be more appropriate. Although distinguishing between the contribution of ecosystem service inputs and the distinct outputs may be difficult, the more general point is that the supply and use approach of accounting provides a useful framework for considering the selection of valuation techniques, since both the type of ecosystem service and the beneficiary or user must be determined to assign an entry in the table.

3.2 Institutional considerations and prices for ecosystem services

Before we move on, it is worth pausing to reflect on the institutional considerations in estimating prices for ecosystem service flows. One reason for this is that the presumption of many national accountants working in this space is that practitioners using environmental valuation techniques have been preoccupied with measuring values that do not have a consistency with standard national accounts. Indeed, this was the broadly skeptical framing of the issue in the SEEA EEA and appears based on how environmental valuation tends to be used mainly in cost-benefit appraisal (CBA). In CBA, this typically entails evaluating a policy change (altering the provision of ecosystem services) with policy benefits valued as the change in the area under the demand curve between "current" and "new" provision (i.e. brought about by the policy). Thus, the national accounting presumption is perhaps more about "use" of valuation techniques rather any technique itself. That is, what stretches consistency with standard national accounts, in particular, are imputations based on the total value of provisioning something, rather than the marginal value. In this context, the common concern of national accountants is that environmental valuation includes consumer surplus, which is explicitly excluded from the transaction prices underpinning the valuation in the SNA.

More precisely, in this paper the price (for accounting purposes) represents the value that the buyer (e.g. an economic producer or household) places on receiving the marginal (i.e. last) unit of *something*, e.g. an ecosystem good or service. It is important, then, to set out that these marginal prices do not represent some idealized price. Thus, all accounting entries reflect transactions in ecosystem services as they have been embodied in economic production or human activity.[20] Since the (implicit) transactions have already taken place, the accountant must consider non-market valuation in the context of the institutional arrangements that prevailed at the time of the transaction. If those institutional arrangements are such that the prices are inefficient – in that sub-optimal quantities (or qualities) of some good or service are traded – this is nevertheless still the price with which to value the marginal unit of that good or service that is transacted, at least from a retrospective accounting perspective.[21] Therefore, what is relevant are *actual* marginal prices, rather than *potential* prices that may arise under different (or ideal) institutional settings.

There may be a parallel here with notions of "demonstrating" and "capturing" value in economic assessments of the value of ecosystems. The former (demonstrating value) is concerned with showing that, for example, flows of ecosystem services have value. The latter (capturing value) is concerned with establishing an institutional arrangement which actually realizes this value, which could be a market but need not be.

Most commonly in national accounts, it is assumed that institutional arrangements exist involving observable transactions between buyers and sellers. Since this is not the case for ecosystem services, what must be asked instead is what the producer would receive in exchange for the service, "as if" a market (or similar) had existed.[22] It is important to recognize that, in providing this avenue to valuation, the SNA appears open to the possibility that institutional arrangements may be inferred such that valuations concerning past accounting periods can be estimated. However, the SNA offers no clear guidance as to what institutional arrangements might be appropriate or what criteria might be used to choose between alternative arrangements.

A common perception is that the SNA is independent from institutional arrangements, but this is usually considered from the sense that national accounts concepts can be applied equally in relatively free and regulated economies. Indeed, it should be clear that the national accounting system is not neutral on institutional settings since, at least for market transactions, using the existing settings is not a neutral position. However, accounting makes no judgement on whether these settings are appropriate, a task that may be highly relevant in assessing ecosystem services values in certain policy and decision-making contexts. Calculating these actual prices is likely of great relevance in understanding the distance been the current situation and a potential policy

[20] In effect, we assume that physical measures of ecosystem services flows can be obtained and that the remaining task is estimating relevant prices. We appreciate, however, that the reality will be more challenging. Direct measurement of the physical flows is unlikely to be straightforward and the selection of appropriate indicators and measures is a substantial task that is not detailed in this paper. For measurement proposals in an accounting context, see SEEA EEA Technical Recommendations (UN et al, forthcoming)

[21] For example, if a resource (e.g. a fishery) is open access and over-used such that rents are dissipated, then it is appropriate that the transaction price reflect this institutional context.

[22] This framing is precisely the expectation of the SNA in the valuation of natural resources on the balance sheet, where observable asset markets do not exist – see SNA Chapter 13.

target. Thus, the regular estimation of prices for accounting also provides a means of tracking progress towards policy targets.

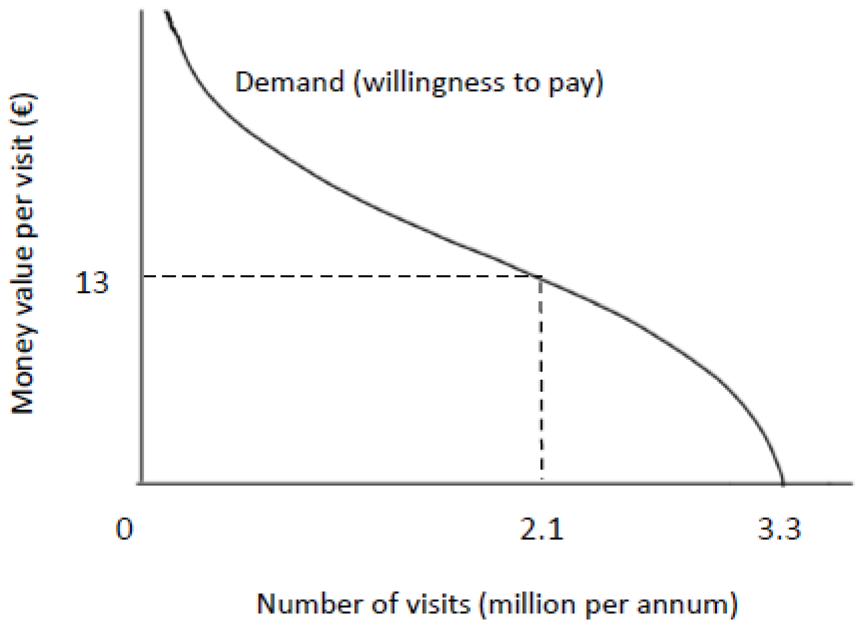
It is clear that the estimation of prices for ecosystem services requires some assumptions regarding institutional arrangements. One option may be to consider that the institutional arrangements that give context to the flow of ecosystem services may imply that the ecosystem services have zero price, particularly those with clear public good characteristics. This would be a strict interpretation of the notion of using existing settings in national accounts valuation. Of course, to the extent that the estimation of a zero price passes a "sense check" and that a zero or very low value is appropriate, then the national accountant can fall back on this option. However, other options must be considered, and these can be found in the environmental economics literature.

