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Discussion paper 5.1:
Defining exchange and welfare values, articulating institutional arrangements and establishing the valuation context for ecosystem accounting

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Working Group #5 – Valuation concepts and accounting treatments

Discussion paper 5.1:
Defining exchange and welfare values, articulating institutional arrangements and establishing the valuation context for ecosystem accounting

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Section 1. Valuation of ecosystem services in national accounts context

The intent of the section is to give a quick overview of some key national accounts concepts relevant for ecosystem accounting, aimed at a non-accountant audience. It has a brief discussion on household production satellite account in response to a request from WG5.

1.1 Recap of key concepts

SNA and SEEA production boundary (based on Obst et al 2015). In the SNA, production is defined as an "activity carried out under the control and responsibility of an institutional unit that uses labour, capital and goods and services to produce outputs of goods or services" (EC et al. 2009, para 6.24). From this starting point a number of clarifications and conventions are applied to determine the standard SNA production boundary. The key point relating to the measurement of ecosystems is that a purely natural process without any human involvement or direction is not production in an economic sense (EC et al. 2009, para 6.24).[1]

To avoid double counting ecosystem services are defined in the SEEA EEA as **contributions of ecosystems to economic and other human activity** (UN et al. 2014b), not as **benefits** as common in the environmental and ecological economics literature. Ecosystem services lie outside the SNA production boundary, and ecosystem accounting (as conceived in the SEEA EEA) expands the SNA production boundary in order to recognize ecosystem services as outputs of a production process. The possibility to alter concepts and measurement boundaries lies at the core of the satellite accounting approach introduced with the 1993 SNA. Environmental accounts are not the only form of satellite accounting, for instance household production accounts extend the household production boundary to recognize unpaid household work, tourism satellite accounts provide additional disaggregations / functional allocations of activities already within the scope of the SNA. It is important to keep in mind that the production boundary in the National accounts is very much a convention (e.g. own account production of goods (say from gardening) are considered productive, but own account production of services (e.g. cooking a meal) are not, that has been decided upon by both theoretical as well as pragmatic considerations such as data availability.[2]

Transactions. The SNA is a quadruple entry system in which transactions (between so-called statistical units (e.g. households or companies)) are the foundation. Transactions are distinct from transfers (e.g. taxes or subsidies) by the fact that there is always something provided in return. A key implication of the transaction based nature of the system is that supply (of a product) has to equal use, implying that each transaction is characterized by a single unique value (monetary in the SNA, monetary and physical in the SEEA) that is identical for both the supplier and the user. This implies however that consumer surplus cannot be recorded in the accounts, as this by definition drives a

[1] Here the distinction is made between (i) the active cultivation of crops, livestock, orchards and other biological resources which is included in the production boundary, and (ii) the growth of natural resources (such as timber in primary forests, fish on the high seas) which is not under the control of an economic unit and hence lies outside the production boundary. While the growth of natural resources is not considered production, the harvesting of those natural resources is within the production boundary (e.g. through logging or fishing activity).

[2] e.g. while form a theoretic point of view there was long standing agreement to treat R&D expenditure as investment, due to measurement difficulties the change was not made until in the 2008 SNA.

wedge between supplier and user. In short, the SEEA EEA conceives of ecosystems as (quasi-)statistical units engaging in transactions of ecosystem services.[3]

The SNA recognizes 3 forms of output: market-output, output for own final use and non-market output (Para. 6.95). Non-market output is defined as "output undertaken by general government .. that takes place in the absence of economically significant prices" (para 6.97). Economically insignificant price is defined as: having "little or no influence on how much the producer is prepared to supply and is expected to have only a marginal influence on the quantities demanded… a price that is not quantitatively significant from the point of view of either supply or demand. (ibid) ". The value of non-market output is estimated as the sum of costs of production: intermediate consumption + compensation of employees + consumption of fixed capital + other taxes (less subsidies) on production. Some national accountants have therefore reasoned as follows: ecosystem services are a form of non-market output, therefore they need to be in principle valued at cost (of supplying them), for instance the costs made in order to maintain the assets that supply them free of charge (the so-called "maintenance costs approach" advocated in the SEEA 1993; see also Vanoli 2005; Vanoli 2015*)*. A variant of this thinking is to choose the replacement costs of the service (in case it would be lost).[4]

The third type of output (paraphrasing p.106 and 110 of the 2008 SNA here) – closely related to **household production** - is **output (production) for own final use** in the SNA. Output for own final use consists of products retained by the producer for his own use as final consumption or capital formation. This includes for instance: the value of goods produced by an unincorporated enterprise and consumed by the same household; the value of services provided to households by paid domestic staff; the value of the imputed services of owner-occupied dwellings; the value of the fixed assets produced by an establishment that are retained within the same enterprise for use in future production (own-account gross fixed capital formation). In principle (para 6.115) "All goods produced by households are within the production boundary and those that are not delivered to other units should be treated as either being consumed immediately or stored in inventories for later use." In terms of valuation, "output for own final use should be valued at the basic prices at which the goods and services could be sold if offered for sale on the market. In order to value them in this way, goods or services of the same kind must actually be bought and sold in sufficient quantities on the market to enable reliable market prices to be calculated for use for valuation purposes. The expression "on the market" means the price that would prevail between a willing buyer and willing seller at the time and place that the goods and services are produced. In the case of agricultural produce, for example, this does not necessarily equate to the prices in the local market where transportation costs and possibly wholesale margins may be included. The nearest equivalent price is likely to be the so-called "farm-gate" price; that is, the price that the grower could receive by selling the produce to a purchaser who comes to the farm to collect the produce." (Para 6.124) "When reliable market prices cannot be obtained, a second best procedure must be used in which the value of the output of the goods or services produced for own final use is deemed to be equal to the sum of their costs of production (Para 6.125)" (see above)

[3] NB: it may be possible to conceive of ecosystem services not as transactions in the system but as transfers (e.g. subsidies provided by ecosystems to consumers). This could be implemented by adding an additional valuation layer in the system.

[4] This may help to explain why national accountants are generally quite fond of replacement cost approaches, while these approaches are often rejected by environmental economists for lack of representing preferences.

Services. Another concept that is important is the definition of service. In the SNA "the production of services must be confined to activities that are capable of being carried out by one unit for the benefit of another. Services are the result of a production activity that changes the conditions of the consuming units, or facilitates the exchange of products or financial assets." (Para 6.16-6.17). Examples of these changes are changes in the condition of the consumer's goods; changes in the physical condition of persons (e.g. transport); changes in the mental condition of persons (education) (Para 6.18). The SNA makes clear (Para 6.19) that these changes may be temporary or permanent. This definition of services rules out things like sleeping, as this is something you cannot ask someone else to do on your behalf i.e. it cannot be carried out by one unit for the benefit for another (this is sometimes called the 3rd party criterion – see Landefeld et al 2000, p.294). From a national accounts' perspective one should therefore consider whether time spent (e.g. in nature recreation) would be ruled out based on the 3rd party criterion or whether with the introduction of ecosystems as quasi-institutional sectors allowing to record a transaction between units (ecosystem and conventional statistical units) the 3rd party criterion is circumvented. Second, whether non-use service values e.g. bequest / existence variety would qualify as services (arguably not).

1.2 Valuation in National accounts

The 2008 SNA is explicit in warning against a welfare interpretation of GDP: *"GDP is often taken as a measure of welfare, but the SNA makes no claim that this is so and indeed there are several conventions in the SNA that argue against the welfare interpretation of the accounts." (EC et. al. 2009, para 1.75).* This position has become stronger over time, especially considering that someone like Simon Kuznets (one of the main founders of the National Accounts) wanted to develop a system close to welfare. Rather, the main objective of the SNA is to "compile measures of economic activity in accordance with strict accounting conventions based on economic principles." (ibid para 1.1). One may debate however the strictness given that these conventions themselves (e.g. production boundary) are changing over time

Exchange prices (current / constant). The core national accounts valuation concept is the application of market prices: "market prices are the amounts of money that willing purchasers pay to acquire goods, services or assets from willing sellers" (EC et al. 2009, para 3.119). However, "a market price refers only to the price for one specific exchange under the stated conditions. A second exchange of an identical unit, even under circumstances that are almost exactly the same, could result in a different market price" (EC et al. 2009, para 3.119). A fortiori, the SNA would not rule out (perfect) price discrimination. It is important to distinguish the national accounts concept from other interpretations of the term "market prices" (e.g. a free market price occurring exclusively in a purely competitive market situation) - in fact "a market transaction could take place in a monopolistic, monopsonistic, or any other market structure." (EC et al. 2009, para 3.119).) "exchange prices can be defined as the price at which goods, services and assets are exchanged regardless of the prevailing market conditions". Exchange prices can be defined as the imputed price that were likely to obtain if a market for that ecosystem service would have existed. Exchange prices are distinct in concept from shadow prices as they do not incorporate the effect of externalities. Given the transaction based nature of the accounts, as well as the focus on actual exchanges (rather than exchanges in case of perfect markets) the SNA does not recognize externalities.

In the absence of transactions exchanged in markets the main approaches used to estimate the relevant exchange price of transactions between economic units are as follows:

- The first best alternative is to use the exchange price of the same or a similar good or service;
- The second best approach is to estimate the exchange price based on the costs of production which is most commonly applied in the measurement of public services such as health which are non-market.

The issue being of course that many ES (especially regulating and cultural ES) cannot be estimated via either method mentioned above.

Accounts are always ex post, published with the best knowledge at a certain point of time over a period in the past. Oftentimes, the interest in national accounts statistics lies not so much in describing the level of say GDP, but its development over time. (a well-known exception is the EU were the national accounts are more or less like the tax declaration of countries used to asses countries' contribution to the EU). In national accounts parlance, a change in value is always decomposed in a change in volume (picking up both quantity and quality) and a change in price. The development is always described "in volume terms" i.e. after correcting for price changes. This is more sophisticated than merely deflating an indicator such as GDP. Usually, all products (goods and services) are being deflated by best possible estimators (either ppi's cpi's etc.), supply-use tables etc. are being deflated.

1.3 Household production

The household satellite account is also an example of an account that extends the SNA production boundary in this case by incorporating the value of unpaid household work into national accounts. Due to this similarity as well as the potential overlaps with assessing ecosystem services such as nature-based recreation, we discuss this satellite account in a bit more detail here.

The 2008 SNA states: "Thus, the reluctance of national accountants to impute values for the outputs, incomes and expenditures associated with the production and consumption of services within households is explained by a combination of factors, namely the relative isolation and independence of these activities from markets, the extreme difficulty of making economically meaningful estimates of their values, and the adverse effects it would have on the usefulness of the accounts for policy purposes and the analysis of markets and market disequilibria."(para 6.30). However, the 1993 SNA introduced the possibility of satellite accounts, to study certain phenomena without disrupting the central set of accounts.

One of the motivations to develop household production accounts was to shed light on issues such as the extent to which the growth rate of production reflects the increasing participation of women in the labor force (and hence a shift from household non-market to market production) rather than an increase in output per se (see Landefeld and McCulla 2000.).[5] A second motivation arose from a lack of consistency in measuring production in the SNA (the famous example that marrying your housekeeper reduces national income). As with the ecosystem accounts now, a similar discussion took place during its development as to whether the household accounts ought to focus on market-like activities occurring at home, or on welfare produced within the home. Eventually it was decided that the household would be most relevant if they have a market-like basis. One of the main reasons being

[5] When it comes to nature recreation, there seems to be a nice parallel example to unpaid household labor. Arguably, we are growing our output by introducing fitness rooms which to a certain extent is only substituting for exercising in nature.

that in order to assess questions of substitution (as above) it is more appropriate to analyze market-like outputs than assess welfare (and value them using similar remuneration rates as in the market). E.g. a meal is valued based on how much it would cost of have someone else cook a similar quality meal, but without assessing the extra care that may have been put into that meal.

Two other clarifications are important; regarding the role of individuals and volunteer time. The basic units in the accounts are economic units that can engage in transactions and are capable of owning assets (para 2.16), such as enterprises and households. "Households are institutional units consisting of one individual or a group of individuals. All physical persons in the economy must belong to one and only one household. The principal functions of households are to supply labour, to undertake final consumption and, as entrepreneurs, to produce market goods and non-financial (and possibly financial) services. The entrepreneurial activities of a household consist of unincorporated enterprises that remain within the household except under certain specific conditions." (para 2.17) Therefore, individuals are not identified anywhere in national accounts as "units" (unless they coincide with household units in one person households). Individuals therefore also cannot transact with other members within the household. This causes some difficulties as a lot of the work in the ES valuation literature is centered around individuals.

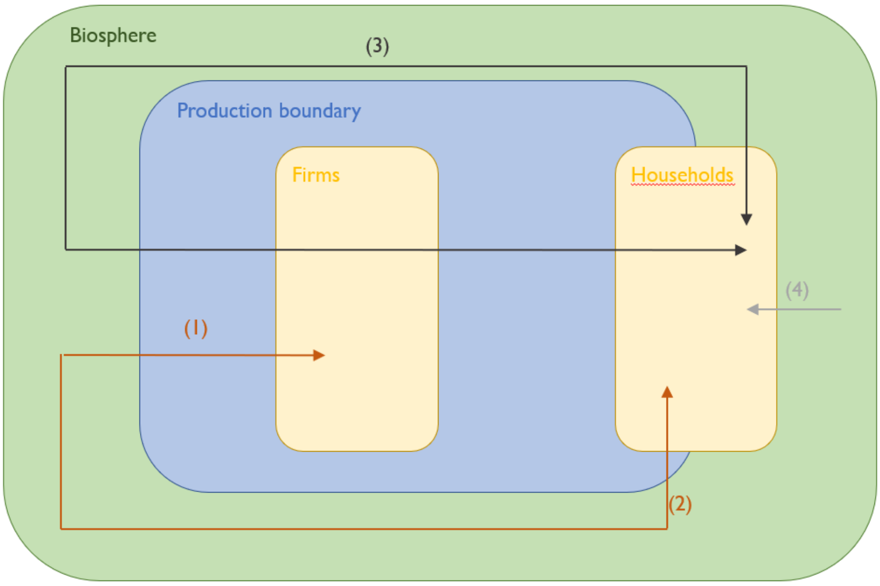
Regarding volunteer labour the SNA states that "The provision of unpaid services to households is excluded from the production boundary. This exclusion applies whether the household being provided with the services is the one to which the volunteer belongs or another." (para 29.156). Therefore, coaching a soccer team, or watching your neighbour's kids is not considered a productive activity – unless payments occur (e.g. for babysitters).

Some national accountants perceive a tension between on the one hand extending the production boundary by recognizing ES (and hence the need to impute a value for them) while at the same time the national accounts principle of recording prices regardless of market organization. Many ecosystem services are simply provided free of charge, which reflects the current institutional regime (the lack of market does not imply an absence of governance). On the other hand, precedents clearly exist in national accounts e.g. when making imputations for owner occupied dwellings of imputing prices for transactions that do not actually take place. The substitution argument provided in case of household accounts may also apply in ecosystem accounting in selecting valuation approaches. What would the most likely market mechanism be in case ecosystem services were marketed (using a previous metaphor, 'what would the most likely output/remuneration be if a meal would be cooked by a third person?').

1.4 The purpose of monetary valuation in ecosystem accounts

Ecosystem accounts can be conceived as making the contributions of ecosystem services to economic activity - which in the SNA itself remain mostly hidden - visible. It is important to define the pathways or channels through which final ecosystem services benefit economic units, distinguishing between what is already accounted for in the SNA, and what is not. Figure 1.1 extends the three channels on the relationship between human wellbeing and the environment that are identified by Freeman III, Herriges and Kling, (2014) and mentioned in paragraph 6.51 of the 2017 Technical Recommendations (UNSD, 2017). In essence, what is in SNA already are the transactions (in)between firms and households, depicted by the blue rectangle in **Error! Reference source not found.**.1 From an accounting perspective, when introducing ecosystem services, we are looking at the immediate ‘transaction’ between the ecosystem and the immediate agent in the economy. The input that the ecosystem brings is used by the immediate actor to produce a good or service that then brings benefits to society. We are looking at a *producers’ perspective*, or at the link between the ecosystem service and the user (economic unit). Both, firms and households can be users.

Figure 1.1: SNA Production boundary



There are four channels relevant for ecosystem services accounting (Fig.1.1):

(1) Final ecosystem services as an input to firms, that are used to produce goods or services that are sold to other firms or directly to households. E.g. agricultural production. These are usually direct and indirect use values in TEV.

(2) Final ecosystem services as an input to households, that are used to produce a benefit, and are already included in the accounts. E.g. subsistence agriculture, or potable water directly extracted by households. These are usually direct and indirect use values in TEV

(3) Final ecosystem services that bring benefits to households, but they are co-jointly produced by households and firms. For instance recreation. E.g., if we think about a travel cost model, the gasoline for transport, the hotel nights, etc., are already accounted in the SNA, because jointly produced by many economic sectors (hotels, retail gasoline, etc.) as well as households. But there are many recreational activities that takes place without market transaction (the part of the households that is not within the production boundary in the figure). So, this case is more complex because there is not a one-to-one linkage with one ecosystem bringing inputs to only one sector, and there are many activities without market transactions.