These options are considered here using an application by Caparrós et al. (2015) which provides an illustration of these issues in an accounting setting. The study estimates the value that visitors to natural areas in Andalucía place on these nature recreation activities. Specifically, the authors employ a choice experiment survey – a type of stated preference method (see Section 4.3). Leaving aside, for the moment, broader debates about the suitability of stated preference methods for national accounting purposes (but see Section 5 below), this technique is used in their paper to elicit willingness to pay for a trip from a sample of visitors, in the form of the (hypothetical) entry fee. This information is used to construct a demand schedule such as that shown in Figure 2, which is based on findings for one specific region (Cazorla) in the Caparrós et al. study.

Using the information in Figure 2, the application of the observed institutional settings would, in this instance, provide a zero price reflecting the observed 3.3 million visits. This reflects an assumption that such "buyers" (visitors) will make trips up to the point where the marginal value for the last user is zero. What this says it that, given the existing institutional setting, with no rationing of provision (and no congestion), the marginal value that is consistent with current supply and use of the ecosystem for this recreational purpose is zero.

To consider alternative options, a starting point is to determine the value that the marginal user places on a recreational visit. For example, if there are 2.1 million trips each year (i.e. an estimated level of demand and hence supply) then, according to Figure 2, the valuation that the marginal (i.e. last) visitor places on his or her trip is €13. So, given an institutional setting which resulted in this total visitation of 2.1 m trips, this marginal value equates to the transaction price between buyers and the seller.

Figure 2. Valuing nature recreational services (Source: adapted from Caparrós et al. 2015)



Caparrós et al. assume that the relevant institutional setting might be established by making use of information about (marginal) supply prices, relying on assumptions about the costs of providing nature-based recreation opportunities at sites in the region. In effect, what they ask is the following: if a market-like institutional arrangement were to facilitate the exchange of recreational service between buyers (i.e. visitors) and sellers (i.e. the owner of the ecosystem), what would the resulting transaction price be?

For one particular arrangement – monopolistic competition[23] – the authors estimate a marginal value equal to about €13 for a visit (or recreation day). This has the virtue of looking like a "conventional" accounting transaction and, moreover, is associated with a non-zero transaction price. In this sense, perhaps this approach - based on a simulated market but still recognizing the current institutional setting – offers potential for reconciling the economic and accounting perspectives, although it does necessitate assumptions about what alternative institution can realistically be simulated.

The results under this assumption of monopolistic competition can be contrasted with an alternative institutional arrangement involving (perfect) price discrimination (e.g. Day, 2013 and Caparrós et al., 2015), i.e., a situation where each and every user pays a price equivalent to the marginal value they place on the visit. In this situation, some users place a high value on their visit, while other users place a much lower value on their visit. This equates to the area under the demand curve between 0 and 2.1 million visits.

Another alternative would be to use a summary measure based only on buyers' willingness to pay (and so obviating the need to consider a hypothetical supply side). This could be a mean demand price (what the average buyer would pay) or a median demand price (what a majority of buyers would pay). In terms of Figure 2, the former (mean) value would be greater than the

[23] This corresponds to an assumption that the market setting is one in which "currently" there are limited sellers (i.e. recreational sites with each site having its own demand function).

simulated entry price, reflecting the fact that apparently there are a (relatively) small number of visitors who would pay a lot for their visit.

Day (2013) suggests that using mean demand prices might be reconciled with an institutional setting *as if* our seller – the ecosystem – is able to elicit and capture how much each buyer would have paid for their visit (that is, the maximum willingness to pay of each of these users). Focusing instead on a median value perhaps assumes a setting where, if our seller (or perhaps some entity such as the government on its behalf) put this value to a referendum, at least half of users would vote for this transaction price.

Ultimately, the question that must be answered for accounting purposes is how reasonable is the institutional setting that a valuation assumes for a given accounting period. That is, is the institutional arrangement upon which a particular value is based both sensible and credible? At this time, a clear answer to this question cannot be provided. It is hoped, however, that the discussion here:

- makes clear that the valuation of ecosystem services for ecosystem accounting will require acceptance of and assumptions regarding the institutional arrangements;
- explains that making assumptions concerning these arrangements is not incompatible with national accounting but, equally, the assumed arrangements are likely to be different from the type of ideal market arrangements that may be most commonly applied in environmental economic valuation;
- highlights that the economics literature provides a range of alternative models for both the demand and supply side arrangements that may be used to inform a decision for national accounting purposes.

Notwithstanding this positive direction, it is clear that there are knotty issues to deal with. In practice, progress may boil down to choosing the least bad option – given a balance of these different ways of making this judgement – in estimating prices using environmental valuation techniques. Indeed, the discussion also highlights that there are some aspects of estimating prices that are not normally considered in the context of applying environmental economics valuation approaches.

4. Techniques of environmental valuation and the national accounts

In this section, we further draw out issues of alignment between economics and accounting, identified previously by discussing the channels by which ecosystem services are used by "buyers," in the context of techniques that can be used to value these services. Table 4 summarizes the basics of this subsequent discussion and, in doing so, draws a link back to the points rehearsed previously about economic channels and national accounts from Section 3. This includes indications of available techniques to value ecosystem services in different channels.

For each of the channels, we consider three questions in turn. The first is to ask, what is the relevant (marginal) value concept in economics for a given channel? The second is to ask how this marginal price can be said to be consistent with the understanding of a price for national accounting. This second question is the lynchpin. It arbitrates whether the progress made in translating economic valuation concepts into practical techniques for value measurement can also be used for national accounting purposes. In turn, a key ingredient here is whether it can be imagined that there is a plausible economic relationship (at least, in principle) that can be described between buyer and seller that would facilitate the interpretation of an economic value as a price for ecosystem accounting.