(4) Final ecosystem services that bring benefits to the households, but are not accounted in the final value of any good or service. This are usually regulating services that are not within the production boundary (air purification, carbon sequestration) and non-use values.

Table 1.1 The extent to which ecosystem services are included in SNA

ESS	Included in SNA*	Channel	Sectors	Comments
Crops	Yes	1,2	Agriculture	including subsistence farming + kitchen gardens
Pollination	Yes	1	Agriculture	seen as intermediate ecosystem service
Timber	Partial	1,2	Forestry	yes, but firewood gathering / collection likely not
Fish	Yes	1,2	Fishing	yes for subsistence fishing; recreational fishing (or hunting) better seen as cultural service
Water	Partial	1,2	Water supply	not self-abstraction by households, at insignificant values for industries
Carbon sequestration	Partial	4	-	in case of existing emisison permits or carbon taxes, relevant transactions are recorded in SNA
Soil retention	Partial	1	Agriculture; water supply; energy	difficulty here is that the counterfactual (say increased sedimentation in absence of ecosystem present) can have both positive (higher donwstream agricultural yields) and negative effects (clogged up dams/reservoirs) on economc production.
Air filtration	Partial	1	across	in part - healthier workers are more productive
Water purification	No	4		water purification costs by water supply sector can be seen as substitute
River flood regulation	No	4		insurance value can be seen as a complement / substitute
Coastal flood regulation	No	4		insurance value can be seen as a complement (e.g. to service provided say by mangroves and coastal reefs)
Water flow regulation	Partial	1	Transport; Agriculture; Water supply	yes for water transport, not so much for other uses
Local climate regulation	No	4		effec on productivity likely less than for air filtrataion
Nature based tourism	Yes	3	Hotel and restaurant services	
Nature based recreation	No	3	across	apart from specific expenditures (e.g. costs of ransport; park entrance fees; ice cream)
Green parks	Yes	1,2	Real estate / owner occupied dwellings	effect on property prices (with effect on real estate brokers as well as owner occupied dwelllings)
* included -> indirectly based on products they contribute to				

Table 1.1 is a first attempt to list for the most common ecosystem services to what extent they are already included in common measures of production and income in the national accounts.

In principle all provisioning services are already included in the SNA measurement boundary through the products they contribute to (e.g. crops; fish; timber), but they are of course not attributed to ecosystems (nor of course identified as ecosystem services). Please note that subsistence farming / fishing should in principle be imputed as part of the non-observed economy estimates. In such cases, the household would be treated as a non-incorporated enterprise, and the output would hence be recorded as agricultural output (not as household output). The same applies for kitchen gardens and in theory also non-timber forest resources. Likely national accountants will only make imputations in case of significant non-observed activities (e.g. national pastimes such as berry picking / bushmeat perhaps etc.)

The provisioning service of water (to households) is more difficult. In principle this will not be imputed in the national accounts as it is not considered a productive activity.[6] In case of self-abstraction by industries or agriculture (which is covered for instance in physical terms in the SEEA CF), a transaction could be recorded in case payments for a permit are made (say to a municipality). If this payment is considered as a proper estimate of the exchange value, the flow would need to be reallocated for the purposes of ecosystem accounts compilation.

[6] To the authors best knowledge.

For regulating services, it becomes more complex. In case of carbon sequestration, when a country participates in emissions' trading schemes or has implemented a carbon tax, relevant transactions are already recorded in the SNA (in both instances as taxes) and would need to be reallocated for the purposes of ecosystem accounting.

Some regulating services are indirectly reflected in the accounts, for instance as healthier workers tend to be more productive. The current SNA output therefore partially already includes services such as air filtration and water purification, but of course not identifiable as such.

For some regulating services the effect is that the current SNA output is lower than in the absence of the service (i.e. the ESS and the SNA service can be seen as substitutes). For instance, in case of coastal and river flood protection, the effect of such services is that say insurance premiums would be lower (compared to the counterfactual). To complicate things, property prices (and hence imputations for owner occupied dwellings) are higher due to the ESS.

In case of cultural services, nature-based tourism is mostly included, whereas nature-based recreation to a large extent is not.

The value of some services (e.g. proximity to urban green parks) is not only reflected in the current accounts but also in capital accounts (such as housing prices).

Finally, by extending the production boundary, the ecosystem accounts will have an upward effect on output and GDP conventionally measured (equal to the amount if the so-called non-SNA benefits exemplified as channels 3 and 4); at the same time they may have a downward effect on net measures of output to the extent of the degradation costs being recognized, and whether and how disservices are recorded).

These recording issues will be further discussed in issue paper 5.4.

Section 2 Accounting in Wider Valuation Frameworks

While ecosystem accounts are spatially and physically comprehensive, accounting conventions for valuation are clearly delimited to exchange value. The intent of the section is to place accounting compatible valuation in the context of wider valuation frameworks. The section aims at facilitating communication with other scientific disciplines conducting valuation of nature and other purposes for valuation than accounting.

2.1 Introduction

The term 'value' has numerous meanings in everyday life. 'Value' also has specific meanings in social and natural science research, analysis and assessments.[7] This paper considers different meanings of value used in psychology, ethics, ecology, anthropology, cultural heritage and economics.

There are also several typologies which attempt to identify, differentiate and categorise values according to certain shared characteristics. The various 'everyday' and technical meanings of value mentioned above can be allocated to the different categories of value proposed in these typologies. This section of the discussion paper considers typologies described by Turner et al. (2003) and IPBES (2015, 2019), which distinguish anthropocentric, non-anthropocentric, instrumental, relational and intrinsic types of value (see subsection 2.3 for definitions). The paper also discusses the typology of values used in the Total Economic Value (TEV) framework (see e.g. TEEB, 2016), and considers how the definitions and types of values described in Turner et al, IPBES and TEV may be applicable to the SNA.

The different meanings and types of value described in this section of the paper will be relevant to particular areas of investigation, assessment, and decision-making, depending on their characteristics, and the nature of the information they can provide. For example, different meanings and types of value will be applicable to policy questions relating to the protection of indigenous cultural heritage from those relating to the value of ecosystem services associated with coastal mangroves.

While acknowledging the usefulness of different meanings and typologies of value for different purposes, this section of the discussion paper argues that very few of these meanings and value types will be relevant to the issue of how ecosystem assets and ecosystem services can be expressed in a format consistent with the existing structure of the SNA, without some reframing. The' operating space' for the meanings and types of value that can be incorporated in the SNA (or SEEA) will be rather more limited than the space for other ways of exploring human-economy-environment relationships (e.g. social cost-benefit analysis, social impact assessment, DPSIR[8]).

[7] The Mathematical sciences also have specific uses for the term 'value', but these are not considered in this paper as they have no particular relationship with definitions and categorisations of ecosystem assets and ecosystem services for inclusion in the SNA and SEEA.
[8] The Drivers-Pressure-State-Impact-Response conceptual framework.

As discussed below (see subsection 2.6), the information on economic activity in the SNA has the characteristics of being, anthropocentric, instrumental, and quantifiable. It is suggested that if other types of information are to be included in the SNA (or SEEA), they should share these characteristics, or at least be capable of being re-expressed in ways that allow compatibility.

Anthropocentric-relational and -intrinsic, and non-anthropocentric-intrinsic types of value such as those used in psychology, ethics, anthropology, and cultural heritage do not share these characteristics, and arguably, are not compatible with the format of the SNA/ SEEA and cannot be readily reframed to be so.

However, this section suggests that ecosystems and ecosystem services offer more promise, as they already possess the characteristics of being instrumental and quantifiable, although they are non-anthropocentric. Valuation of ecosystem services can reframe them in anthropocentric terms, and also enable ecosystem assets to be expressed in monetary terms, as the present value of the stock of natural capital is equal to the present value of the sum of benefits from these ecosystem services (see Maddison and Day (2014).

The following subsections consider meanings attached to the term 'value' in everyday life, and in the natural and social sciences (subsections 2.2 -2.3), and three typologies of value which potentially could be used to categorise these different meanings of value (subsection 2.4). Subsection 2.6 considers whether, and how, these different meanings and typologies of value relate to the format and reporting specifications of SNA and SEEA and can help to expand the boundary of the SNA (and SEEA) through addition of monetary information on ecosystem assets and ecosystem services.

2.2 Values from different perspectives[9]

As a prelude to discussions about the valuation of ecosystems and ecosystem services in the SNA found in other sections of this discussion paper, the present subsection considers how 'value' is defined in common usage and in a range of social and natural sciences, in relation to human interactions with biodiversity and nature.

The term 'value' has a range of meanings which vary according to the context in which it is being used. Commonly used meanings of value include the following.

(i) value as a criterion for direct or reciprocal exchange based on the amounts of goods, services, money or obligations thought to be a fair and suitable equivalent for something else;
(ii) value as a criterion for financial/ monetary worth;
(iii) value as a means of assessing [use and] usefulness, in terms of the material or non-material (relational) importance or significance to the possessors, or potential possessors, of an entity;
(iv) value as a synonym for standards or ethics guiding individual behaviour;

[9] The discussion of values and typologies in sections 2.3-2.4 expands on material used in Conner et al. (2016).

(v) value as a tool for cultural expression by defining important and enduring beliefs shared by the members of a culture about what is good and desirable, and what is not;

(vi) value as a synonym for standards or ethics guiding individual behaviour;

(vii) value as a term for non-human attributes and intrinsic qualities.

(Adapted from Business Dictionary, 2012.)

The above meanings appear to encompass two different senses of value. Meanings (i)-(iii) define value as a characteristic attributed to an entity following some form of assessment and measurement (e.g. economic value, ecological value). The process of assessment and measurement is 'valuation', although this term is commonly only used for the process of identifying and estimating the (relative) economic value of specific entities in monetary terms. Meanings (iv)-(viii) appear to define value in the sense of an abstract, higher-level concept or principle, such as in 'intrinsic value' or 'outstanding universal value'.

2.3. Value in the social and natural sciences

Apart from the 'everyday' meanings in subsection 2.2, the concept of 'value' is used in different social and natural sciences. A review of these different meanings is useful as background for later sections of the discussion paper. The relevance of these meanings to SNA and SEEA is discussed in subsection 2.6 below.

2.3.1. Value in Psychology

In his work on Values Theory, Schwartz (2005) defines values as "desirable, trans-situational goals, varying in importance, that serve as guiding principles in people's lives" and which have the following characteristics:

- "Values are beliefs tied inextricably to emotion.
- Values are motivational, and refer to the desirable goals people strive to attain.
- Values transcend specific actions and situations. They are abstract goals.
- Values serve as standards or criteria.
- Values are ordered by importance relative to one another.
- People's values form an ordered system of value priorities that characterize them as individuals." (Schwartz 2005, p0).

Schwartz suggests that universal human requirements (i.e. the needs of individuals as biological organisms, the requisites of coordinated social interaction, and the survival and welfare needs of groups) can produce "motivationally distinct, universal, basic human values" irrespective of cultural context. These 'Basic Human Values' represent principles and goals which guide human behaviour. and consist of self-direction, stimulation, hedonism, achievement, power, security, conformity, tradition, benevolence. and universalism *(Schwartz 2005, p1).* Schwartz suggests the universality and cultural neutrality of these values.

2.3.2. Value in Philosophy

Several branches of philosophy are concerned with the meaning of value, especially axiology. “Axiologists study value in general rather than moral values in particular and frequently emphasise the plurality and heterogeneity of values while at the same time adopting different forms of realism about values:”(Smith and Thomas, 1998). Areas of interest include aesthetics and ethics.

A core feature of environmental ethics is the principle that the living environment has certain inalienable legal rights to live and flourish (see for example Jamieson, 2008), and that these rights to exist mean that the living environment has value in and of itself, separate and independent from the benefits humans may derive from it for their own purposes. Thus, it has value by virtue of its existence.

Religion and faith-based principles can provide ethical, moral or spiritual arguments for humans to respect this value. Studley (2010, p108) notes that many sacred traditions in Buddhism, Hinduism or, Daoism support an ethic that respects the value of the natural world. Sirina refers to the ‘ecological ethic’ of the Evenki and Eveny peoples in Siberia, as a ”… system of mutual responsibility of people to nature and her spirit masters, and of nature to people…This concept encompasses the norms and rules regulating the social community’s relations with the natural environment (incorporating mythological ideas and ethical concepts), as well as the practical actions based on these norms and rules” (Sirina, 2008, p9).

Ostrom (2015) discusses the issue of norms and rules regulating the use of ecosystem services in the context of governance arrangements for managing common pool resources. This issue will be relevant to subsection 2.3.6 below, in relation to the application of exchange values to certain types of community managed ecosystem services, which may be subject to governance arrangements which are not compatible with the assumptions underlying the attribution of exchange values.

2.3.3. Value in Ecology

Concepts of value are important and commonly used in the natural sciences.[10] For example, ecologists use specific criteria to assess the ecological value of ecosystem components and processes:
“Ecological value is the perceived importance of an ecosystem, which is underpinned by the biotic and/ or abiotic components and processes that characterise that ecosystem. Application of specific criteria and identification of critical components and processes or comparable approaches) are used to assess ecological value." (Aquatic Ecosystems Task Group, 2012, p2.).

[10] Given that this paper is concerned with the relevance of different meanings and types of value in ecosystem accounting, it may be noted that the term ‘account’ is used in biology to provide a description about a species of interest. The content of a species account may include information on taxonomy, threats, and human use. See https://msu.edu/course/plb/423/Assignments/plant_species_account.html). This type of account is purely descriptive. Soil scientists also refer to ‘soils accounts’ which analyse the chemical or physical condition of soils. These accounts have no explicit relationship with how information is presented in the SNA and SEEA, although they could be reframed as part of a physical condition account, showing opening and closing balances, additions and subtractions etc.

Some relevant criteria are: diversity, distinctiveness, vital habitat, naturalness and representativeness. Ecological value concerns the extent to which the ecosystem, habitat etc. in question meets certain criteria which reflect pre-established ecological concepts. The extent to which such ecosystems meet these criteria is generally measured in quantitative terms.

The concept of 'High Conservation Value' is also used in planning and management by ecologists and natural resource managers. The Forest Stewardship Council Australia (2013) defines High Conservation Value in terms of six criteria:

- HCV 1: Forest areas containing globally, nationally and regionally significant concentrations of biodiversity values (e.g., endemism, endangered species, refugia).
- HCV 2. Forest areas containing regionally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance.
- HCV 3. Forest areas that are in or contain rare, threatened or endangered ecosystems.
- HCV 4. Forest areas that provide basic services of nature in critical situations (e.g., watershed protection, erosion control).
- HCV 5. Forest areas fundamental to meeting basic needs of local communities (e.g., subsistence, health).
- HCV 6: Forest areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

Objective measures of the extent to which certain ecosystems, habitats, species etc. meet the relevant criteria can show their value as subjects worthy of conservation action. Where there is a need to prioritise locations and species already assessed as meeting the criteria for high conservation value (e.g. where conservation budgets are limited), conservation agencies may need to use other non-ecological considerations, such as management costs or level of local community support, to help to inform decision-making.

2.3.4 Value in anthropology

The relationship between the social value of transactions, and the economic value of the goods and services transacted, is an area of interest for anthropologists. Economic anthropologists argue that economic systems are embedded in social relationships; particularly where reciprocity plays a major role in transactions. Thus, in some cases the social value of the transaction may be as, if not more, important to giver and receiver than the market value of the entity involved. Polyani recognises three types of reciprocity:
(i) reciprocity where exchange of goods is based on reciprocal exchanges between social entities, including the production of goods to gift to other groups;
(ii) redistribution where trade and production are organised around a central entity such as a community leader and redistributed to other members of society; and

(iii) household economies where production is focused on the needs of individual households for food, textile goods, and tools for their own use and consumption.

Polanyi argued that these forms of economic relationships are different from those operating in market economies, in that they are based around the social aspects of the society they operated in, and are explicitly tied to social relationships (Polanyi, 1957 p43-55). Such social values relate to the benefits that access to, or ownership of, entities can provide to their owner in terms of status, rights and obligations or, conversely, social sanctions from the misuse of these entities.

Social anthropologists consider such social values to be affected by culturally-mediated rules and institutions, which influence the attribution and prioritisation of values. "Gender, caste, class, age, ethnicity and so on shape human's interactions with nature. Diverse groups, even in the same locality, have different values and interests, and conflicting values are struggled over and negotiated in resource use conflicts' (Fisher et al., 2005 p41-42).

2.3.5 Value in cultural heritage

Cultural heritage values can be considered in relation to the activities of national and international bodies such as ICOMOS (International Council on Monuments and Sites). For example, the Australia ICOMOS Charter for the Conservation of Places of Cultural Significance, defines 'cultural heritage value' as synonymous with 'cultural significance' (Environment South Australia, 2015). Cultural significance is defined in the Charter as aesthetic, historic, scientific, social or spiritual value for past, present or future generations. The charter identifies four categories of value, i.e. social or cultural, historical, scientific, and aesthetic values (ICOMOS 2015). The potential cultural values of a site, object, location or other entity are estimated by an assessment of their level of significance (i.e. high, moderate or low significance). Qualitative assessments of significance are used to estimate the cultural value of sites, objects or other entities.