Lastly, we ask how this price can be estimated; that is, what techniques are available for the practitioner in terms of empirical estimation? Our discussion here is relatively brief, and so is not intended to be exhaustive in terms of the options or permutations for particular techniques to value specific categories of ecosystem services. Clearly, there is a huge literature on environmental valuation more generally (see, for example, Champ *et al*. 2017). However, the main options are, arguably, covered - including a discussion of what role, if any, approaches based on "valuation at cost" might have, given their intuitive appeal from a national accounting perspective.

Table 4: Techniques of environmental valuation and the national accounts – An overview

Economic channel		Explanation from economic perspective	Examples of ecosystem services	Valuation methods	Link to national accounting perspective
Economic production	**ES#1**	The ecosystem good or service is an input to economic production along with other factors.	• Waste disposal services • Non-renewable and renewable ecosystem goods (food, fiber, water etc.) • Water purification	Indirect methods such as production functions	The value of the ecosystem service is implicit in the value of economic production as measured in standard national accounts (e.g. in conventional GDP). The valuation method would identify that contribution and attribute the service to the ecosystem asset.
Household consumption	**ES#2**	Households choose the level of ecosystem service via purchase of some market good, which is heterogeneous in the various characteristics in which it is comprised (including the ecosystem service).	• Air filtration • Cultural services involving use (physical interactions with nature such as recreation) and non-use (such as off-site experiential), if reflected in purchases and donations	Indirect methods such as hedonic pricing (e.g. in property markets)	The value of the ecosystem service is reflected in household consumption as measured in standard national accounts (e.g. in conventional GDP). The valuation method would identify that contribution and attribute the service to the ecosystem asset
		Households choose the level of ecosystem service to enjoy via purchase of complementary market good (or substitute market good).	• Recreation • Water purification • Air filtration	Indirect methods such as travel cost, defensive expenditures	The value of the ecosystem service can be measured with reference to purchases of a market good that is consumed by households. These outlays themselves are transactions with other institutional units. The implied ecosystem service, inferred from such purchases, can be interpreted as an additional output consumed by households.
	ES#3	Households enjoy an ecosystem service unrelated to any purchase of market good.	• Cultural services involving "pure" non-use	Direct methods such as contingent valuation, (discrete) choice experiment	The value of the ecosystem service is not associated with any purchase of a market good. Any transaction between household and the ecosystem is an additional output consumed by the latter.

Source: See text as well as adapted from Brown et al. (2007) and Day and Maddison (2013)

4.1 Valuing ecosystem service inputs to economic production (ES#1)

What all of these services have in common is that they are used as direct inputs to economic production. In terms of relevance, this is likely to be mostly for activities in the agricultural sector and activities involving the production of natural resources as primary products, including, for example, water abstraction and distribution. This channel will also apply in cases where regulating and cultural services are direct inputs to production. Indeed, a whole range of economic activities necessarily rely on various ecosystem services, although this is may be via relatively long supply chains, and attribution of use to a beneficiary is more complicated.

In the case of agriculture, some of these ecosystem services are provided to farmers on land which they themselves own (or perhaps rent from some landowner). Examples would include the services from soil resources. Alternatively, services may originate elsewhere, as perhaps in the case of pollination services, which might rely on proximity to suitable pollinator habitats. In both cases, determining the economic price for all of these relationships might usefully start by thinking about how (small changes in) any input contributes to production of some output.[24] A key concept here is the marginal value product. This is the additional output that is produced by increasing the contribution of any factor input by one unit. That is, the product of this change in output and the output price is the value of the marginal value of any input.

To what extent can marginal value product be interpreted as a price suitable for accounting purposes? If a market-like institution existed to arbitrate this trade, the value of this marginal product could be interpreted as the price at which this trade would likely, and explicitly, occur. Of course, the typical institutional arrangement here is that the ecosystem input is unpriced: the farmer does not pay for the amount of this input used in production. Nevertheless, the interpretation remains the same, despite the transaction being implicit rather than explicit. That is, for the current level of provision of the ecosystem service (in physical terms), this is the price that the buyer would be willing to pay and what a seller would be willing to accept for an additional unit of supply.

A number of methods exist for estimating the marginal value product for (unpriced) inputs that are ecosystem services; indeed, these methods are well-established in the environmental economics toolkit (see, for example, Haab and McConnell, 2005; Barbier, 2007; Vincent, 2011; Freeman *et al*. 2013). Most commonly, the focus is on the value of production, and so measures the way in which revenue changes as a result of (a change in) the provision of an environmental input. This, then, involves estimating a production function to tease out the physical increase in output that results from a marginal or unit change in provision of some input, such as an ecosystem service. Multiplying this (physical) marginal product by output price gives the marginal value product of the ecosystem service.

Alternatively, the technique may focus on some related aspect of this economic production, such as cost, and seek to estimate the way in which the environmental input lowers the costs of other inputs (where these other inputs are market goods). Another method involves looking at a profit function itself to estimate directly how producer profit changes with different levels of an environmental input. These different methods, however, will yield different estimates, reflecting different assumptions about the constancy of other (i.e. non-ecosystem) inputs or produced output (see, for example, Vincent, 2011). This matters for economic analysis because what is important for understanding the economic costs and benefits of policy actions that change the provision of ecosystem services, is an assessment of how the policy changes economic behavior. Critically for the national accounts, the relevant consideration is whether

[24] There is no reason why the output being referred to need only be a market good (see, for example, Barbier, 2007, for an application where the output is a non-market good, namely improved health status and mortality risks as a result of the provision of an ecosystem service, specifically flood protection). However, in what follows, the definition of output must align with the national accounting definition.

the method reflects what actually happened, i.e. does the valuation technique estimate the marginal product of the ecosystem input as prevailed during the relevant accounting period.

A related but different technique is the estimation of resource rent. This technique is commonly used in an accounting context to measure the value of natural resources. The resource rent, or at least the most common way to estimate these rents, is a residual approach. That is, it takes the value of production (specifically, gross operating surplus) of an economic producer and makes a sequence of deductions reflecting, for the most part, the contribution of other factor inputs such as produced assets, labor, fuel and so on. What remains is the resource rent.

A critical question, common to approaches based on estimating a residual, is whether what is "left over" solely measures the intended object of interest. Indeed, while some applications of this method to estimating resource contributions do not raise this concern, relying on this approach is unlikely to be appropriate for estimating the value of specific ecosystem services. For example, suppose we want to estimate the value of a specific ecosystem input such as pollination services. This would proceed by deducting a range of intermediate costs represented by identifiable (other) inputs. What is left over after these deductions is likely to incorporate the contribution of pollination to production, but also many other factors such as a mix of biophysical attributes, as well as intangible economic factors such as market access and so on. Such concerns are identified in the relevant discussion in the SEEA Central Framework in UN (2012a) but clearly are particularly pertinent in the ecosystem context. Approaches based on production functions potentially provide a way of addressing those concerns, so long as such functions themselves can be estimated, and the specific contribution of an ecosystem service be identified with greater relative precision.

4.2 Ecosystem services as an input to household consumption (ES#2)

For the second channel, or ES#2, valuation methods can be used to assess the marginal value of an ecosystem service, to uncover the way in which these values are revealed in actual expenditure on market goods. These market goods can be either complements to or substitutes for the ecosystem service. These ecosystem services and market goods are inputs used in combination to produce some output. This output might be an SNA benefit – and so already reflected in the national accounts – or it might be a non-SNA benefit. The key point is that, while the ultimate benefit being produced might be a non-market (and non-SNA) output, a market-like institutional arrangement can be envisaged to arbitrate the way in which an ecosystem service flow contributes to generating this benefit, and a price can be uncovered as a guide to the value of that input.

As an illustration, one prominent application is where the provision of an ecosystem service is one of many characteristics (i.e. attributes or inputs) determining the value of residential properties – what is often called hedonic pricing.[25] There are similarities here with ES#1 in that the value of this input is its marginal contribution to some SNA benefit or output, in this case housing services, and at least some aspect of that benefit, such as the amenity that results from proximity to green space, can be related to an ecosystem asset.[26] While the housing example is

[25] In the property example, however, the ecosystem service is a characteristic of the market good which has been purchased. To use the jargon, the market good being purchased is heterogeneous in the sense that its value is comprised of more than one attribute. Residential property is a prominent illustration of this sort of market good. The range of ecosystem services which might be reflected in the value of property (alongside a further range of non-environmental attributes) is potentially large. It is likely to include air flow regulation as well as those services providing what might be broadly termed cultural amenities. Importantly, while these examples are rather different, the theory is the same in both instances.

[26] Notably, both the values of current housing services and residential property are in the accounts (in production accounts and balance sheets, respectively). There is a subtle but important difference in terms of how ecosystem services might be an attribute of such values (see, for example, Taylor, 2003). Housing

the most pervasive, other potential applications of this hedonic approach might be envisaged. Freeman et al. (2013), for example, cite the values placed on nature that are an attribute influencing expenditures made on nature-based publishing and other media products, memberships of conservation organizations, and so on. While, in principle, this seems reconcilable with establishing prices for these transactions, consistent with the national accounts, as a practical matter implementing hedonic pricing may be a challenge.

Other methods which seek to uncover values for ES#2 include the travel cost approach in relation to valuing recreational ecosystem services. From a national accounts perspective, it is conceptually possible to identify the costs incurred by households in visiting or undertaking recreation in the environment. This suggests an important role for estimates of travel costs. In this method, the recreational service is consumed alongside, or more precisely as a result of, the use of a market good, e.g. fuel and recreational equipment. In other words, the ecosystem service and these market goods are complements.[27] What this means is that outlays arising from a trip involving nature recreation are used as a basis for assessing the marginal value of demand for that recreational service.

The *total* travel cost reflects, in essence, the broader *entry price* that a visitor is willing to pay (and, moreover, has paid) for the marginal visit (Day, 2013). This seems to map reasonably to being interpreted as a price arbitrating the transaction between the (recreational) user and the ecosystem. There will be further considerations, of course. This includes whether the estimated price takes into account (and so "nets out") the costs of produced capital and other inputs, or whether the value of nature recreation can be attributed to particular ecosystem services.

There are also judgements to make about the consistency of the types of outlays which comprise travel costs, consistent with national accounting. Actual entry fees are perhaps the most obvious dimension of these outlays. If the site is owned by an institutional unit and recreational visitors can be excluded from use, some entry fee might be charged for visits. It seems a relatively short step to attributing at least some of this fee to the ecosystem service. Outlays involved in travelling to the site as well as any equipment needed to enjoy the recreational service are also relevant. Such outlays will be recorded somewhere in national accounts as part of production and household final consumption expenditure. That is, they reflect actual expenditures for goods and services produced by economic units and, in a direct sense, do not represent the contribution of the ecosystem to household consumption. But the notion here is not necessarily a "reattribution" of those expenditures, but rather their use as a guide to the value of a non-SNA benefit (specifically, the role of ecosystem services in producing that benefit). Hence, these expenditures might be identified separately from current presentations of national accounts data, to reflect a new category describing the recreational service (Day, 2013; Vincent, 2015).

A final component of travel cost is one which, on the face of it, seems to be the least consistent with the SNA. This is the value of the time that visitors spend travelling for the purposes of nature recreation and the time spent at the recreation site itself. However, the use of time for consumption by the same household is not incorporated into the SNA production or consumption boundary, in part because there is no third party that could supply this particular service. A logical consequence of such existing accounting conventions might be to rule out considering that component of travel cost, although in other respects it is an important

services presumably reflect only the provision of current flows of ecosystem services, whereas the asset value of properties (providing housing services) may reflect some forecast of future provision, which may differ from a simple capitalization of what now prevails.

[27] The purchase price of the complements can be interpreted as the value of the recreational service, and so the marginal demand price of the service is zero when the quantity demanded of the market good is zero. (Freeman et al. 2013). Specifically, this refers to weak complementarity (see, for example, Freeman et al. 2013). The level of the recreational service enhances the enjoyment of consuming a market good and, correspondingly, the service can only be consumed if that good is purchased.

underlying element of the price governing the implicit transaction of nature recreational services between users and producers.