A specific definition of cultural value is used by UNESCO in determining places and entities suitable for listing on the World Heritage register. Such places are defined as having 'Outstanding Universal Value'. The Department of Sustainability, Environment, Water, Population and Communities (2012) defines Outstanding Universal Value as follows.

- Outstanding: Outstanding properties[11] should be 'exceptional', or 'superlative'; they should be the most remarkable places on Earth.
- Universal: Properties need to be outstanding from a global perspective.
- Value: What makes a property outstanding and universal is its 'value' i.e. the natural and/ or cultural worth of a property. (This value is determined based on standards and processes established under the World Heritage Convention's Operational Guidelines.)[12]

Outstanding Universal Value (OUV) is defined through qualitative expert-informed assessment, and does not explicitly involve choices or rankings of relative levels of OUV between different sites. OUV can be applied to sites on the basis of their natural and or cultural heritage features. Thus, in this context, value could be ascribed to any sites that met the appropriate criteria, and would not involve

[11] World heritage-listed sites are referred to as 'properties'.
[12] See https://whc.unesco.org/en/guidelines/

choices having to be made between different sites which also met the required criteria based on their relative 'level' of outstanding universal value.[13,14]

2.3.6. Value in Economics

Mazzucato (2018) highlights the changing perspectives of economic value in the history of economic thought, especially relating to the creation and expropriation of value. For example, the 17th century mercantilist approach stressed the central role of international trade in capturing value for national economies. The underlying argument was that a country should export as much as possible of high-value goods and import only low value goods (e.g. raw materials) not available nationally that were necessary for their industries. The role of government was to foster various forms of national protectionism and preferential trade arrangements.
The 18th Century Physiocrats identified agriculture as the only source of value creation, and argued that manufacturing and commerce took up as much value as inputs to production as they created in output, and thus created no net product. They argued that the complex system of preferences, tariffs and other local taxes at the time should be abolished, and agriculture should provide the only source of taxation revenue (History of Economic Thought, 2019).

These ideas were rejected by classical economists such as Smith, Say, Ricardo, Malthus, Mill .These economists considered market economies to be largely self-regulating systems, governed by natural laws of production and exchange (i.e. the invisible hand). Smith argued that national wealth was determined by national income, which was in turn based on the labour of its inhabitants, organised efficiently through the division of labour and the use of accumulated capital . Classical economists advocated free trade and competitive markets, with Government providing for the common good, where market failure occurred. Most of the costs supporting the common good should be borne by those best able to afford them (Wikipedia 2019a).

Present day neoclassical economics rests on the assumptions that: (i) people have rational choice between outcomes that can be identified and associated with values; (ii) individuals maximise utility and firms maximise profits; and (iii) people act independently on the basis of full and relevant information information. These assumptions are used to build a framework to explain the allocation of scarce resources among alternative uses i.e. "Given, a certain population, with various needs and powers of production, in possession of certain lands and other sources of material: required, the mode of employing their labour which will maximize the utility of their produce" (Jevons quoted in Wikipedia, 2019b).

Mazzucato (2019) notes that neoclassical economics treats value as subjective; the value of an entity is something determined by a mutually agreed transaction between seller and buyer, in contrast to previous schools of thought which regarded value having an objective existence (see for comparison, definition of non-anthropocentric intrinsic value described in subsection 2.4).

[13] Subject to the overall objective of achieving a 'A Representative, Balanced and Credible World Heritage List' (see UNESCO 2013 p15).
[14]. Other values can be attributed to sites that have OUV. For example, natural or cultural-listed sites attract visitors and provide recreational experiences World heritage-listed sites are referred to as 'properties'., for which economic values can be estimated.

Mazzucato also suggests that the assumptions underlying neoclassical economics have developed the status of near orthodoxy, and have blurred the distinction between value creation and value capture, with e.g. financial institutions claiming they are value creators, rather than intermediaries in the appropriation and distribution of value created by, and in, other sectors of the economy. This distinction is highly important for national accounting and its assumptions about the meaning of value (especially in 'value-added'), and questions about the proper definition of natural capital and the distinction between ecosystem functions, assets and services (see ecosystem service discussion papers in WG4).

Although the following discussion of economic meanings of value is based on a neo-classical perspective, it is important to recognise evolving trends in economic thought relating to the treatment of ecosystem assets and ecosystem services. The development of SEEA as a way of expanding the boundary of the SNA, and the current review of SEEA EEA are examples of how prevailing neo-classical concepts of value and prices are being rethought.

From a neo-classical perspective, economic value is a measure of the well-being experienced by an individual (i.e. their 'utility'), usually concerned with the consumption of goods or services, but also relevant to 'non-consumptive' experiences such as spending time in nature or feeling healthy. Economic value is experienced by individuals, not by groups or societies (or non-humans). Although individual economic values can be aggregated to estimate a value for a group, society itself is not seen as an independent entity.[15] Economic value is by definition, an anthropocentric type of value (see subsection 2.4).

The value of a good for service to an individual is expressed in terms of the level of benefit they forgo by choosing to allocate their scarce resources of money, time, land, labour etc. to one purpose rather than another (the opportunity cost). The utility (the benefit) they obtain from their preferred allocation of resources will need to be at least equal to the utility they would have obtained from allocating their resources in some other way) (their marginal benefit). Where markets exist, consumers use monetary measures to express their preferences and their ranking of alternative allocations, through their purchasing behaviour.

Value is also used in SEEA in the context of 'exchange value'. For accounting purposes, exchange value should be distinguished from the more limited term 'market prices', which implies that only prices obtained from monetary-based market transactions should be considered. Exchange values encompass market (monetary) and non-market exchanges of assets, and allow for imputed values for some activities which are not included in market transactions (such as payments to other family members engaged in family-run small businesses when they are not explicitly identified in other ways). Exchange values in accounting also reflect observed values and prices ('ex post') that are influenced by different types of institutional arrangements, from low to heavily regulated, or from monopolies to competitive markets. The SNA records the observed value of economic output irrespective of the actual market mechanism in place. (Obst 2019).

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[15] Nevertheless, social cost-benefit analyses carried out by government agencies do estimate marginal changes in economic value (expressed as changes in direct and indirect ['external'] costs and benefits) from alternative policy options for individuals, businesses and government, and assess the marginal economic benefits for 'the community' compared to the status quo.

Section 3 of this paper notes the that the SEEA Experimental Ecosystem Accounting Technical Recommendations (SEEA 2015, p93) propose the use of exchange values, which reflect “the price at which ecosystem services and ecosystem assets would be exchanged between buyer and seller if a market existed”. Caparrós et al. (2017) suggest that it is probably more precise to restrict the term ‘exchange values’ to those cases where the market really exists, and use the term ’simulated exchange values” where the price comes from a simulated market’.

It is worth noting here that the potential application of exchange values to ecosystem assets and ecosystem services in the SNA/ SEEA has raised a number ethical concerns in some quarters about the ‘monetisation of nature’ (let alone the concept of ecosystem ‘assets’). As mentioned in paragraphs three and four of the summary of this section of the discussion paper, value has a range of meanings and a range of different definitions in the natural and social sciences. These different definitions help to provide insights into the interrelationships between inter alia species, ecosystems, social, cultural and economic systems, and communities and economies. Different definitions of value will be relevant to different areas of research, analysis and policy development, with different foci of interest.

Environmental economists and national accountants have specific, circumscribed, interests in identifying conceptually robust methodologies that could be used to help them address the question of how to measure ecosystems and ecosystem services in ways that are compatible with the SNA and SEEA protocols. Exchange value and simulated exchange value provide one possible way of doing this. Most of the other perspectives of value discussed in this paper cannot help to answer this specific question. Other non-economic measures of value, including ethical issues about pricing of nature, will be relevant to different, equally valid, research and policy questions.

2.4. Some typologies of value

2.4.1. IPBES and Turner et al.

The International Platform on Biodiversity and Ecosystem Services (IPBES, 2015, 2019), and Turner et al. (2003), provide typologies of value which distinguish between ‘anthropocentric’ and ‘non-anthropocentric’ values. Anthropocentric values relate to human use of entities, whether such use involves direct, indirect or ‘non-use’ of these entities. Non-anthropocentric types of value reflect the idea that entities have value independent of human use, in their own right. These categories can be further divided into anthropocentric-instrumental (IPBES, and Turner et al.), anthropocentric-relational (IPBES), anthropocentric-intrinsic (Turner et al.), non-anthropocentric-instrumental (Turner et al.) and non-anthropocentric-intrinsic (IPBES and Turner et al.), as described below.[16]

The relevance of these typologies to SNA and SEEA is discussed in subsection 2.6.

[16] It should be noted that in practice, the categories in these typologies may be less discrete than suggested, and different value may fall into more than one category.

Anthropocentric instrumental value

Instrumental value is the value attributed to things that are seen as means to achieve some end for individual or community benefit (see IPBES 2014, p9). Instrumental values refer to direct or indirect human uses of nature and ecosystems, rather than nature existing in its own right (as is the case with intrinsic values). Examples of entities with instrumental value include plants and animals used for food and medicine, soil fertility for agricultural production, habitats for commercially useful wild species, wetlands for water flow regulation and natural environments used for recreational activities.[17]

Anthropocentric relational value

Relational values are another type of anthropocentric value attributed to entities used by individuals and communities to achieve a particular outcome or benefit. In this case, the entities provide psychological, social or cultural value to humans as individuals and groups, such as food security, physical and mental health, wellbeing, livelihoods and education. These types of value are 'relational' in that they concern values associated with community interactions, rather than values which provide benefits to people as individuals.[18]

Non-anthropocentric instrumental value

Entities with non-anthropocentric value have worth independent of human interests. Although value in ecology may be non-anthropocentric, in that it does not relate to human considerations, it is also instrumental, as explained by Hargrove (1992):

"In environmental matters non-anthropocentric instrumental values - concerning the instrumental relationships of benefit and harm between nonhuman plants and animals - are quite common and completely uncontroversial. Such values, which can easily be converted into facts, are indeed discovered in the world and are independent of human judgment. One thing in nature either instrumentally benefits other things or it does not, regardless of what humans think about it and whether or not humans even know that these instrumental relationships exist. What we believe, know, and how we value it makes no difference" (Hargrove 1992, p186-7).

Non-anthropocentric instrumental value can be distinguished from non-anthropocentric intrinsic value (see below), as it is commonly expressed through objective, quantitative metrics; in contrast, non-anthropocentric intrinsic value by definition, cannot be quantified and measured. For example, tropical rain forest ecosystems have fundamental value as part of the maintenance of habitat for large numbers of species and so have 'instrumental' value, which exists without direct reference to human interests (and so are non-anthropocentric).[19]

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[17]. Exchange values of ecosystem services in ecosystem accounts belong mainly in this value category.

[18]. Recreation service values in ecosystem accounting may capture some relational values under this definition.

[19]. N.B. The ecosystem services derived from tropical rainforests used in economic production can also be ca tegorised as having anthropocentric instrumental types of value.

Anthropocentric intrinsic value

Hargrove (1992, p 186) and Turner et al. (2003, p495) suggest a category of 'anthropocentric intrinsic' value which appears to correspond to the IPBES category of 'anthropocentric relational value' described above.

Turner et al. note that: "In this value category entities are assumed to have sakes or goods of their own independent of human interests. It also encompasses the good of collective entities, e.g. ecosystems, in a way that is not irreducible to that of its members". Hargrove identifies 'weak anthropocentric intrinsic value', where some values including (environmental values) are assigned by human judgement from a human viewpoint and are intrinsic and non-instrumental (Hargrove, 1992, p186).

This category appears to have some similarity to 'existence value' as defined in the Total Economic Value framework (see subsection 2.4) in that, although the value refers to entities which have 'value in their own right', it is humans who are attributing this value, and exhibit their willingness to pay to know that the entity attributed with this value will persist.

Non-anthropocentric intrinsic value

In contrast to anthropocentric intrinsic value, this type of value commonly involves an ethical, moral or spiritual conviction that certain entities have inherent value beyond human considerations or human attribution of intrinsic value (see for example, Jamieson, 2008). Examples of entities which may possess intrinsic value are Gaia, Pachamama and Mother Earth and totem animals. e.g. Ssozi (2012) notes that in Baganda communities in Uganda:

'There were certain tree species that were not supposed to be cut down as well as animal species that were not supposed to be killed. …Each clan has a totem which could be an animal, insect or plant, and it is forbidden to eat one's totem, the mother's, and grandmother's'.

For many indigenous peoples intrinsic value can also mean *'of the ancestral realm'*. For example, in New Zealand Māori cosmology, knowledge was imparted to the natural world before humans came. Thus, humans need to understand the ancestral nature of the natural world and respect its primacy and inherent value in their interactions with it (Mead 2003).

Differences between IPBES and Turner el al. typologies

The IPBES approach has recently been described in Pascual et al. (2017), and is summarised in Table 1 below, which uses the categories of non-anthropocentric and anthropocentric, with divisions into non-anthropocentric-intrinsic, anthropocentric-instrumental, and anthropocentric-relational. This categorisation does not include the categories of non-anthropocentric-instrumental, or anthropocentric-intrinsic (see above) identified by Turner et al. (2003) after Hargrove (1992). Otherwise the IPBES and Turner at al. categorisations are generally alike.

However, Table 1 categorises animal welfare/ rights, and evolutionary and ecological processes, genetic diversity, and species diversity as non-anthropocentric intrinsic types of value, and habitat creation as an anthropocentric instrumental type of value.[20] Arguably, these are not values, in the sense that there should be someone to value them for the potential utility they may confer (i.e. instrumental values), or the intrinsic value attributed to them by humans (i.e. human intrinsic value) or the non-anthropocentric intrinsic value they may possess irrespective of the human world.

Animal welfare/ rights could more accurately be categorised as being an anthropocentric-intrinsic type of value, in that they implicitly involve specific duties and responsibilities for humans, rather than originating outside the human sphere (as applies to non-anthropocentric-intrinsic type of value such as 'Mother Earth'). Evolutionary and ecological processes, genetic diversity, and creation of habitats (see footnote on this page) are examples of biophysical processes. From the point of view of defining ecosystem assets and ecosystem services for accounting, it is important to distinguish between the biophysical functions and processes which create the circumstances in which ecosystems can develop, and the ecosystems themselves as assets from which final ecosystem services are taken up by users.

Table 1 also identifies 'regulation of climate' as an anthropocentric instrumental value. This classification highlights the importance of distinguishing between a 'service' and a potential 'beneficiary'. The need for this clarification here is noted in Haines-Young and Potschin (2017 p12) with reference to Version 5.1. of the Common International Classification of Ecosystem Services (CICES):

"In V5.1 services are conceptually different from benefits because the things considered as services are still part of the ecosystem that generates them. For the benefit to be realised some transformation by human action or perspective that lies outside that ecosystem is needed. For example, in the case of the Class 'Wild plants (terrestrial and aquatic) used for nutrition' the example service given is 'the harvestable volume of wild berries' and an associated benefit 'quantity of jam produced".

According to this logic, 'regulation of climate' is not a value, it is an intermediate service which requires transformation to provide benefit. In CICES version 5.1 (2019) 'regulation of climate' is categorised in the following hierarchy which distinguishes services from benefits:

"…...*Group*: Regulation of chemical composition of atmosphere and oceans, *Example service*: Sequestration of carbon in tropical peatlands, *Example good of benefit* Climate regulation resulting in avoided damage costs or mitigation of impacts of ocean acidification (CICES version 5.1 2019).

[20] It is assumed here that that habitat creation is a naturally occurring process over time as a result of different biophysical processes; as distinct from habitat restoration, which involves human intervention.

Table 1: IPBES typology of values

FOCI OF VALUE	TYPES OF VALUE		EXAMPLES
NATURE	Non-anthropocentric (Intrinsic)		Animal welfare/rights
			Gaia, Mother Earth
			Evolutionary and ecological processes
			Genetic diversity, species diversity
NATURE'S CONTRIBUTIONS TO PEOPLE (NCP)	Anthropocentric	Instrumental	Habitat creation and maintenance, pollination and propagule dispersal, regulation of climate
			Food and feed, energy, materials
		Relational	Physical and experiential interactions with nature, symbolic meaning, inspiration
GOOD QUALITY OF LIFE			Physical, mental,emotional health
			Way of life
			Cultural identity, sense of place
			Social cohesion

Source: Pascual (2012)

2.4.2. Total Economic Value typology

A common microeconomic framework which has been used to consider different economic values relating to human interactions with nature is the Total Economic Value (TEV) framework (see TEEB, 2016). This framework classifies values into 'direct use,' 'indirect use' and 'non-use' values. Direct use values refer to goods and services that are used directly for consumption and can be 'consumptive' (e.g. direct harvest of forest products, fish or medicinal plants) or 'non-consumptive' (e.g. recreation).

Indirect use values concern functions and services that provide an input into another activity which has economic value, e.g. crop pollination, flood mitigation (some types of ecosystem services). With respect to the ecosystem services language of provisioning services and cultural services, provisioning services roughly correspond to direct and indirect use values (including subsistence use) in the TEV framework, and cultural services roughly correspond to non-use values (Haines-Young and Potchin, 2016).