Other cases of ES#2 arise when flows of ecosystem services might defend people from environmental harm or burdens. Examples include regulating services that lead to improvements in water quality or air quality. Where expenditures on market goods (such as air purifiers, water filters and so on) provide this same benefit, it may be that these expenditures provide the basis for estimating the (marginal) value of the transaction between the ecosystem and the household. Put another way, such expenditures are substitutes for the ecosystem service. Given that better environmental quality (brought about because of the provision of some level of an ecosystem service) presumably would mean less cost would be incurred, the value of this expenditure or costly behavior gives some indication of the amount that the consumer might exchange in return for these ecosystem services. If so, those values of market goods purchased as defensive outlays might offer a proxy for transactions in (at least certain types of) ecosystem services.

4.3 Ecosystems as an input to household wellbeing (ES#3)

What about ecosystem services that are directly consumed by households? What this directness means is that there is no economic behavior – i.e. expenditures on a (complementary or substitute) market good – with which to tease out the price of the ecosystem service that is subject to this transaction. In other words, households are consuming a service that is relatively far removed from market behavior. Thus, by definition, other methods are needed to value these services. Typically, these other methods will be some form of stated preference (SP) approach (e.g. contingent valuation, CV, or choice modelling variants such as choice experiments, CE). While SP methods could potentially be utilized for other channels (e.g. ES#2), these are the only established techniques which can be used to value ES#3.[28]

SP techniques are survey-based methods which, in the context of the focus of our paper, seek to elicit the monetary value of ecosystem services by directly asking people (usually private individuals or households) what economic value they attach to specified changes in those goods and services. Respondents are directly asked to value a specified change in provision of the good or service in question via a hypothetical market where the outcome in question can be traded (e.g. Alberini and Kahn, 2008). This contingent market defines the nature of this exchange. This typically includes a description of the institutional context in which it would be provided and the way it would be financed. A random sample of people is then directly asked to express, for example, their maximum willingness to pay (WTP) and minimum willingness to accept (WTA) compensation for the provision of some good or service.

Typically, what is specified is a non-marginal change (i.e. some policy relevant change in provision). However, CE techniques (and their variants) can be used to estimate unit or marginal changes in the provision of some ecosystem service flow. In theory, where suitably designed, these methods need not be inconsistent with national accounting. That is, they can be used to estimate prices that are not only consistent with economic principles, but also fit precepts of valuation in national accounts. Of course, this does not mean that all studies in the empirical record satisfy this dual requirement, nor are other debates about these methods irrelevant.

---

[28] Needless to say, there are complications. Some ecosystem assets conceivably provide a number of ecosystem services – some of which are inputs to (economic and/or household) production, and some of which are consumed directly by households. Moreover, a given ecosystem service might be valued in distinct ways, i.e. via more than one economic channel, as described above. The implication is that some of these channels associated with that one ecosystem service, or the multiple services provided by a single ecosystem asset (and so associated transaction prices), are admissible in an SNA-consistent account that seeks to value the flows of these services.

4.4 Restoration, replacement and valuation at cost

In this paper we have focused on whether monetary values – estimated based on what ecosystem services are worth to beneficiaries – can be interpreted as prices which would be consistent with standard national accounting. A rather different approach would be valuation at cost. That is, to paraphrase the SNA (EC et al, 2009), valuing a good or service by the amount that it would cost to produce it currently. In the context of ecosystem services, this has two potential interpretations:

1. It could refer to *restoration* cost. This relates to the expected cost of recreating the underlying ecosystem asset to a pre-determined condition, hence allowing for the sustained delivery of a basket of ecosystem services.[29]

2. It could refer to *replacement* cost, reflecting the expected cost of re-creating a specific, individual service currently provided by an ecosystem asset through some alternative means (e.g. flood protection or wastewater treatment could be provided by a produced asset).

Each of these interpretations of cost-based approaches involves challenges. For example, an issue in using restoration costs – at least in terms of how the SEEA EEA is currently conceptualized – is that they do not relate to specific, individual ecosystem services. And while, as a practical matter, costs can be estimated directly using observable data, this does not mean these data are readily available or straightforward to calculate.

Nevertheless, it is perhaps unsurprising that valuation at cost has an appeal from an accounting perspective. On the face of it, this would "mimic" in outline the treatment of many public services in the national accounts (e.g. law and order, education, health), which are valued at the cost of provision and not according to the value that the associated beneficiaries ("buyers") place on the outputs generated as a result of these government expenditures. However, there is clearly a major difference. In the case of public services in the current national accounts, the costs used in the estimation of these services are costs which have actually been incurred. In the ecosystem accounting context, cost-based approaches are (typically) used to estimate outlays which, hypothetically, would have had been incurred to replace (or restore) actual ecosystem service flows.

In essence, the replacement cost approach estimates what a seller would require in compensation to provide the replacement service; it does not necessarily reflect what a buyer would pay. (In other words, this is the converse of the problem usually identified in the case of the environmental valuation techniques discussed elsewhere in this section.) Confirming whether the requirements of this fuller-picture transaction are satisfied necessitates asking the same questions that economists pose to ascertain whether replacement costs can be interpreted as meaningful economic prices. Brown (2017) outlines and elaborates on three (necessary) conditions.[30] In the context of ecosystem services, these are:

---

[29] This "NCC approach" is, at least in NCC (2015), somewhat more nuanced in that it emphasizes both benefits and costs in accounting for natural capital. This is conceived in terms of what is happening to underlying asset and stresses the value of (net) investment in natural capital assets with reference to the (future) services provided, alongside an assessment of what it costs to maintain or restore such assets. See Mayer (2013) for a more single-minded focus on cost-based approaches in this same context. The starting point for this approach is typically a prior constraint involving the sustainable use of natural capital.

[30] Brown (2017) provides further analysis and interpretation of the criteria identified in Shabman and Batie (1978) and cited in e.g. Hanley and Barbier (2009). Brown (2017) traces this back to Eckstein (1958) in the context of the use of CBA in water resource planning.

1. The replacement provides the same benefit as the existing ecosystem service (i.e. the existing ecosystem service and the produced replacement are perfect substitutes).
2. The replacement is the next least-cost alternative for providing the benefit (i.e. the value of the ecosystem service must be greater than or equal to the cost of producing the service via this alternative means, so that society would be better off paying for replacement rather than choosing to forego the ecosystem service.
3. The replacement would be demanded up to some point if the ecosystem service did not exist (i.e. the benefits of providing the replacement are at least as great as the costs).