Non-use values include option, bequest and existence values. Option values are the benefit placed on the potential future ability to use a resource (whether by current or future generations), even though it is not currently used, and the likelihood of future use may be very low. Bequest value is the value attributed to maintaining something for the benefit of future generations. Existence value is the value obtained from knowing certain things exist for economic, moral, ethical or other reasons.[21]

TEV has become a popular approach (e.g. TEEB, 2016) to estimate the 'total' economic value of an ecosystem or specific environment. However, value estimates should not be summed to produce a 'total' value for several reasons, including the following (see, Turner et al. 2003, pp 498-500, and Plottu and Plottu, 2005, p 52?). Godden (2010) raises the following concerns with using TEV framework for informing environmental management policy.

- 'Total' in economics usually has a quantitative, aggregate meaning, as in 'total benefits', 'total costs'. In the TEV framework 'total' carries the meaning of 'comprehensive' i.e. including all classes of value. However 'Total economic value' is not comprehensive, as it does not address the status of entities that have not yet been identified as having economic value.[22]
- The framework does not explicitly distinguish between stock values and flow values of entities (e.g. direct use values are normally identified as flows, whereas existence, bequest and option values are stock values, and indirect values may be changes in stocks, or resource flows used to manage stock).
- The framework is inherently static for direct use values, where per period flows are considered without reference to changes in the stocks (e.g. fish, timber, soil) from which they arise.
- There is potential for double-counting between use, and indirect use values: as the flows underlying indirect use values in the current period affect the potential flows of services which become direct use values in the future.
- Bequest and option values reflect only values of the current generation, but they are also relevant to future generations (as are existence values); also the rate of resource use can affect future stocks and thus values ascribed by future generations to these assets.

[21] Direct and indirect use values roughly correspond to anthropocentric instrumental values in Turner et al. and IPBES, non-use values relate to anthropocentric intrinsic values identified in Turner et al., and given the anthropocentric basis of TEV, to anthropocentric relational values in IPBES (see Pascual et al.,2017). However, see the discussion in the text below about the problems with the conceptual shortcomings of the TEV framework.

[22] Entities which have not be attributed with value are not the same as those which have been attributed with option value, as option value assumes that the entity in question has already been recognised as having direct or indirect value, but the realisation of the benefits which relate to its use are being deferred. Harmon and Putney, perhaps controversially, suggest that those entities which have not been ascribed value by humans for various reasons, have 'intrinsic' value in their own right, which represents a form of 'potential' or 'latent' value, existing before the 'embryonic' intrinsic value is transformed into some other form of value' (Harmon and Putney, 2003, p15.).

- Different valuation methods with associated assumptions are used to estimate use, indirect use and non-use values.[23]

The single point estimate of the TEV of local, regional or national natural capital (mangroves, coral reefs etc.) found in many TEV assessments may provide some headline interest, and a baseline for assessing changes in value, condition or some other relevant indicator against.[24] However, Maddison and Day (2014,p 40-44) provide a comprehensive critique of the use of TEV in environmental management decision-making, and argue that TEV is an unsuitable tool for understanding the total and marginal value of environmental assets. Instead they propose an alternative approach based on: (i). establishing the fundamental economic characteristics of the environmental good or service and (ii) defining precisely how that good or service enters the household's choice problem.

Haines-Young and Potschin (2016) have attempted to relate the ecosystem service categories of provisioning, regulating and maintenance and cultural as described in CICES, to direct, indirect, option, bequest and existence categories used in the TEV framework. However, given the above concerns with TEV, it is not regarded as a suitable framework for defining ecosystem service values, especially as part of a process to incorporate ecosystem service and ecosystem asset values in an extended SNA (SEEA) framework.

2.4.3. The Common International Classification of Ecosystem Services (CICES)

Although not strictly a typology of values in the same way as Turner et al., IPBES and TEV as discussed above, CICES does indirectly relate to value by being concerned with potential beneficiaries from provisioning, regulating and maintenance, and cultural ecosystem services (see Haines-Young and Potschin, 2017). Beneficiaries would presumably attach some value to the goods related to the service in question, whether this value be instrumental, relational or intrinsic. The relationship between services, and final goods and beneficiaries, and indeed, the relevance of CICES to ecosystem accounting (see Maddison and Day 2014) is discussed elsewhere in other sections of the discussion paper.

2.5 How can different perspectives and typologies of value help to explain relationships between environmental assets and the economy?

The above subsection has described several different perspectives and typologies which relate to human interaction with the environment. This subsection considers whether these different

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[23]). TEV assessments collect information using market prices, economic values (based on consumer and producer surplus), revealed preference approaches (e.g. hedonic pricing, travel cost method with or without cost of travel time included), stated preference approaches, cost-based approaches and production function approaches. and use of benefit transfer. Although linked by the idea of willingness to pay (or accept), 'value' is estimated in different ways using different assumptions. Maddison and Day (2014, p34) note that these methods focus almost exclusively on the consumption side of the economy. "Almost no guidance is provided for valuing environmental changes that impact on firms or the productivity of factors of production. Indeed, the only method discussed with relevance in this context is the production function approach and this…can only provide approximate measures of economic value".

[24] See for example, the total economic value of coral reefs, mangroves and seagrasses as discussed in Conservation International, 2008.

perspectives and typologies provide insights into ways that economic, and ecosystem assets, and ecosystem services can be incorporated into decision-making about management of environmental assets in general, and into SNA and SEEA in particular. IPBES suggests that:

"Decision-making process would benefit if they addressed the values of biodiversity and ecosystem services through plural approaches" (IPBES 2019).

Plural approaches such as valuation of the economic, anthropological and ecological characteristics of biodiversity and ecosystem services, may be relevant to many decision-making processes and decision-support tools, such as environmental impact assessments. Table 3 below suggests some types of information that different perspectives and typologies can provide to assist decision-making.

Table 3: Overview of meanings and typologies of value and information provision for decision - making

Perspective and typologies	*Information relating to human–nature interactions*
Psychological perspective on anthropocentric relational values	Information on underlying personal values which influence a community's attitudes towards its relationship with nature
Ethics perspective on anthropocentric and non-anthropocentric intrinsic values	Information on beliefs and attitudes to human relationships with nature, and conceptualisations of value of nature in its own right outside of the human sphere
Economic anthropological perspective on anthropocentric instrumental values: reciprocal values	Information on socio-economic dimensions of use, exchanges/trades of ecosystem goods and services, and socio-economic relationships between different parties engaged in exchanges/trade
Cultural anthropological perspective on anthropocentric relational values	Information on cultural dimensions of use, e.g. rules, rituals, customs relating to harvesting and use of ecosystem services
Cultural anthropological perspective on non-anthropocentric intrinsic values	Information on beliefs and attitudes to human relationship with nature
Economic perspective on anthropocentric instrumental values: direct, indirect and non-use values	Quantitative and qualitative data on direct and indirect allocation of resources to supply/obtain ecosystem goods and services, including opportunity costs and other costs and benefits associated with transactions

As noted in Table 3 above, psychological perspectives of value can provide insights about how universal human requirements (i.e. the needs of individuals as biological organisms, the requisites of coordinated social interaction, and the survival and welfare needs of groups) can produce universal, basic, human values that influence choices about actions, policies, people, and events.

Philosophy (ethics) can provide insights into entities which are attributed with non-anthropocentric intrinsic value, and which can include Gaia, Pachamama, and certain species or totem animals.

Ecological perspectives can provide examples of non-anthropocentric instrumental values. As noted above, in environmental matters, non-anthropocentric instrumental values relate to the instrumental relationships of benefit and harm between "non-human plants and animals…What we believe, know, and how we value it makes no difference" (Hargrove 1992, p186-7). Non-anthropological instrumental values can be contrasted with entities attributed with non-anthropocentric intrinsic value, as below.

Economic anthropology can provide insights into anthropocentric instrumental values attached to non-monetary transactions which occur outside the formal market economy, in particular in relation to reciprocal exchange. Unlike transactions of goods and services where value is expressed in terms of gains or losses in economic welfare (in microeconomics), in reciprocal exchange, value relates to the social function of the transaction, especially where transactions involve the giving of gifts.

Cultural anthropology can be used to explore anthropocentric relational values that communities ascribe to the economic, social and ceremonial uses of entities. These values are anthropocentric-relational in that access to, or ownership of, certain entities can provide the owner with social benefits in terms of status, rights and obligations or, conversely, social sanctions from the misuse of these entities.

Cultural anthropology can also provide insights into other types of anthropocentric relational values relating to common agreed societal beliefs and rules about what does and does not have value. For example, cultural heritage value is formally ascribed to entities which are assessed as representing the cultural heritage of the community in question (as in the case of national and international heritage registers).

Economic perspectives relate to anthropocentric instrumental types of value i.e. "the value attributed to things that are seen as means to achieve some end for individual or community benefit" (i.e. instrumental values [see IPBES 2014, p9], including exchange value).

2.6 Linking economic and ecosystem assets in the SEEA

As mentioned in paragraphs 3 and 4 of the introduction to this section of the discussion paper, value has a range of meanings and definitions in everyday use and in the natural and social sciences. These different meanings and definitions can help to provide insights into the interrelationships between *inter alia* species, ecosystems, social, cultural and economic systems, and communities and economies. Different definitions and typologies of value will be relevant to different areas of research, analysis and policy development, with different foci of interest.

This final subsection of the paper considers whether, and how, the above definitions and typologies of value can be related to ecosystem assets and ecosystem services for incorporation and SEEA (i.e. to what extent can SEEA accommodate these plural values?). Table 4 below shows how the anthropocentric/non-anthropocentric, total economic value, and ecoservice classifications discussed above relate to each other e.g. anthropocentric instrumental values equate to direct use values in the TEV framework and to directly consumed provisioning services in the ecosystem services classification as used in Haines and Potschin (2017), and discussed in subsections 4.3 - 4.5 of this discussion paper.

Table 4: Comparison between an anthropocentric/ non-anthropocentric typology and other typologies

Anthropocentric and non-anthropocentric classification (Turner et al.; IPBES; see subsection 2.4.1.)	Closest TEV classification (see subsection 2.4.2.)[25]	Closest ecosystem service classification (see subsection 2.4.3. and 4.3-4.5)[26]
Anthropocentric instrumental type of value	*Direct use value*: Direct consumption, final use (e.g. harvested foods, seafood) *Option value/bequest value* Where deferred *direct use value*	*Provisioning services* Also relate to TEV *direct use values* (if direct consumption is final use, e.g. bush meat). *Regulating services*[27] (Where direct consumption is final use e.g. evaporative cooling provided by urban trees improving thermal comfort).
Anthropocentric relational/ anthropocentric intrinsic type of value	*Direct use value*: Non-consumptive (e.g. recreational value) *Non-use value (including existence value)*	*Recreation services* e.g. cross-country sporting events, visual landscapes
Non-anthropocentric instrumental type of value (ecosystem functions and processes)	Not clearly distinguished in TEV. May be incorrectly defined as *indirect use values* if ecosystem functions and processes are confused with ecosystem services, especially *regulating services.* NB Ecosystem processes and functions are precursors to ecosystem services, which then may provide inputs to final consumption, or inputs to creation of other ecosystem services. As they are non-anthropocentric instrumental types of value they do not correspond to (anthropocentric) *non-use values*	Non-anthropocentric instrumental types of value such as ecosystem functions and processes, are precursors to anthropocentric Instrumental *regulating services* and *provisioning services.*
Non-anthropocentric intrinsic type of value (This type of value may be part of the worldview of many indigenous communities)	Not considered in TEV, which is *per se* anthropocentric. (See footnote re anthropocentric nature of existence value)	Not relevant, as is an anthropocentric classification (i.e. ecosystem services need to have defined human beneficiaries)

[25] TEV, including 'existence value', is by definition anthropocentric, because it is ultimately humans attributing this value to something under this framework, viz. 'existence value' is commonly estimated through stated preference methods.
[26] Ecosystem services are by definition anthropocentric.
[27] CICES v5.1 refers to regulating and maintenance services (Haines-Young and Potschin 2017).

Given the problems with using the TEV framework of direct use, indirect and non-use value discussed above, this value typology is not recommended as a suitable approach. However, the categories described in Turner et al, (2003) and IPBES (2015, 2019) can provide some help.[28] The anthropocentric-instrumental, non-anthropocentric-instrumental, and non-anthropocentric-intrinsic categorisation can be used to differentiate those types of value that are relevant to SEEA from those that do not have appropriate characteristics.

As noted above, the information on economic activity in the SNA and SEEA has the characteristics of being, anthropocentric, instrumental, quantifiable and exclusive (i.e. rivalrous). It is suggested that, if other types of information are to be are included in SEEA, they will need to also have these characteristics, or at least be capable of being re-expressed in ways that allow compatibility with SEEA. As shown in Table 5 only anthropocentric instrumental and non-anthropocentric instrumental types or values share any of the characteristics of economic values.

Table 5: Types of value that are suitable for inclusion in SEEA

Type of value	**Instrumental**	**Quantitative**	**Exclusive/ rivalrous**
Anthropocentric Instrumental	*Yes*	*Yes*	*Yes*
Anthropocentric relational (weak intrinsic)	No	No	No
Non-anthropocentric Instrumental	*Yes*	*Yes*	No
Non-anthropocentric Intrinsic	No	No	No

Figure 2.1 below shows the types of values that may be suitable or unsuitable for inclusion a SEEA framework graphically. The area enclosed by the red circle suggests the domain in which these values lie (see Box A 'Domain of values relevant to EEA'). For example, those intrinsic values that are non-anthropocentric, are also non-instrumental and non-quantifiable and cannot easily be reframed as anthropocentric, instrumental and quantifiable.[29]

Ecological/ ecosystem values offer better prospects; despite being non-anthropocentric, they are instrumental and quantifiable. Although economic values are expressed in monetary terms as exchange values, ecological/ ecosystem values are expressed in terms of physical indicators for extent and condition (such as ecological integrity indicators for connectivity and carrying capacity), which can be included in the SEEA as physical accounts.[30]

28 But see comments about IPBES definitions above.

[29] As shown in the diagram we can also distinguish 'non-exclusive' from 'exclusive' types of value. Non-exclusive types of value are those where the attribution of value to one entity does not prevent it being attributed to another entity. E.g. the attribution of 'outstanding universal value' to a world heritage site does not prevent other sites being attributed with this type of value. In contrast 'exclusive' types of value are rivalrous; attribution of value to one entity means that the same level of value cannot be allocated to other entities (as reflected in the concept of opportunity costs). From this perspective, given the finite nature of national or household budgets (and non-renewable global resources), monetised exchange values ultimately involve exclusivity.

[30] As noted in the introduction to this paper, ecosystems and ecosystem services can be considered via numerous non-economic frameworks for other policy and management purposes.

Arguably, if ecological values are to be incorporated in the SEEA, they will need to be reframed in a way that allows them to be directly compared to economic asset values i.e. to be monetised, and anthropocentric, as well as being instrumental and quantifiable. Valuation of final ecosystem services[31] provides the means by which ecosystem assets can be reframed as anthropocentric and monetised, and thus expressed in terms which are consistent with other assets in the SNA and SEEA. This process is shown on the far right-hand side of the diagram below (see Box B).

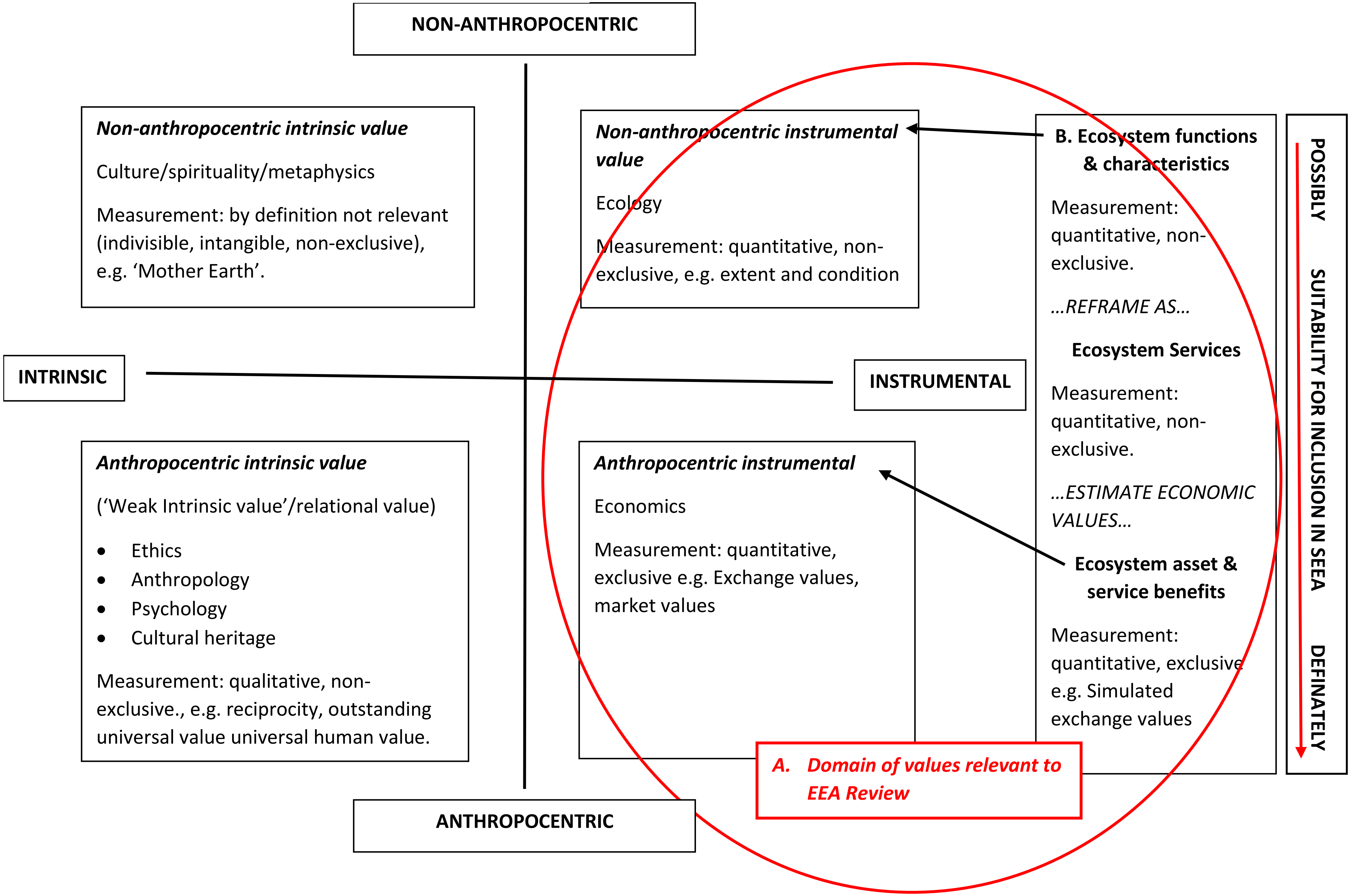
Ecosystem assets provide the stock of the goods and services which flow to production and consumption via ecosystem services, and thus their value is derived from the use (or non-use) value of the related ecosystem services (i.e. the present value of the stock of natural capital is equal to the present value of the sum of benefits from these ecosystem services; see Maddison and Day, 2014).