Reassurance that the use of replacement cost is meaningful amounts to having a positive response that each of these conditions is fulfilled. There are many replacement cost studies. One example is by Comello et al. (2014), which looks at the value that economic producers place on a tidal estuary in California that purifies water in the presence of an excessive total phosphorus load. The reference point for this cost-based valuation is a survey of wastewater treatment plants and, specifically, their unit costs of removing nutrients (including phosphorus).

This sort of study typically elicits information relevant for assessing whether the initial two conditions (relating to perfect substitutes and least-cost alternatives). For the third condition, there is perhaps more ambiguity, requiring further evidence about individual or societal demand. Therefore, cost-effective ways of judging when replacement cost approaches might be used to value ecosystem service flows are important. The basis of one check might be provided through assessment of the prevailing institutional and regulatory arrangements surrounding the provision of a particular service (or underlying asset). For example, legal requirements that certain ecosystem assets be preserved, such as trees in city parks, might be indicative of an expectation that the services from those trees would be replaced if lost. Vincent (2015) suggests that, in principle, this sort of scrutiny (alternatively or additionally) could be provided by environmental valuation techniques, particularly contingent valuation methods to establish demand for the benefits provided by ecosystem services more broadly.

4.5 Situations where environmental conditions impact human health

A common consideration in the analysis of the relationship between people and the environment is the impact that environmental conditions may have on human health. One common situation is that of pollution, where poor provision of water quality, sanitation and air quality leads to considerable burdens in the form of elevated mortality (and morbidity) risks. Nordhaus (2003), for example, shows how improvements in this provision (brought about in the late 19th and early 20th centuries) translated into huge economic gains. World Bank (2016) shows how contemporary levels of air pollution, both indoor and outdoor, result in economic losses (both impacts on wellbeing loss of labor productivity) that are significant in relation to the size of many national economies.

It is noteworthy that the SNA's current production boundary does not consider health outcomes. Rather, the focus is on the measurement of the outputs of the health industry, e.g. the output of doctors, nurses, hospitals, pharmaceuticals, etc. Whether or not this activity has positive or negative impacts on health outcomes is covered to some extent in terms of understanding the changing quality of the outputs.[31] But it is not the case that the value of the output of the health industry incorporates the broader individual and societal benefits that result from having a healthier population. Nevertheless, providing such benefits is an important element of what ecosystems do, as numerous economic studies have made clear. Therefore, it is important to

[31] For example, improvements in practices that reduce death rates during surgery would likely lead to an improvement in quality of the output.

ask whether there is a mismatch (or not) between values in those economic assessments and the health values that might enter national accounts.

Particularly relevant here are cases where the flow of ecosystem services subsequently has a material impact on human health, and so the value of a service needs to be understood in terms of its contribution to this outcome. Based on the model of defining transactions in ecosystem services described in earlier sections, the logic (from an accounting perspective) would be to consider that health outcomes result from the consumption of ecosystem services. An example of this would be the flow of air filtration services from the current stock (e.g. number and density) of trees in a local area that contributes to air quality. Another example would be flood protection services that reduce mortality risks from coastal inundation. The treatment here is analogous to the benefit to an individual's health as a result of consuming sufficient vitamins or visiting a doctor (i.e. consuming health services).

There are two important aspects that may be considered in other valuation and assessment contexts, but would not be immediately captured from an accounting perspective. First, in understanding the link between the environment and the individual, there is no consideration of the impact that a reduction in an individual's health may have subsequently – for example, on their income, labor productivity, family life, etc. Second, the relationship between the ecosystem asset and people is not structured to attribute "fault" to the environment – i.e. there are no disservices in this treatment. These two aspects are important in determining appropriate valuation approaches.

Given the accounting context, one approach to valuation of ecosystem services would be to estimate the lowest cost option available to an individual to replace the ecosystem services that are being consumed (even at a reduced level). The values revealed in subsequent economic behavior - which involves defensive or averting actions - might fit the bill for estimating prices. Some of these behaviors may themselves reflect outlays or spending; that is, actual transactions. For example, where goods are substitutes for some ecosystem service (e.g. air purification), expenditure on these goods (e.g. an air filtration system is a ubiquitous example) might reveal something about people's willingness to pay for the service itself. Some of these defensive activities might not involve monetary expenses, but rather are revealed in behavior changes involving time use (e.g. staying indoors). In such cases, the value of time use raises the same issue of SNA compatibility as when considering aspects of travel costs incurred in the process of enjoying nature recreation services. Nevertheless, from an economic perspective, time has a value, and for the ecosystem service user who experiences a material impact on their health, this will frame the price at which that user would undertake further transactions.

In economic appraisal, another perspective on assessing health values makes use of the insight that relatively risky occupations (other things being equal) command higher wages. These wage risk premia can be interpreted as a measure of willingness to accept risks to life and limb in the workplace. While this is clearly a valuation based on a transaction (between employer and employee), one question is whether the very different institutional context of the risk – vis-à-vis that of ecosystem services (which contribute to enhanced health) – matters.

The challenge from an accounting perspective lies in framing the relationship between humans and the environment in terms of the volume of ecosystem services that are actually exchanged, and tracking this volume over time. Separately, it will be relevant to monitor ecosystem condition, the resulting flow of ecosystem services, and the change in human health outcomes. The focus is on the nature and magnitude of the transactions with the environment, which may or may not bear a relation to notions of benefits, from economic assessments, that arise as a result of that engagement.

5. Discussion and conclusions

This paper builds on existing discussion about the consistency (or otherwise) of the approaches to valuing ecosystem services that are currently within the toolkit of the environmental economist, keeping in mind the valuation requirements of national accounting as applied to accounting for ecosystems. We have taken a reasonably optimistic perspective on this. First, we maintain that these two traditions are not as far apart as some might claim; and second, there is now considerable progress on both ecosystem valuation and ecosystem accounting to show how this might work in practice. However, we have noted a number of complications and challenges that accompany this broadly positive standpoint.

Our emphasis on prices might seem somewhat single-minded given the broader debate surrounding extensive adoption of valuation in ecosystem accounts. For example, there is likely to be concern about the potential for monetary valuations to provide misleading signals to decision makers.[32] Even so, there are vital decision-making processes that currently involve monetary valuation, but which do not, or only partially, incorporate environmental concerns. National accounting is clearly one of the information sets that underpins these processes, and so it is important to consider how this shortcoming can be addressed. In doing so, it might be useful to think in terms of a hierarchy of concerns that flow from this starting point.

Our focus in this paper has been on what we consider to be at the top of this hierarchy: the consistency between concepts and methods used in environmental economics to value flows of ecosystem services, and the concepts of prices needed for valuation in national accounts. The critical first question is whether this valuation yields monetary estimates which can interpreted as prices for accounting, as well as being conceptually meaningful in economic terms. This paper concludes that, in many cases, there is a positive answer to this. However, in other regards, accounting conventions may raise supplementary obstacles. To give one example, the use of information on the relationship between ecosystem services and human health outcomes could well be problematic from a national accounting perspective.

However, debate does not (and should not) end in establishing a conceptual alignment. At a second tier of this hierarchy, there will be practical concerns about these methods. A particular concern surrounds the robustness of these environmental economics-based valuations compared to the usual standard of accuracy in national accounting. In fact, much of the focus in environmental economics itself has been concerned with testing methods, scrutinizing situations in which they work and where they do not. Those debates and findings are clearly relevant to applications for ecosystem accounting, although they need to be interpreted sensibly (e.g. to paraphrase an argument in Champ et al. 2017, perfection is not a workable benchmark against which to evaluate practical methods). Some apparent anomalies and biases associated with particular methods will be more relevant than others to the estimation of accounting-relevant prices.

At a third tier, there are questions about institutional processes and the capacity of those organizations charged with valuing ecosystem services. Practical questions in managing this process might also prescribe which valuation techniques are used and when. One concern, for example, might be that as valuation techniques become ever more sophisticated (which is clearly a good thing if it is a reflection of greater validity and reliability), they also require more and more specialized expertise. And, not surprisingly given the breadth of ecosystem service types, there is a corresponding array of different valuation techniques for compilers of accounts

[32] This could include suggesting that there may be substitutability between ecosystems and other asset types (including produced and financial capital) and, by definition, not incorporating intrinsic values of nature.

to master. Practical questions in managing this process might also prescribe which approaches are used and when.

All of this amounts to a challenging agenda. It may be that, at some point along the path through this hierarchy, certain techniques of environmental valuation will not satisfy the requirements for integration into the national accounts. While the specific grounds for such judgements need to be explicit, the general point is that the choice of valuation approach should be aligned with the measurement and analytical intent. So even if some valuation techniques may not be appropriate for use in ecosystem accounting, these techniques remain vital for use in the domain of policy appraisal, such as in cost-benefit analysis.

It is also relevant to consider the specific accounting context. The use of transaction-based pricing is necessary where the intent is to integrate the valuation of ecosystem services and, subsequently, ecosystem assets and flows (such as ecosystem degradation) with the standard measures of national production, income, saving and wealth, including GDP. At the same time, there may be an important opportunity to recognize a variation in accounting intention, with a focus on the contribution of ecosystems to current and future welfare. In this case, parallel accounting structures, as well as alternative valuation concepts, may be relevant, particularly to account for ecosystem services in channel ES#3.

More broadly, there is a real need for an extended discussion between national accountants and environmental economists, to understand the nature of the differences in their approaches to valuation. This paper can be viewed as a detailed attempt to better frame that discussion, recognizing that – while clarification of a number of issues has been reached – ongoing dialogue will be required. In considering these measurement challenges, there are many areas within the standard national accounts that face similar methodological issues. For example, the measurement of capital stocks of produced assets is a long-standing challenge requiring many assumptions based on limited data. More recently, accounting for research and development expenditures has opened up many issues in the treatment of non-market production and spillovers of benefits to multiple beneficiaries.

Ultimately, the existence of conceptual challenges in ecosystem accounting should not be a reason for delaying the testing and implementation of accounting approaches. There is already a more than substantive body of evidence on which to base meaningful estimates. Using the framing provided in this paper, we intend to pursue two additional directions. The first is the description of more specific advice on using methods associated with different channels for estimation the transaction prices for specific ecosystem services This work will be directed towards supporting current efforts in ecosystem accounting. Second, we will expand on the introductory discussion of the valuation of ecosystem assets provided in this paper. Issues such as the estimation of asset lives, the choice of discount rates, and integration with existing national accounts balance sheet values are of particular relevance. The aim in both of these efforts is to utilize the existing expertise and experience across the economic and accounting disciplines to find solutions to clear and current measurement challenges.

References

Abraham, and Mckie (2006) "A framework for nonmarket accounting", in Jorgenson, D. et al. (eds.) *A New Architecture for the US National Accounts*, Chicago University Press, Chicago.

Alberini, A. and Kahn, H. (eds.) (2008) *Handbook of Contingent Valuation*, Edward Elgar Publishing, Cheltenham.

Arrow, K. et al. (2012) "Sustainability and the measurement of wealth", *Environmental and Development Economics*, 17: 317-353.

Banzhaf, S. and Boyd, J. (2012) "The architecture and measurement of an ecosystem services index", *Sustainability* 4:430-461

Barbier, E.B. (2014) "Challenges to ecosystem service valuation for wealth accounting", in IHDP-UNU/ UNEP (2014) *Inclusive Wealth Report 2014*, Cambridge University Press, Cambridge,

Barbier, E.B. (2011) *Capitalizing on Nature*, Cambridge University Press, Cambridge.

Barbier, E.B. (2007) "Valuing ecosystem services as productive inputs", *Economic Policy*, Jan. 177-229.

Blades, D. (1989) "Measuring pollution within the framework of the national accounts", in Ahmad, Y. et al. (eds.) *Environmental Accounting for Sustainable Development*, The World Bank, Washington DC.

Boyd, J. (2007) "Nonmarket benefits of nature: What should be counted in green GDP", *Ecological Economics*, 61: 716-723.

Boyd, J. and Banzhaf, S. (2007) "What are ecosystem services: The need for standardized environmental accounting units", *Ecological Economics*, 63: 616-626.

Brown, T.C. (2017) "Substitution Methods", in Champ *et al.* (eds.) *op cit*.