2.7 Conclusions – key messages from this section

The term 'value' is used in a variety of ways in everyday use, bur also has specific meanings in the natural and social sciences. Different typologies can be used to categorise these meanings into different types of value; which will be relevant to different research assessment and policy issues. For the purposes of ecosystem accounting, and to be compatible with economic values already in the SNA and SEEA, values will need to be anthropocentric, instrumental, quantifiable and monetised. Ecological values are instrumental and quantifiable, but not anthropocentric and monetised. Valuing ecosystem services through exchange values reframes them as anthropocentric, instrumental, quantifiable and monetised. Monetised ecosystem asset values can then be derived from the monetised ecosystem service values.

[31] see Maddison and Day (2014) for a discussion of issues relating to the definition of intermediate and final services.

Figure 2.1: Domain of values relevant to EEA



SECTION 3. Value and price concepts in environmental economics in the context of national accounts

The purpose of this section is to distinguish value and prices concepts for accounting, and to highlight the institutional assumptions underlying the simulation of markets for the purpose of estimating exchange price for ecosystem services where none is observable.

3.1 Welfare measure and national accounts

In the System of National Accounts (2008) market prices are defined as "amounts of money that willing buyers pay to acquire something from willing sellers. The exchanges should be made between independent parties on the basis of commercial considerations only, sometimes called 'at arm's length'". To link this to basic economic theory, let us start by positing an economic agent who needs and wants goods and services (from now on just goods). The strength of her desire for one particular good can be expressed in terms of her willingness to pay (WTP): that is, the maximum amount of money that she would willingly give up to acquire a unit of the good.

Let us further assume that the good in question is produced by another economic agent. The willingness to participate in exchange of that agent depends on the compensation being offered. The required compensation can be measured in money terms by her willingness to accept (WTA): that is, the minimum amount of money that she would accept for giving up a unit of the good. If the WTP of one economic agent exceeds the WTA of the other, they might agree on a mutually advantageous exchange in which the good is transferred in return for a money payment, p. The payment must be such that minimum WTA < p < maximum WTP, and could, in principle, occur at any price in that range (Day 2014).

Ignoring complexities associated to wealth effects[32], welfare economics proposes to evaluate the benefits realised by these two agents from participating in the exchange by adding up the buyer's *consumer surplus* (that is, the difference between her maximum WTP and the price) and the seller's *producer surplus* (that is, the difference between the price and her minimum WTA). As in a real economy there are many buyers and sellers, the needs and wants of the buyers are represented through a demand curve*, i.e.* the graph of maximum WTP amounts of buyers in the market ordered from highest to lowest. The compensations required by sellers are represented by a supply curve, the graph of minimum WTA amounts ordered from lowest to highest.

However, as discussed in section 1.2, the SNA abandoned a long time ago the goal of producing a welfare measure for goods traded in markets. Instead, it values goods traded in the economy multiplying the prices observed by the quantities traded. This implies that the absolute values shown in SNA estimates, such as GDP, are not related to the correct welfare measure (the sum of the producer surplus and the consumer surplus, or the corresponding Hicksian variations if one want to take into account wealth effects). It also implies that for large changes in the economy, variations in GDP and variations in surpluses

[32] Economists agree that consumer surplus is not the correct welfare measure (Harberger, 1971). The main reason is that it is based on the Marshalian demand function and fails to incorporate wealth and general equilibrium effects. Hicksian variations, and related measures, are generally considered a better welfare measure (Harberger 1971). We will nevertheless abstract from these technical issues and refer to consumer surplus as a correct welfare measure due to its conceptual simplicity. For the reader interested in a more precise measurement of welfare, note that all the arguments developed in this paper hold substituting consumer surplus by Hicksian variations.

are not even similar. However, for marginal changes differences are minimized and marginal changes in GDP approximate reasonably well changes in welfare.

Although variations in GDP attract generally most of the interest, the statement that only variations in GDP are relevant is debatable. The contribution of each sector to GDP is routinely used to determine the relative importance of a given sector in a country. To highlight the relative importance of the automotive industry in Germany, one of the main indicators is its contribution to GDP. For this purpose, it is the level and not the variation that matters. The automotive industry may not grow in a given year, but it will still be a substantial part of Germany's GDP. By the same token, to determine the relative importance of forestry in a given country, what matters is it contribution to the level of the GDP in a given year. Unfortunately, while GDP is a reasonable measure to determine the contribution of the automotive industry, it fails to incorporate many relevant ecosystem services provided by forests. To correct this, ecosystem accounting proposes to take into account the services provided by the forest to increase their visibility in national accounts. For this purpose only the level of the ecosystems services provided is relevant, not the variations. The bottom line is that both, variations and level of GDP matter (the same is true for related indicators such as NDP).

Weitzman (1976) showed that variations in NDP approximate reasonable well variations in welfare (see Harberger 1971 for a previous and similar result, and Löfgren 2010 for a discussion about the assumptions needed for this result to hold). As we are focusing here on ecosystem service flows, we can extend this argument to variations in GDP. However, this is not an argument to use welfare measures for ecosystem accounting and exchange values for goods traded in markets, as this would provide a measure that would not allow us to compare levels, and would therefore not highlight the contribution of nature to the economic activity. Instead, the argument should be used to show that if we extend the conventions in national accounts to ecosystem services, and in particular the focus on exchange values, we will obtain a measurement that is a good approximation of welfare changes (including welfare changes induced by variations in the ecosystem services provided). In addition, we would obtain a measurement that, when focusing on levels, would allow us to determine correctly what forests contribute to the economy, including all the ecosystem services provided by forests but not traded in markets.

Furthermore, if we are interested (also) in levels, welfare measures have a serious limitation when applied to ecosystem services. The last drop of water has a marginal value that tends to infinity (or the maximum amount of money available in the economy) as life is not possible without it. This implies that the total contribution to welfare of all the water available tends to infinity (we would need to integrate all the area under the demand function and, close to the origin, the part below the demand functions tends to infinity). On the contrary, applying the conventions of national accounts the value of total amount of water available in an accounting period is more modest, as it is valued at the price of the last unit traded (which is usually a point of the demand function far to the right from the origin). Moreover, even if water would not be traded in markets in one particular country, the simulated exchange value would also be rather modest, as water would be valued at the price that would occur if water were traded (as discussed below, the simulated exchange value aims at finding the price that would occur if a good not traded in markets would be traded).

To summarize the discussion above, focusing on welfare measures for ecosystem services would be inconsistent with the level measurements provide by national accounts for goods traded in markets. This would not allow comparing levels, and would not allow determining the contribution of ecosystems to economic activity. Furthermore, in level terms many ecosystems services would have a welfare value that tends to infinity, while neither their exchange value nor their simulated exchange value would tend to infinity. On the other hand, variations in welfare are approximated well by an ecosystem accounting measure based on welfare but also by a measure based on (simulated) exchange values. For these reasons, in this discussion paper we assume that the goal is maintaining consistency with SNA and, hence, estimating values obtained multiplying prices times quantities also for ecosystem services.

3.2 Accounting prices, shadow prices and exchange prices

As discussed in more detail in Fenichel and Obst (2019), for capital (stocks) the literature on green accounting has argued that “shadow” prices are the correct prices to value a unit of capital at a given stock level under an existing economic program. In the context of natural capital valuation, some authors (Dasgupta, 2009) distinguish ”accounting prices” from “shadow prices”, arguing that the former can be derived for any observed real world behaviour while the latter should be reserved for prices derived in an optimization framework. Other authors (Fenichel et al., 2018) argue that one can use the term shadow price also in a context without optimization (reserving the term “optimal shadow prices” for the ones obtained from an optimal management program).

From a national accounting perspective, the problem is that using the standard definition in green accounting of “shadow prices”, or “accounting prices”, these prices are not necessarily consistent with national accounts. Shadow prices are estimated starting with a social welfare function that discounts future net welfare. As pointed out in Fenichel et al. (2018), when welfare effects are limited to firms, measure of profits or producer surplus may suffice. In this case, accounting prices would be consistent with the prices recorded in national accounts. However, more generally demand side valuations are also needed and green accounting literature commonly recommends the use of compensating or equivalent surpluses (consumer surplus) to estimate the social welfare function (Fenichel et al., 2018). If this is the case, the shadow prices obtained would not be consistent with national accounts, at least not for level values (see the discussion in the previous sub-section, and Fenichel and Obst 2019 for variations in capital values).

In any case, in this discussion paper we will focus on flow values, leaving the discussion about natural capital for Fenichel and Obst (2019). Standard national accounts are mainly built observing prices for transaction that occurred during the accounting period (i.e. flow values). Examples from these types of transactions range from buying an apple at your local supermarket to buying an entrance to the cinema. However, many services provided by ecosystems have no associated transaction and hence no observable price. While you have to pay to enter your local cinema there may very well be no entry-fee to your local peri-urban forest. The challenge is to find a “price” for this visit, for which you paid no price.

The prices for these non-market ‘transactions’ have frequently been called ‘accounting prices’, because they are going to be used for accounting purposes. The problem is that, as discussed above, in much of the green accounting literature accounting prices have been defined as including compensating or equivalent surpluses (consumer surplus). Hence, it would be confusing to use a similar term for flow values that are supposed to exclude compensating or equivalent surpluses (consumer surplus).

In national accounting prices observed in market transactions are called exchange prices. We will extend this terminology to include cases where prices are not directly observable but are obtained based on simulations, as discussed in more detail in the next sub-section.

3.3 Exchange values and simulated exchange values

As stated in section 1, in this discussion paper we assume that the goal is maintaining consistency with SNA and, hence, estimating exchange values obtained multiplying prices times quantities. When traded in regular markets, prices and quantities are observable. When goods are not traded in one particular local market, but they are traded elsewhere, the approach proposed by the SNA is to use prices of similar markets (SNA, 2008): “3.123 When market prices for transactions are not observable, valuation according to market-price-equivalents provides an approximation to market prices. In such cases, market prices of the same or similar items when such prices exist will provide a good basis for applying the principle of market prices. Generally, market prices should be taken from the markets where the same or similar items are traded currently in sufficient numbers and in similar circumstances. If there is no appropriate market in which a particular good or service is currently traded, the valuation of a transaction involving that good or service may be derived from the market prices of similar goods and services by making adjustments for quality and other differences.”

The problem arises because for some goods, such as open-access recreation, there are no markets where the same or similar items are traded currently in sufficient numbers and in similar circumstances. One of the solutions proposed in the literature has been to simulate the price and the quantity that would have been observed if a similar good would have been traded in a market, calling it the “Simulated Exchange Value” (SEV) method (Caparrós et al., 2003 and 2017). The SEEA EEA TR (2017: p. 97) also proposes to extend the concept of exchange values, to include “those values that reflect the price at which ecosystem services and ecosystem assets would be exchanged between buyer and seller if a market existed”. However, it is probably more precise to reserve the term exchange values for those cases where the market really exists, and use the term “simulated exchange values” for the case where the price comes from a simulated market (Caparrós et al, 2017).

Irrespectively of the terminology, and as discussed in more detail in the next sections, if the market is simulated there are several prices that could emerge, depending on the assumed institutional context. Furthermore, which institutional context is most appropriate for each particular ecosystem service is debatable. To try to determine the most appropriate price for each ecosystem service, or the most appropriate range of prices, we will first discuss a set of criteria that might be useful to narrow down the prices that are adequate in each case.

3.4 Criteria for determining adequate simulated exchange prices in the context of national accounts

In this subsection the goal is to choose a set of criteria that any simulated exchange price should meet. The proposed criteria are the following:

1. Consistency between the valuation of goods traded in markets in SNA and the valuation of goods not traded in markets. As discussed above, consistency with SNA is paramount, even at the expense of not producing a perfect welfare estimate.

2. Credible (likely) institutional context and market structure. In the SEE-EEA-TR (2012, p. 100) we can read: "The key point here is to recognise that national accountants are aiming to estimate a value that would have been revealed in the "most likely" institutional arrangements" and "national accountants are relatively pragmatic in such contexts and are likely to consider what market arrangements are most likely given the country, the likely behaviour of market participants, existing tax and regulatory settings and the type of ecosystem service." The reason for the need for credible institutional setting is that the goal is to extend the approach in SNA (2008, point 3.123) of using prices from similar markets to cases where there are no similar markets. The idea is to simulate markets that, although they might not exist in one particular country or region, they "could" exist. The discussion in section 1.1 on household production, in particular output (production) for own final use, is relevant for this issue.

3. International comparability. If a good is traded in some countries but not in others, the value recorded by the SEEA-EEA should be comparable. This implies that if the ecosystem service is marketed in other countries, the simulated institutional context should be as similar as possible to the one existing in those countries.

3. 5 Context specific simulated exchange prices and values

Let us start by using open-access nature-based recreation to fix ideas. The goal is to estimate an exchange price for an open-access recreational area where there is no market and hence no price. To progress, it is necessary to assume an appropriate institutional context about the recreation area and here we work through this using the simple partial equilibrium model of a recreation area shown in Figure 3.1, and the further simplified model shown in Figure 3.2. In both cases the demand function is the site-specific demand function, that is the demand for recreation in one particular area. The difference between the two figures is that in the former uses rather general function while the latter assumes a linear site-specific demand function and constant costs.

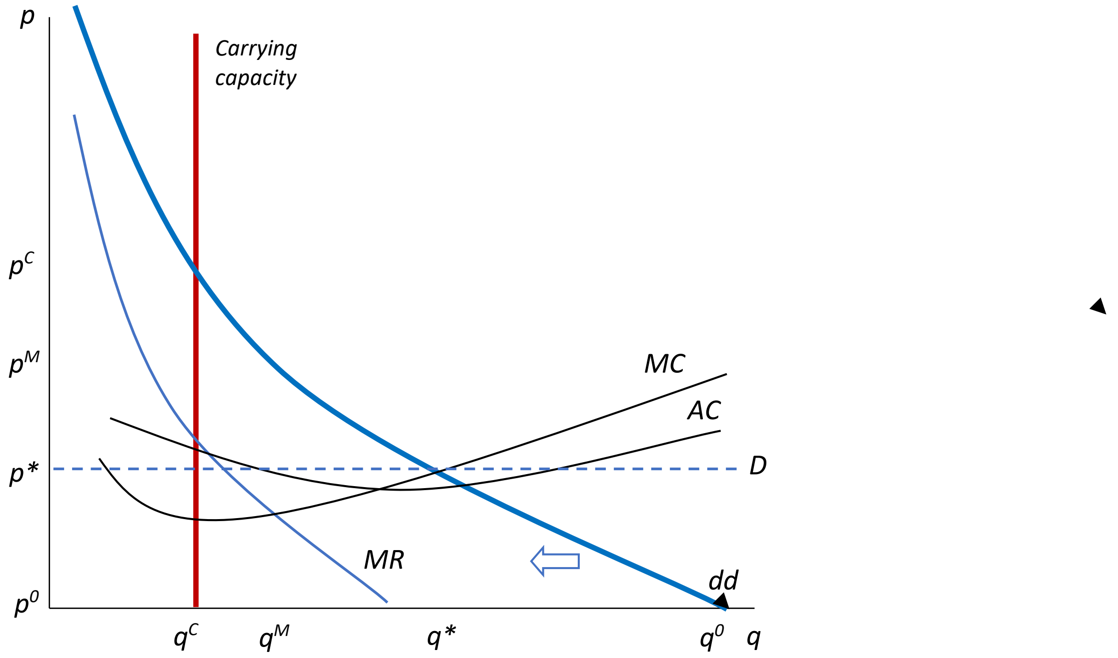


Figure 3.1 Simulated exchange values under short-term monopolistic competition (site-specific demand) and a limit to access based on the carrying-capacity of the ecosystem

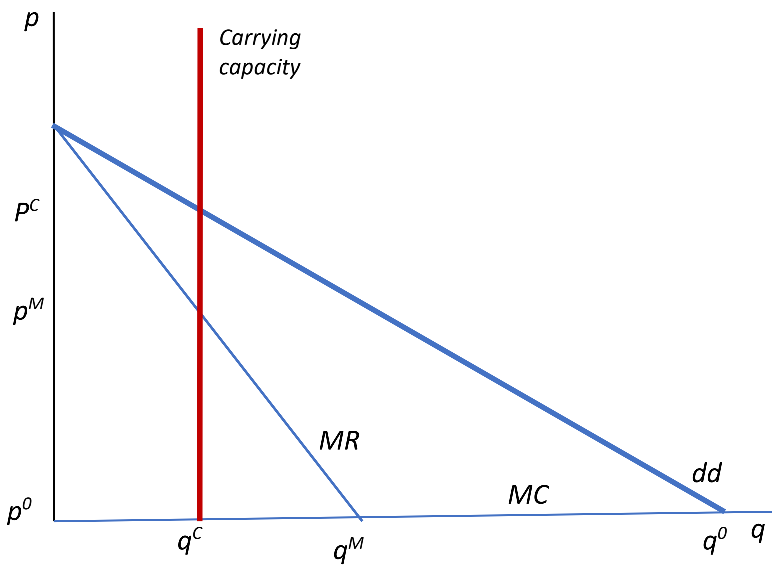


Figure 3.2 Simplified simulated exchange values under short-term monopolistic competition and a limit to access based on the carrying-capacity of the ecosystem (linear site-specific demand and constant costs)

If the greenspace really is open access, partial equilibrium micro-economic theory predicts that the recreationists will increase their use until the marginal value of visits is zero (point q^0 in Figure 3.1 and 3.2). Thus, the 'exchange price' is zero (p^0 , Figures 3.1 and 3.2) and, as a direct consequence, the exchange value is zero as well.

However, if there is a (public) institution governing the use of the recreation area, it needs to be funded. Even if funded by general taxes, there are implicit prices paid by visitors (and non-visitors) to support the maintenance of the recreational area (natural park, …). The problem is that these prices are not observable and we are therefore in a situation similar to that discussed in point 3.123 in SNA (2008). In this context, the SNA recommends to take "market prices … from the markets where the same or similar items are traded currently in sufficient numbers and in similar circumstances. ... If there is no appropriate market in which a particular good or service is currently traded, the valuation of a transaction involving that good or service may be derived from the market prices of similar goods and services by making adjustments for quality and other differences."

Hence, if a similar market exists, because we are dealing with a National Park which is open-access, but other National Parks in the country are marketed, one alternative is to take the prices charged in those parks, conveniently adjusted for quality and other differences. This alternative is consistent with economic theory if the prices are determined by market forces, while it is more problematic when prices are determined politically (as is frequently the case).

In any case, here we are primarily concerned with the case where no similar market exists. If no similar market exists, the closest alternative to the one proposed by the SNA (2008) in point 3.123 is to simulate a market to determine the price that would occur if the market were created (if the good were internalized). To do this, the first step is to determine the institutional context and the market structure. The problem is that several institutional settings could be imagined. Let us briefly discuss the main alternatives, starting with the market structures:

- *Perfect competition.* This implies that there are a very large number of greenspaces with recreational values available and that all have the same characteristics. In addition, the assumption is that new entries of recreational sites are possible without limitations. The consequence of this assumption is that there will be one price for all the recreational sites, and that the price will be given by the costs of producing the good (the recreational visit), including capital costs. The resulting price, p^*, would be given by the intersection between the marginal cost (MC) function shown in Figure 3.1 and the demand for the whole sector (function D in Figure 3.1, shown as a discontinuous line). Note that from the point of view of the individual recreational area, this demand function is a horizontal line, as the owner cannot impact the price.
- *Monopolistic competition with a unique site-specific price.* The assumption is that there is a given number of recreational areas which are sufficiently different, and that new entries are (in principle) possible but need a considerable amount of time. Thus, in the short run, the number of recreational areas is fixed. As the characteristics vary across recreational sites, the demand function is specific for each recreational area considered. That is, we would have site-specific demand functions. This implies that there is price discrimination between sites, or that sites are imperfect substitutes. However, all consumers face the same simulated price when they decide to visit one particular site (the simulated price is, in addition, to the travel costs paid by each

visitor, which may be different). In the short-run, monopolistic competition is almost identical to a monopoly, and the producer sets the price to maximize her net revenue, taking into account the site-specific demand function and the costs involved. In Figure 3.1 the site-specific demand function in the short term is labelled *dd* and has the familiar downward sloping shape. This function assumes that the owner has some control over the price set in her area, but that it can assume that it has no impact on the demand of the other areas. Note that this is the function obtained in most studies where the demand for one particular recreational area has been estimated, as studies rarely take into account the impact on other sites (alternatively, the impact of potential prices in other sites). The resulting price would be p^M, found at the point where the marginal cost function (MC) crosses the marginal revenue function (MR). In the long run, monopolistic competition assumes that new entries are possible and that this will drive benefits to zero, as every new entry reduces the demand for all (shifting the demand inwards). However, this is not particularly relevant as we are concerned about estimating prices for the current accounting period. In addition, at least for iconic recreational areas new entries are difficult even in the long-run. Figures 3.2 shows a monopolistic competition scenario under the assumption that the demand is linear and costs are constant, i.e. that they do not depend on the number of players (under this assumption the MC function coincides with the x axis). In this case, it is easy to show that the price, p^M, would be given by the median of the demand function, and q^M would be equal to 50% of the visitors that access the area when there is no price. These assumptions are reasonable in many applications and simplify the data requirements considerably (Caparrós et al., 2003, 2017).

- *Monopoly with single price.* There is only one recreational site and new entries are not possible. This situation is unlikely in most cases. As the implications are very similar to those of the monopolistic competition in the short run, we will not discuss it in detail.

In addition to these basic market structures, one can consider at least two additional assumptions that would shape the institutional context.

- *Perfect price discrimination.* Perfect price discrimination means that the producer is able to charge a different amount to each visitor and that this price will equal the maximum willingness to pay of that particular consumer. Note that the assumption is not that the consumer with the highest willingness to pay obtains the good, as in an auction, but that each consumer will pay his or her maximum willingness to pay. In the case of perfect competition, price discrimination among consumers is not possible, as if one producer tries to charge more to a given consumer because her willingness to pay is larger, the consumer will immediately switch to another producer, as all goods are identical by definition. When there is market power (monopolistic competition or monopoly) perfect price discrimination may be possible, although a relatively complex mechanism is needed to detect the maximum willingness to pay of each consumer. Under this assumption prices are not only different between sites they are also different between consumers. Because nature-based recreation is a different experience for each consumer, all have different WTP, but the difficulty to find a market mechanism able to internalise all these different WTP values remains.
- *Carrying capacity (or any other external limit to access).* If the greenspace has a maximum carrying capacity in terms of visitors, one can add the assumption that the number of visitors is limited to ensure that the carrying capacity is not surpassed (any alternative external limit to the number of visit would have the same impact). In this case, if the number of visitors is sufficiently high, the

marginal valuation of the last visitor accepted will likely be positive. If this marginal valuation is also larger than the costs, the price will be given by the marginal valuation of the last visitor accepted even under perfect competition. The carrying capacity can also imply a higher price in the case of monopolistic competition, but only if it implies to limit the visitors below the number of visitors that would have been willing to accept the price that the producer would have chosen in the absence of the carrying capacity. If the limit has bite, one could also argue that it is defining a vertical supply function. Figures 3.1 and 3.2 show a situation where the carrying capacity is so low that it would define the equilibrium, resulting in the quantity q^C and the price p^C. Note that if the carrying capacity would be to the right of q^M, respectively q^*, it would have no impact on the resulting prices under monopolistic or perfect competition.

Note that the different options just discussed have also consequences in terms of the amount of consumer surplus left out. Under perfect competition the consumer surplus left out from the ecosystem accounts would be maximized, while it would be minimized under a monopoly with perfect price discrimination. However, this does not mean that any of these assumptions renders the consumer surplus more acceptable in national accounting terms, it only happens that for one of them (monopoly with perfect price discrimination) the consumer surplus vanishes and it has therefore no numerical consequences to add it or not.

Let us now move on to the discussion about the most appropriate institutional context. The challenge is to select the most appropriate one according to the three criteria laid out above. As the discussion will show, the choice is highly context dependant.

Consistency with the national accounts does not help, as all institutional settings considered yield a price that is consistent with national accounts. As noted by Obst et al. (2016) national accounts do not only include values obtained in perfect markets. Hence, simulated exchange values are not restricted to perfect markets either.

Credibility (likelihood) of the institutional setting and the market structure is probably more helpful, although it is clearly context specific.

- For iconic nature–based recreational sites, such as a National Park, the assumptions behind perfect competition, i.e. a large number of identical parks and free entry of new identical parks, are not realistic. Monopolistic competition (or monopoly in the extreme case where there is only one National Park) seems more appropriate. This market could realistically be created by charging an entrance fee to the National Park. Implementing this option would imply estimating one demand function for each National Park (or each sufficiently differentiated iconic recreational site) and then estimate a different price for each of them. That is, prices would be differentiated by site. Adding perfect price discrimination, in the sense of one price per consumer, is probably not realistic in this context. There is probably no example of a recreational site, nature-based or not, where a mechanism able to extract the entire consumer surplus from each visitor is in place. On the other hand, the assumption of a carrying capacity is realistic in this case, as the number of visitors is restricted in many iconic recreational sites.
- For peri-urban greenspace, the assumption of perfect competition might be more adequate, if there are a large number of greenspaces and if these are relatively homogenous in quality and accessibility. Although different travel costs to access the areas would break this homogeneity in many instances. If the areas are homogenous also in regard to travel costs, one could argue that the law-of-one price would apply and that there would be no price discrimination among sites

(i.e. no spatial price discrimination). Perfect price discrimination in the sense of one price per consumer is also not compatible with a perfect market, as discussed above. The assumption of a carrying-capacity may be appropriate in many cases; although in others current visitation rates will be below the carrying capacity, so that it would have no influence on the price.

International comparability. The simulated market structure should allow for international comparability. This implies that if the good is traded under a given market structure in other countries the simulated institutional context should be similar to the one prevailing in those countries. Again, this is context specific:

- Some countries charge entrance fees in their National parks. These fees are typically different for different National Parks, although all consumers pay the same price (or at most two different prices, one for tourist and one for locals). That is, there is spatial price discrimination, but (almost) no discrimination between consumers. The assumption of monopolistic competition with one price for all consumers is the assumption that is closest to this situation.
- Peri-urban recreation spaces in a number of countries are club goods
- Access to urban and peri-urban green spaces is open in almost all countries, so that this criteria is not particularly useful in this context.

Summing-up the discussion above, for iconic recreational sites probably the most appropriate institutional context is defined by monopolistic competition, with price discrimination among iconic nature-based recreational sites but without price discrimination among consumers. If the carrying capacity has bite, in the sense that it would restrict access more than in an internalized market under this assumption, it should also be considered.

For non-iconic and relatively homogeneous greenspaces, the most appropriate institutional context may be that of perfect competition, ideally coupled with a consideration of the potential carrying capacity of each site.

3.6 Estimating site-specific demand and supply functions

Applied to recreation, the SEV method assumes that site-specific demand functions are available for all the recreational areas considered. These demand functions can be estimated using a variety of methods. Both revealed and stated preferences methods can be used for this task. Among the first, the most common one is the travel-cost method (Randall, 1994). Among the latter, both contingent valuation and choice experiments methods have been used to estimate the demand function for nature based recreation (Bateman et al., 2002).

Estimating the supply function for recreation may also be a challenging task. The first step implies estimating the costs involved in providing the recreational opportunities in the area considered. In most cases the cost involved are paid by the government, and are not easily separated from other general costs. Ideally one should obtain a cost function that depends on the number of visitors, as cleaning costs, for example, clearly depend on the number of visitors. However, information constraint may force to accept a supply function that does not depend on the number of visitors (as the one used in Figure 3.2). If the costs involved in providing the ecosystem services are exclusively public, one could also use this information to value the ecosystem service based on costs (as done for health and education services provided by the government). The drawback of this strategy is that the resulting estimates are not related to preferences.

If the supply function turns out to be vertical, as is the case when a limit is in place, the SEV would simply be the crossing point between the demand function and the vertical supply function (see Figures 3.1 and 3.2).

3.7 Simulated quantities and actual quantities in physical accounts

As already mentioned, if there is true open-access to a recreational site visits will occur until the point where the demand for trips crosses the horizontal axis. This implies a marginal trip price equal to marginal trip cost. In some cases access may be restricted to a maximum number of visits per day. Although strictly speaking not anymore an open-access situation, in this case the last visitor will have a positive WTP and this information could be used to set the simulated exchange price based on her marginal WTP. Here the quantity of visits observed in reality and in the simulation would be identical. People may still have positive WTP for environmental improvements in open access. What they don't value is the weak complement that is a marginal trip.

In the general case, where there is no limit to the daily visits, the actual number of visits is larger than the simulated number of visits. This is a significant problem, as monetary accounts should be consistent with physical accounts. This situation is akin to the one occurring when one values mushrooms recollected freely by their market price, as some mushroom gatherers would not have come if they needed to pay for the mushrooms. The SEEA-CF (2012) proposes to use this method for non-timber forest products such as mushrooms, valuing all the mushrooms recollected at the market prices prevalent in 'similar' markets. That is, the quantity recorded is the one actually observed, but the value recorded is larger than the value that would have occurred if the market would really be in place. This is one alternative that could be considered. It would allow consistency among the quantities recorded in monetary and physical accounts, but the value recorded would be an over-valuation, which goes against the prudence that should govern any accounting exercise. Hultkrantz (1992) uses this method for the estimation of values for several non-timber products only partially traded in markets in Sweden.

Another alternative would be to estimate an additional "price" such that the value of the simulated exchange price times the simulated quantity is equal to this new price times the quantity consumed in reality. This is probably confusing as it introduces an additional price.

Finally, our preferred alternative is to keep the visits that actually occurred in both accounts (physical and monetary) but consider that only a fraction of the visits have a positive economic value (those that would occur under the simulated scenario) and attribute a price equal to zero to the remaining visits. In this case, the quantity of visits is the same in both accounts, but not all visits have the same price. This is the approach followed in Campos et al. (2019).

3.8 Marginal Value Pricing using random utility models of travel choice

The discussion has concentrated so far on the marginal WTP of the last visitor. A recent proposal by Brett Day in Barton et al. 2019, called Marginal Value Pricing (MVP), suggests focusing instead on the value of the marginal unit of land devoted to recreation. The supply of greenspace accessible to people is necessarily constrained (often significantly so given its open access properties), such that the value of a unit expansion in supply will be positive and hence the implicit exchange price of this constrained supply will also be positive (note that the method does not propose to use the market value of that unit of land, but the implicit price defined by its use for nature based open access recreation). The MVP approach proposes using this marginal valuation of greenspace to calculate accounting entries for the flow of services provided by the open access greenspace currently supplied to households.

With regards to practical application, the MVP approach would require a standard measure of access to greenspace that would quantify levels of current supply. Since the supply of access to greenspace is spatially specific, the measure would necessarily differ across the accounting area, such that implementation would require separate greenspace supply statistics to be calculated over some reasonably fine resolution statistical unit of population. From accounting period to accounting period, measured changes in the supply of greenspace would be reflected in changing greenspace supply statistics. Exchange prices would then be calculated for the measured supply in each unit through identification of marginal values for greenspace in that unit. The accounting entry for recreation would be taken as this local marginal value multiplied by the local marginal supply summed over all local units.

3.9 Inventing money in simulated markets

The methods discussed above have all in common that transactions that actually do not exist are simulated. This holds when the 'price' is obtained by simulating a market (SEV), but also when the 'price' is an implicit price for the last unit of land devoted to recreation (MVP). The problem is that the budget constraint is not actually affected, and relative prices are not modified. This produces an inconsistency, as individuals would consume smaller amounts of the product (visits, mushrooms, ...) if they would need to pay for them. They would also consume less of other products.

This is a serious limitation of any method based on simulations, but it applies to several of the conventions currently followed in the SNA. This occurs when a house occupied by its owner is valued at its market rental price and also when non-timber products collected freely are valued at their market price. In fact, it applies to many of the cases where 'market-price-equivalents' are estimated following the recommendations set out in point 3.123 of SNA (2008), see the discussion above. In any case, as this is a standard practice in SNA (2008) ecosystem accounting should probably acknowledge this limitation, but continue using simulated values.