Brown, T.C. Bergstrom, J.C. and Loomis, J.B. (2007) "Defining, valuing and providing ecosystem goods and services", *Natural Resources Journal*, 47: 329-376.

Caparros, A. Oviedo, J.L. et al. (2015) "Simulated exchange values and ecosystem accounting", Consejo Superior de Investigaciones Cientificas (CSIC), Madrid.

Champ, P. et al. (eds.) (2017) *A Primer on Non-market Valuation*, 2nd edition Kluwer Academic Publishing, Dordrecht.

Comello, S.D., Maltais-Landry, G, Benedict R. Schwegler, B.R. and Lepech, M.D. (2014) "Firm-Level Ecosystem Service Valuation Using Mechanistic Biogeochemical Modeling and Functional Substitutability", Ecological Economics, 100: 63-73.

Convention on Biological Diversity (2010) *Strategic Plan for Biodiversity 2011-2020*, http://www.cbd.int/sp/targets/

Dasgupta, P. and Mäler K.-G. (2000) "Net national product, wealth and social wellbeing", *Environmental and Development Economics*, 5(1): 69-93.

Day, B. (2013) “An overview of valuation techniques for ecosystem accounting”, School of Environmental Sciences, University of East Anglia, mimeo.

Day, B. and Maddison, D. (2015) *Improving Cost Benefit Analysis Guidance*, Natural Capital Committee, London.

European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations, World Bank (1993) System of National Accounts 1993, United Nations, New York

Fenichel, E.P. and Abbott, J.K. (2014) “Natural capital: From Metaphor to measurement”, *Journal of the Association of Environmental and Resource Economists*, 1(1): 1-27.

Freeman, A.M. III et al. (2013) *The Measurement of Environmental and Resource Values: Theory and Methods*, 3rd edition, RFF Press, Washington DC.

Hamilton, K. and Atkinson, G. (2007) *Wealth, Welfare and Sustainability*, Edward Elgar, Cheltenham.

Hamilton, K. and Clemens, M. (1998) “Genuine saving in developing countries”, *World Bank Economic Review*, 13(2): 333-356.

Hanley, N.H. and Barbier, E.B. (2009) *Pricing Nature*, Edward Elgar Publishing, Cheltenham.

Hein, L., Obst, C., Edens, B. and Remme, R. (2015) Progress and challenges in the development of ecosystem accounting as a tool to analyse ecosystem capital. Current Opinion in Environmental Sustainability. 14, 86-92

IHDP-UNU/ UNEP (2014) *Inclusive Wealth Report 2014*, Cambridge University Press, Cambridge,

IHDP-UNU/ UNEP (2012) *Inclusive Wealth Report 2012*, Cambridge University Press, Cambridge.

Jorgenson, D. and Landefield, S. (2006) “Blueprint for expanded and integrated US national accounts: Review, assessment and next steps”, in Jorgenson, D. et al. (eds.) *A New Architecture for the US National Accounts*, Chicago University Press, Chicago.

McConnell, K.E. and Bockstael, N.E. (2005) “Valuing the environment as a factor of production”, in Mäler, K.-G. and Vincent, J.R. (eds.) *Handbook of Environmental Economics*, Elsevier, Amsterdam.

Nordhaus, W.D. (2006) “Principles of national accounting for nonmarket accounts”, in Jorgenson, D. et al. (eds.) *A New Architecture for the US National Accounts*, Chicago University Press, Chicago.

Obst, C., Hein, L., Edens, B. (2013) Ecosystem services: Accounting standards, *Science* Letters, 25 October 2013

Obst, C., Hein, L., Edens, B. (2015) National accounting and the valuation of ecosystem assets and their services, *Environmental and Resource Economics*, DOI 10.1007/s10640-015-9921-1

Peskin, H. (1989) “A proposed environmental accounts framework”, in Ahmad, Y. et al. (eds.) *Environmental Accounting for Sustainable Development*, The World Bank, Washington DC.

Peskin, H. and Peskin, J. (1978) “The valuation of nonmarket activities in income accounting”, *Review of Income and Wealth*, 24(1): 71-93.

Schreyer P. and Obst C. (2015) *Towards Complete Balance Sheets in the National Accounts: The Case of Mineral and Energy Resources*, OECD Green Growth Papers, 2015-02

TEEB (2010) *The Economics of Ecosystems and Biodiversity, Mainstreaming the Economics of Nature. A Synthesis of the Approach, Conclusions and Recommendations of TEEB*. Routledge, Oxford.

United Nations (2015) SEEA Experimental Ecosystem Accounting: Technical Recommendations, Consultation Draft – December 2015. Draft prepared as part of the joint UNEP / UNSD / CBD project on Advancing Natural Capital Accounting funded by NORAD.

UNEP-WCMC (2015) Experimental Biodiversity Accounting as a component of the System of Environmental-Economic Accounting Experimental Ecosystem Accounting (SEEA-EEA). Supporting document to the Advancing the SEEA Experimental Ecosystem Accounting project. United Nations.

United Nations, European Commission, Food and Agricultural Organization of the United Nations, International Monetary Fund, Organisation for Economic Co-operation and Development, The World Bank (2014a) System of Environmental-Economic Accounting 2012 – Central Framework. United Nations, New York

United Nations, European Commission, Food and Agricultural Organization of the United Nations, Organisation for Economic Co-operation and Development, The World Bank (2014b) System of Environmental-Economic Accounting 2012 – Experimental Ecosystem Accounting. United Nations, New York

Vanoli. A. (1995) “Reflections on environmental accounting issues”, *Review of Income and Wealth*, 41(2): 113-137.

Vincent, J.R. (2015) *Valuing Environmental Services in the SNA*. Report was prepared for the Policy and Technical Experts Committee (PTEC) of the World Bank’s Wealth Accounting and Valuation of Ecosystem Services (WAVES) program.

Vincent, J.R. (2011) “Valuing the environment as a production input”, in Haque, A.K.E. et al. (eds.) *Environmental Valuation in South Asia*, Cambridge University Press, Cambridge.

World Bank (2016) Natural Capital Accounting http://www.worldbank.org/en/topic/environment/brief/environmental-economics-natural-capital-accounting