3. 10 Payment for ecosystem services and biodiversity

The discussion of the simulated exchange values has focused so far on nature based open access recreation because it is relatively close to markets. In principle one could also apply the method proposed above to passive use values, such as biodiversity preservation and other ecosystem services where a hypothetical market can be constructed. Atkinson et al. (2012) cite many studies that have used stated choice methods to value biodiversity and other ecosystem services. These methods construct a hypothetical market by, for example, asking households what they would be willing to pay to protect a given species. As for free access recreation, these studies typically report consumer surplus or, to be more precise, compensating or equivalent Hicksian variations. Nevertheless, one could use data from these discrete choice experiments to estimate the maximum amount of money that could be internalised in a hypothetical market, as proposed by the SEV method. This could essentially be done in any case where a Payment for Ecosystem Services (PES) scheme is feasible.

PES schemes have been used in the real world to protect biodiversity. When transactions occur as part of the PES scheme, they are recorded in national accounts. The proposal would consist of simulating PES also in areas where they are currently not in place, and to estimate the resulting simulated exchange value. Campos et al. (2019) followed this path. However, it is fair to state that more research is needed to streamline the conditions under which the SEV method can be applied to biodiversity or other passive use values. See also Adamowicz et al. 2019.

3. 11 Simulated exchange values in available pilot applications

An example where a set of iconic nature-based recreational sites are valued under the assumption of monopolistic competition can be found in Caparrós et al. (2017). Previously, Caparrós et al. (2003) assumed a monopoly and Campos and Caparrós (2006) estimated a range of prices, using perfect competition as a lower bound and monopoly as an upper bound. Caparrós et al. (2017) also shows that the simplified approach discussed in Figure 3.2, based on simply multiplying 50% of the visitors by the median WTP, provides a reasonable approximation of the SEV estimated using a more sophisticated approach. In particular, they show that as long as costs are constant, using the median is a good approximation even if the demand is not linear. Finally, Caparrós et al. (2017) compare the values obtained estimating the SEV method to the correct welfare measures (compensating Hicksian variations) under different assumptions, showing that SEV values are more robust to changes in assumptions. The reason is that welfare measures are more sensitive to the shape of the tails of the WTP functions (see the discussion above about the tendency to obtain disproportionally large welfare values close to the origin of the demand function), and alternative assumptions tend to influence particularly these tails.

Hein et al. (2016) apply a similar method to clean air, calling it maximum societal revenue (MSR), and arguing that it is well suited for national accounting. Their goal is to find the 'fee charged by society in the hypothetical case that society would act as a profit maximizing entity able to charge a fee for clean air, under the assumption that this fee would only be paid by people whose WTP equals to or exceeds this fee'. They also state that "MSR represents the point where the multiplication of a WTP and the number of people expressing at least this WTP is at its maximum". This concept coincides with what we have called SEV above.

3.12 Conclusions - key messages of this section

Focusing on welfare measures for ecosystem services would be inconsistent with the measurements provide by national accounts for goods traded in markets. This would not allow comparing levels, and would not allow determining the contribution of ecosystems to economic activity. Furthermore, in level terms many ecosystems services would have a welfare value that tends to infinity, while neither their exchange value nor their simulated exchange value would tend to infinity. On the other hand, variations in welfare are approximated well by an ecosystem accounting measure based on welfare, but also by a measure based on (simulated) exchange values. For these reasons we assume that the goal is maintaining consistency with SNA and, hence, estimating values obtained multiplying prices times quantities also for ecosystem services.

In national accounting prices observed in market transactions are called exchange prices, yielding exchange values when multiplied with observed quantities. We extend this terminology to include cases where prices are not directly observable but are obtained based on simulations, calling the estimations obtained simulated exchange values.

When traded in regular markets, prices and quantities are observable. When goods are not traded in one particular local market, but they are traded elsewhere, the approach proposed by the SNA is to use prices of similar markets. The problem arises because for some goods, such as open-access recreation, there are no markets where the same or similar items are traded currently in sufficient numbers and in similar circumstances. The solution proposed is to simulate the price and the quantity that would have been observed if a similar good would have been traded in a market.

To estimate simulated exchange values one needs to determine the most realistic institutional context.

For iconic recreational sites probably the most appropriate institutional context is defined by monopolistic competition, with price discrimination among iconic nature-based recreational sites but without price discrimination among consumers. If the carrying capacity has bite, in the sense that it would restrict access more than in an internalized market under this assumption, it should also be considered.

For non-iconic and relatively homogeneous greenspaces, the most appropriate institutional context may be that of perfect competition, ideally coupled with a consideration of the potential carrying capacity of each site.

More research is needed to streamline the conditions under which the SEV method can be applied to biodiversity or other passive use values.

SECTION 4. Approaches for assessing valuation methods in the context of national accounts.

The intent of this section is to identify the valuation methods available for estimating exchange prices for the benefits of ecosystem services. The section aims to identify preferred (tier 1) and less preferred (tier 2-3) valuation methods based on accounting compatibility criteria and the final aim of determining per unit area values for ecosystem assets.

4.1 Economic valuation techniques for accounting

The System of National Accounts (SNA) indicates that if the goods and services are traded in regular markets, prices and quantities are observable (e.g. carbon storage), and these might be used (SNA 2008). If goods are not traded in one particular local market, but they are traded elsewhere, the approach proposed by the SNA is to use the prices of similar markets (where the same or similar items are traded currently in sufficient numbers and in similar circumstances). However, for some goods there are no markets where the same or similar items are traded currently in sufficient numbers and in similar circumstances. In those cases, it is needed to look for economic non-market valuation techniques consistent with the SNA.

The economic valuation of ecosystem services covers the direct use, indirect use and non-use values a wide range of provisioning, regulating and cultural services. There is often a range of methods that can be applied to any particular ecosystem service (Table 4.1). However, these different approaches vary in their ability to pinpoint different types of services, their compatibility with the System of National Accounts, and in the ease with which they can be adjusted to this purpose.

Valuation techniques can be broadly classified into two classes that differ in the basic mathematical procedures and types of data employed in the valuation process (Young, 2005):

Deductive methods involve logical processes to reason from general premises to particular conclusions (Young, 2005; Young and Loomis, 2014). These methods employ constructed models comprising a set of behavioral postulates (i.e. profit or utility maximization) and empirical assumptions appropriate to the case at hand. The data to fit a deductive model will typically include assumptions about the relations between input levels and output (the "production function") plus forecasts of the relevant input and output prices. The accuracy of the results of deductive reasoning depends on the validity of the behavioral and empirical premises, the appropriateness and detail of the model specification and the forecasts of the production function and prices. The main advantage of the deductive methods is that they can be constructed to reflect any desired future policies, economic and technological scenarios, and sensitivities of the results to varying assumptions (Young, 2005; Young and Loomis, 2014).

Inductive methods involve a process of reasoning from the particular to the general, or from real-world data to general relationships (Young, 2005; Young and Loomis, 2014). This involves the use of formal statistical or econometric procedures to infer generalizations from individual observations. Inductive methods involve observation of prices on ecosystem services rights transactions, land and property transaction, responses to survey questionnaires, or from secondary data from government reports. The accuracy of inductive techniques depends on several factors, including the representativeness and validity of the observational data used in the inference, the set of variables and the functional form used in fitting the data, and the appropriateness of the assumed statistical distribution (Young, 2005; Young and Loomis, 2014)

The distinction between deductive and inductive methods is new to the discussion of valuation methods in the SEEA EEA. The distinction may be useful in the sense that it identifies a difference in valuation practice between valuation research and applied valuation in the consultant and accounting community. Deductive methods tend to compensate for lacking data richness and statistical estimation using assumptions about causality. This allows for use in situations with less data and consequently eases spatial extrapolation and value transfer. Running the risk of oversimplification, the choice between deductive - inductive valuation methods illustrates a decision in ecosystem accounting between location specific, high cost and higher accuracy valuation, and generalizable lower cost, but also lower accuracy valuation.

Table 4.1. Summary of methodological approaches and their typical applications (provisioning, regulating or cultural services) (X = typical application))

Group	Type	Method	Description	Computational demand	Result	Provis-ioning	Regul-ating	Cult-ural
Market prices and quantities			Observed prices, quantities and input costs. Includes actual damage costs	Spreadsheet analysis / econometrics	Observed exchange value	X	**X**	X
Simulated exchange price and quantities			Prices are estimated by utilizing an appropriate demand function and setting the price as a point on that function using (i) observed behavior to reflect supply (e.g. visits to parks) or (ii) modelling a supply function.	Econometrics	Hypothetical exchange value			X
Deductive methods	Cost-based using market prices	Damage costs avoided	Monetary value of damages avoided (as an upper estimate of WTP)	Spreadsheet analysis	Point estimate		X	
		Restoration cost	Cost of replacing the ecosystem asset. Values a bundle of services	Spreadsheet analysis	Point estimate		X	
		Replacement cost	Cost of replacing the service. In rare cases this might be the restoration cost.	Spreadsheet analysis	Point estimate		X	
	Residual	Unit resource rent	Prices determined by deducting costs of labor, produced assets and intermediate inputs from market price of outputs (benefits).	Spreadsheet analysis	Point estimate		X	
		Change in net rent	Similar to unit resource rents, but to value partial changes in the ecosystem service supply (instead of discrete change). Does not hold other inputs constant.	Spreadsheet analysis	Marginal Product		X	
		Mathematical programming	Derive producers' rents or marginal costs using optimization model	Linear programming	Marginal Product		X	
Inductive methods	Revealed prefer-ence	Production & cost functions	Econometric analysis of industry data	Econometrics	Demand function		X	
		Travel cost methods	Econometric analysis of visitor travel cost data to derive demand curve	Econometrics	Demand function			X
		Hedonic pricing	Econometric analysis of property data to derive demand curve for environmental characteristics	Econometrics	Demand function			X
		Averting behavior	Actions taken to avoid experiencing an external damage, as partial measure	Econometrics	Demand function		X	
	Stated preference	Contingent valuation method	Statistical analysis of answers on WTP for a change in environment	Econometrics	Demand function	X		X
		Choice modelling	Statistical analysis of answers on WTP for a change in environment	Econometrics	Demand function	X		X

4.2 Considerations in the selection of valuation methods

A number of factors need to be taken into account when deciding on valuation methods for ecosystem accounts. Building on the discussion by Barton et al. (2017), these can be simplified to:

1. Degree to which methods are based on empirical analysis (inductive vs deductive)
2. Degree to which methods can isolate the individual service
3. Ease with which value can be expressed in terms compatible with SNA
4. Degree to which methods allow reliable extrapolation based on biophysical, socio-economic and/or institutional context

4.2.1 Degree to which methods are based on empirical analysis (inductive vs deductive)

The two classes of methods are conceptually very different. This has implications for the comparability of their results. For example, published estimates of the economic value of irrigation water based on observed behavior (inductive techniques such as an hedonic function) versus models of hypothesized farmer decisions (deductive techniques such as the residual method) are often inconsistent (Young, 2005). Inductive methods appear to generate more conservative (lower) value estimates than grounded deductive methods. This may be mostly because deductive methods are very sensitive to a full specification of all the inputs in the production function (if a production factor is not well identified, its contribution is allocated to the relevant ecosystem services), aggregation between productive units (not easy to generalize from one economic unit to the whole productive sector), difficult to empirically measure the amount of the ecosystem service used, and price distortions in different inputs (e.g. subsidies in agriculture inputs). Moreover, residual methods can result in negative values. This is a consequence of many sectors using natural resources to produce public services, like water supply, without a profit objective, or because of price distortion in subsidized sectors such as agriculture. A longer list of potential distortion in deductive methods is shown in Table 4.2. A more detailed description of the methods, data requirements, and pros and cons are described in the Appendix.

Generalizations based on observations of actual behavior (i.e. results of inductive methods) are more realistic and reliable than the results of deductive methods (Young, 2005; Young and Loomis, 2014). However, the main advantage of deductive methods is that they usually need fewer data, are simpler, and allow for flexibility in the change of the assumptions (interest rates, etc.), also making it easier to derive estimates for future scenarios (Young and Loomis, 2014).

Methods typically associated with research driven economic valuation of ecosystem services are inductive methods (Table 4.2). Inductive methods rely on large datasets that usually take time to acquire. The methods which are listed in the SEEA EEA as potential methods for use (Appendix 1), are deductive methods, requiring less data, and being more amenable to spatial transfer/extrapolation[33]. Simulated exchange methods, developed for accounting, combine the two classes of methods. These bring together demand functions developed using inductive methods, with a supply function, which involves a deductive approach.. For example, (Caparrós *et al.*, 2017) show an application for recreational ecosystem services by forests in Andalucia, Spain. In their approach, the supply curve was

[33] It should be noted that most methods tend to incorporate a combination of inductive and deductive reasoning, hence the categorization is based on the primary type of reasoning.

based on a cost function (i.e. estimated cost of supply by the government). These approaches need more discussion and research.

4.2.2 Degree to which value of the service can be isolated

Wherever markets exist for the service in question, then **market data** on quantities, prices and input costs would provide the desired estimate of net income required for accounting. These are typically found for provisioning services and certain cultural services. Market data also exist for certain regulating services, such as carbon sequestration. However, payments observed in public PES schemes will represent an administratively determined compensation rather than a market clearing price . These payments may be linked to a spatial unit of ecosystem conservation, that may supply different services to different beneficiaries. In that case, payments reflect a bundle of ecosystem services, and isolating one of the from the value in the market might be difficult.

Residual methods are typically used to estimate the value of regulating services as inputs to production, such as fodder inputs to livestock production. The value is reached after deducting the costs of every input used during the production process. In these cases, the residual would embody every contribution from ecosystems not accounted in the market (for example all the underlying ecosystem processes supporting agricultural production). This can be better solved by using **production or cost function methods.** These are a group of revealed preferences methods, i.e. they estimate the implicit value of the ecosystem services from the value of goods that are marketed. Production / cost function methods employ more sophisticated econometric techniques to analyze the changes in economic units revenues or cost as a consequence of changes in the supply of a specific ecosystem service. However, the challenge is to identify and measure the ecosystem service that the economic unit uses in physical terms. This is mainly a problem when thinking about regulating services. In the case of **cost-based methods** used to value ecosystem services, the accuracy of the estimate is primarily reliant on the accuracy of conceptual understanding and physical modelling. For cost-based methods to be appropriate for non-market valuation, they need to: (1) provide the same or equivalent good or service; (2) the goods or services are demanded and if supplied with an alternative technology, there must be clear evidence that the services would be demanded from the higher cost alternative; and (3) the alternative must be the least cost alternative way to provide this equivalent good or service. Assuming that this is accurate, then appropriate cost-based methods can be accurately determined, provided that proper logic is applied. Despite these limitations cost-based methods are common in national accounts within health and education services. Variance and bias in cost-based methods is more easily accepted where the purpose of accounting is to observe change over time rather than absolute values (the purposes of accounts are discussion in section 6).

There exist other **revealed preference methods**, for which the capacity to isolate a specific ecosystem good or service depends on the accuracy of the variable used to measure changes in the environmental quality / quantity, as well as for the production / cost function methods. **Travel cost methods** are applied to valuing single destimation recreation. Multinomial logit travel choice models may be applied where visitors have a number of substitute destination to choose between. **Hedonic pricing methods** could be very accurate, but are methodologically demanding.

Properly designed, stated preference methods have the potential to pinpoint non-market cultural and provisioning values very well. For non-use and option values, these are the only methods available. However, they can be problematic in valuing regulating services, mainly because public understanding of these services tends to be poor.

4.2.2 Compatibility with exchange value

Deductive methods such as residual methods and cost-based methods can be used to find point estimates (e.g. the income generated or costs avoided over the time period in question), whereas inductive models are designed to estimate demand function for changes in ecosystem services quantity or quality, and find marginal changes in the demand. Thus the deductive methods tend to be more compatible with exchange values. Revealed and stated preference methods are inductive methods, but because they estimate only the demand function, this needs to be combined with estimates of supply in order to produce a simulated exchange value (see Section X), i.e. the price at the intersection of the demand and supply function.

4.2.3 Degree to which method allows value to be scaled up

The results of the different methods are very sensitive to specific context. Given that inductive methods are based on actual observations, while deductive methods are based mostly on firms' performance or public interventions to bring alternative solutions, deductive methods might be less sensitive to scale. However, this is an aspect that has not been studied in detail. Even if applied well at a local scale, the accuracy of many of these methods may easily be lost in scaling up. Thus, it is important when running non-market valuation for accounting to work with data with national representativeness. This is mostly sensitive for inductive methods.

4.2.4 Other considerations

The above analysis purposefully avoids cost of implementation. All of these methods can be applied at a range of effort and costs, and most are expensive to apply properly. What actually affects cost more significantly is the availability of data. This varies from country to country and cannot be predicted. Thus a final choice at national level can also incorporate cost as a factor. At this point it may also be necessary to evaluate the trade-off between conducting primary valuation studies and using benefits transfer methods based on international data.

4.3 Valuation methods for different ecosystem services

The following sections review and evaluate the methods typically applied to value provisioning, regulating and cultural services in the context of the SNA. The discussion is based on a review of ten working group papers prepared by SEEA EEA Working Group 3. Based on these papers, the main methods and challenges involved in valuing different types of services are summarised in Table 4.2. The ecosystem services reviewed follows the selection and definitions determine by WG3.Numbering of methods indicates relative frequency of use and/or recommendations in the discussion papers.

Table 4.2. Summary of main valuation methods and challenges for different ecosystem services based on 10 papers under Working Group 3, with further input from this study.

Service or group of services	Direct Benefits	Valuation methods	Main challenges/notes
Harvested and cultivated terrestrial and aquatic resources[34]	• Harvested and cultivated terrestrial and aquatic resources	1. **Gross income less** certain **costs**[35] o Ex-vessel/farm-gate market prices less production costs and subsidies; or o Resource rent; or o Gross and net value added 2. **Leases** paid for productive land or **Share prices** paid for harvesting rights 3. **Replacement costs** (e.g. for subsistence harvesting for cases in which appropriate market data not available)	• Data on stocks and harvests can be unreliable • Valuing the harvest doesn't necessarily equate to valuing the change in standing stocks (though this relates to asset valuation – see WG paper x) • Prices include returns to human capital, labour and produced capital • Subtracting subsidies as well as production costs can lead to negative value • Difficulty in obtaining cost data • Allocating fixed costs to fish • Replacement costs may over-value if not done carefully
Water supply[36] as a provisioning service (if included as an ecosystem service)	• Amount of water for household consumption, agriculture, manufacturing, mining and power production • Water for navigation *Indirect (not valued here):* o *Inputs to other ecosystem services such as biodiversity and recreation*	1. Demand function 2. Residual value (e.g. net return to water) 3. Marginal productivity, based on a production function 4. Alternative cost 5. Contingent valuation	• Easily conflated with water quality amelioration services if stated preference measures are used • Shadow pricing is often used in this context, but is not consistent with SNA exchange value
Carbon sequestration[37]	• Avoided climate change damages due to anthropogenic emissions	**1. Emission trading scheme price** **2. Social costs of carbon**	• ETS prices may require downward adjustment when applied at large scale. • SCC estimates should be based on GDP rather than welfare estimates • SCC estimates should be downscaled to national level[38]
Soil retention[39] (prevention of soil loss and/or further downstream transport of eroded soil as a result of vegetation cover and wetland functioning)	• Avoided sedimentation of waterways, reservoirs and harbours • Avoided air pollution loads • *(Avoided loss of future land productivity)* *Indirect (not valued here):* o *Avoided losses of downstream ecosystem services*	1. **Avoided cost** associated with (i) mitigating, (ii) repairing damages (e.g. dredging,), or (ii) replacement of the function[40] (least cost option of (i) to (iii))	• Difficulty in obtaining physical measures– reliant on comprehensive monitoring, but can be modelled in a number of platforms • Avoided damages can be difficult to estimate due to complexities of a spatio-temporal nature • Risk of double counting, noting that soil is directly or indirectly important for the provision of many other ecosystem services, including provisioning services, carbon sequestration and cultural services. **Note a departure from the WG paper, which describes valuation in terms of all of these.*

[34] We have combined the comments from the two papers on terrestrial and aquatic resources - Hein et al. 2018 and Dvarskas & Fenichel 2018, respectiveley - as the papers were complementary and ideas interchangeable
[35] Different variations on this have been suggested, and will need to be settled on for alignment with SNA
[36] This is partly covered in Portela et al. 2018
[37] Based on Edens et al.2018
[38] See Turpie et al. 2017
[39] Based on Burkhead et al. 2018
[40] Note that the replacement cost is classifed here as a potential type of avoided cost rather than as an alternative method to avoided cost method. This is a better way of classifying the approach(es), as it emphasises the need to select the least cost option

Service or group of services	Direct Benefits	Valuation methods	Main challenges/notes
Air filtration[41] (reduction in pollutant concentrations due to vegetation)	• Health benefits from reduced exposure to pollutants • Reduced building maintenance costs (e.g. cleaning)	1. **Avoided costs** associated with building maintenance plus Avoided costs associated with health care, morbidity and premature mortality (based on dose-response functions) and/or **Costs of averting behaviour** [42] 2. **Hedonic pricing**, under the reasonable assumption that all the above are reflected in residential and commercial building prices	• Empirical estimation of service in physical terms is data intensive, but models are improving; • Deciding whether age or quality of life matters in putting a price on avoided mortality, by using VSL, VSLY or QALY; • Estimating the cost of illness can be data intensive, but there are global guidelines on morbidity effects of air quality; • Difficult to estimate averting behaviour costs • Isolating the effects of air quality in hedonic pricing is potentially data intensive.
Water purification[43] (removal of pollutants including anthropogenically elevated nutrient and sediment loads by ecosystem processes)	• Health benefits from reduced exposure to pollutants • Reduced water treatment costs *Indirect (not valued here):* o *Avoided losses of aquatic ecosystem services*	1. **Avoided water treatment costs**, usually based on a cost function and/or **Avoided health costs** 2. Prices in **existing PES markets** for similar hydrological ecosystem services 3. Simulated exchange value based on **Stated preference studies** that are directly to do with water quality for household use	• Physical modelling and conceptual understanding is complex because this is a "sink service", for which ecosystem capacity is limited and overuse leads to ecosystem damage; • Quantification of the service in physical terms is data intensive, modelling is complex and the "easier" modelling platforms are not yet sufficiently reliable; • PES often relates to a bundle of services, also often reflect opportunity cost of providing the service rather than its value; • Risk of double counting, noting that revealed preferences for amenities (e.g. in hedonic and travel cost studies) can have a water quality component; • Simulated exchange value from stated preference studies requires estimation of service supply cost (e.g. management + opportunity cost of land) and attribution of this among all the relevant services
River flood regulation[44]	• Avoided damages, health costs and productivity losses	1. **Avoided costs**, the lower of (i) associated with **damage** (e.g. infrastructure, buildings, health, business productivity, based on probability of flood events and estimated effect of ecosystem on their size and frequency) or (ii) **replacement** of the service with infrastructure	• Valuation is heavily dependent on biophysical modelling, although there is a range of tools for this. • Beneficiaries can be far from area providing service • Benefit is highly context specific, as depends on what is in the area at risk, so value cannot be generalised
Coastal flood regulation[45]	• Avoided damages, health costs and productivity losses	1. **Avoided costs**, the lower of (i) associated with **damage** (e.g. infrastructure, buildings, health, business productivity, based on probability of flood events and estimated effect of ecosystem on their size and frequency) or (ii) **replacement**	• Coastal flood regulation has not been well studied as river flooding, and there are relatively few tools for this. • Benefit is highly context specific, as depends on what is in the area at risk, so value cannot be generalised

[41] Based on Harris et al. 2018
[42] Note this is not an alternative to the first, it is ideally part of the primary methods required
[43] Based on La Notte et al. 2018
[44] Based on Crossman et al. 2018.
[45] Based on Crossman et al. 2018. Although this was covered in the WG paper together with river flood regulation, Crossman et al. 2018 point out that these two services should be considered separately.

Service or group of services	Direct Benefits	Valuation methods	Main challenges/notes
		of the service with infrastructure	
Flow regulation relating to water supply[46], namely infiltration and groundwater recharge	• Avoided infrastructure costs associated with water supply • Avoided losses in hydropower generation in low flow season	1. **Avoided costs**, associated with infrastructure to maintain water and electricity yields (such as bigger dams or deeper boreholes).	• Complex physical modelling
Recreation services[47]	• Wellbeing gained from active or passive use of ecosystems •	1. **Hedonic pricing** for estimation of greenspace contribution to property value; 2. **Market values** for tourism; 3. **Simulated exchange methods** for non-market recreational value, based on demand curve estimated using (a) travel cost method, or stated preference methods. 4. **Marginal value pricing** based on multinomial logit travel choice model	• Accounting focuses on the direct use value, which encompasses passive consumption (e.g. of a view) as well as active cultural use (e.g. recreation, religious use) and tourism. • These manifest in different ways– e.g. property value and travel expenses that should all be accounted for (requiring multiple methods) • Recreational value is a function of facilities, tourism services and institutions as well as ecosystem features, so estimations based on expenditure don't isolate the contribution of the ecosystem. Spatial identification is a bit easier. • Simulated exchange valuation requires assumptions about market structure and institutions, but reasonable assumptions can be made that are appropriate to the context • Certain methods rely on large amounts of survey data

4.3 Provisioning services

Provisioning services include living resources harvested from unmanaged terrestrial and aquatic natural systems to highly managed plantations, aquaculture and livestock systems. Values are estimated based on market data on quantities traded, prices and input costs. While the resource stocks themselves may be involved in the generation of multiple services, including regulating and cultural services (Hein et al. 2018, Dvasrkas & Fenichel 2018), the valuation of provisioning services should deal only with estimating the value of the physical flows (e.g. fish) that are harvested for non-recreational, consumptive use (*contra* Dvasrkas & Fenichel 2018). This value will be added to other types of flows in the computation of the asset value of the ecosystem asset of which the resource base forms a part. The calculation of asset values is discussed further in Discussion Paper 5.3

[46] Flow regulation services pertaining to water supply were not explicitly included in the WG papers, but discussion of this and the methods to estimate it are partially included in the WG paper on Water Supply by Portela et al. 2018. The author's (JKT) personal feeling is that it is the ecosystem service is more correctly described as a service that regulates the timing and magnitude of water flows which influence the cost of supplying water. This is different to water supply, which is a combined function of these services AND man-made infrastructure. When water is included in the list of services, then flow regulation pertaining to water supply becomes an intermediate service. The value of the ecosystems in ameliorating the cost of water supply is then lost. It is also erroneous to say that ecosystems provide water (as is often said of forests, for example). They do not.

[47] Based on Barton et al. 2018 covering amenity, recreation and tourism benefits, which are overlapping.

Provisioning services are usually already considered in the production boundary (mechanisms 1 and 2 in Figure 1.1). Hence, the values of provisioning services are usually based on market information. In accounting, deductive residual methods have been more popular than inductive production / cost methods. This is mainly because the second is more intensive in data requirements. The data for valuation of provisioning services comes from market data or surveys, and observed market prices under the existing institutional arrangements. The exact details of the calculation vary. Subsidies are sometimes, but not always subtracted.

The production boundary issue is an important consideration for harvested resources. A focus on the final end product (e.g. timber, crops, fish) will not alter the current SNA estimates. Contributions to the ecosystems to the final output of a specific sector can be deducted from the value added generated by that sector. Both, residual and production/cost function approaches are straightforward to be included in SNA. Valuation becomes more complex in cultivated systems if one has to separate out the ecosystem contribution (Hein et al. 2018 and Dvasrkas & Fenichel 2018). This is potentially a problem for harvested systems with any degree of managed input. The valuation of managed systems is complex in that the entire lifecycle of the resources falls within the accounting system, and it may benefit (a) from inputs from other (usually adjacent) ecosystems, such as nutrient and waste flows into and out of the culture system (these are intermediate services from one ecosystem to another), and (b) from ecological processes or conditions within the culture system (such as provision of suitable growing habitat for crops or fish, or provision of fodder for livestock). The latter is *internal* to the ecosystem (these would be classified as supporting services under the MEA classification) and as they are not final ecosystem services should not be valued. Since agricultural systems are being included as ecosystems, they cannot be treated as intermediate services. For example, if the ecosystem is being used as a rangeland, from which the main products are game or livestock, the fodder is not valued as a final or intermediate service; it is internal to the ecosystem-based production system. This is a managed ecosystem in which indigenous herbivores have been replaced by domestic herbivores, and in which feed is introduced to some degree. Note that through the combination of physical and monetary accounts, the SEEA EEA system should allow analysists to be able to link the productivity of the rangeland system in relation to its condition through spatial and temporal analysis.

There is a proposal that provisioning value might be ***adjusted*** where it is partly attributed to services from other ecosystems, in order to avoid double counting (Hein et al. 2018). For example, where a forest area contributes to pollination of a crop area, the value attributed to pollination (see regulating services) is attributed to the forest asset and subtracted from value of adjacent cultivated area. Somehow these linkages need to be shown, but the full production values from the cultivated asset also need to be shown.

As for the argument regarding ecosystem condition links to ecosystem asset value given above, similar analysis will ultimately reveal the importance of intermediate services. Related to this is the issue of disservices, which are not dealt with in SNA. If the crop area yields a disservice, e.g. downstream sedimentation due to poor tilling practice, then the costs caused by that sedimentation should be attributed to the source area. The issue of disservices and externalities is dealt with in Discussion Paper 5.2.

4.4 Regulating services

Key regulating services reviewed in Working Group 4 included (1) soil retention, (2) air filtration, (3) water purification[48], (5) water flow regulation affecting water supply, (6) river flood amelioration (7) and coastal flood amelioration[49]. The choice of regulating services to be discussed was not comprehensive, but based on the need to have a set of examples to explore conceptual differences between ecosystem assets, services and benefits. Consequently, several well-known regulating services were not included in these papers. Many of the regulating services are already considered in the production boundary through mechanism (1) and (2) in Figure 1.1. That is mostly those that are embedded in the final output produced by the different economic units. However, many of the regulating services are not completely accounted. That is the case of air filtration for human health, where the effects of changes in air quality in human health might not be completely accounted through the medical services sector.

Valuation of regulating services is both conceptually and methodologically more challenging than that of provisioning services. One of the key issues hampering the consistent valuation of regulating services is the lack of consistency and clarity in conceptualisation of these services and their benefits.

Some of the key issues are as follows:

- Unlike provisioning and cultural services, regulating services are often strongly based on processes which not only vary spatially and temporally but which involve physical flows of water, air or organisms in a spatial dimension. This makes for complex physical modelling and value identification.
- There is a lot of confusion and lack of consistency in the literature and working group papers regarding services relating to water supply. Water for consumption is in itself sometimes regarded as a provisioning service, but ecosystems also regulate the flow and quality of water, affecting the cost of its provision. For example, loss of infiltration capacity may lead to lower dry season flows (causing shortages for run-of-river users) and higher high season flows (requiring bigger reservoirs to sustain the same level of water supply). In particular, it should be better understood that water is not produced by ecosystems. The way in which water-related services are treated needs to be carefully addressed in order to correctly attribute values and to avoid double counting.
- The same services may manifest as intermediate services to other ecosystems or final services to people, depending on location (e.g. quality of water entering a reservoir versus an estuary) or spatial scale (e.g. fish nursery value attributed to an estuary or to ocean fisheries). In principle all regulating services may be intermediate services in some situations.
- Flows of regulating services can be difficult to define, because of the difficulty of determining baseline. This is usually a hypothetical construct. For example, studies valuing natural land cover such as forest sometimes opt for a comparison with bare ground or with the next most likely alternative land cover/use, while others have used modelling to remove the capacity for the service.
- Certain regulating services have both passive and active aspects, with the former being linked

[48] The term water quality amelioration is preferred. It conveys the meaning of reducing damages caused by anthropogenic activities, making things better, but not necessarily removing naturally occurring sediments and nutrients.

[49] River and coastal flooding were considered in a single paper on flow regulation relating to extreme events.

to externalities associated with land use change. For example, water quality at the bottom of a catchment area may deteriorate with changes in land use, partly because ecosystem capacity to ameliorate pollution through assimilation (the active service) is compromised, say by wetland loss, and partly because the land use that replaced natural systems uses pollutants as an input (meaning that the former natural vegetation passively contributed to water quality by virtue of not having been converted to the next land use). Furthermore, the passive value, which is often included in the valuation of natural systems because of the comparison with the counterfactual, is effectively the expected negative externality (disservice) of the cropland that is not yet there (see Discussion paper 5.2). Thus, the method being used is potentially overvaluing ecosystems in untransformed landscapes. Rather care should be taken to include disservices (negative externalities over and above the capacity of downstream ecosystems to remove) in the valuation of their source areas, such as croplands.

Cost-based methods are the most commonly used methods to value regulating services. Either the avoided damages, avoided mitigating costs or defensive expenditure, or the replacement cost of the service are estimated. Ideally, the lowest of all of these estimates should be used.

The replacement cost approach tends to be used most frequently because it is easiest to estimate. Replacement cost includes the costs of engineering solutions to reduce risk that would otherwise be mitigated by natural systems, such as flood conveyance infrastructure or coastal flood defence mechanisms However, used in isolation, this method carries the inherent assumption that such solutions are fully demanded. Some studies have worked around this by making logical assumptions about demand based on the socio-economic context. Restoration costs have also been used as means of estimating the replacement costs of services, since it is also fairly easy to estimate. This approach has been criticised, however, since restoration costs may be higher than engineered alternatives. A related approach has been to estimate the “compensation cost” or “offset cost” as an estimate of the cost of replacing the ecosystem. Compensation/offset costs are commonly found in Natural Resource Damage Assessment (NRDA). Use of such values requires careful evaluation in terms of their likelihood of pinpointing the value of the service.

Estimation of damage costs avoided, which includes health costs, infrastructure damages and the like, is usually more complex, and reliant on dose-response functions, fragility curves, etc. However, understanding these costs is fundamental to determining the value of regulating services. These values are also appropriate for communication with policy makers.

Inductive methods have been also used. Most regulating services could potentially be quantified using production or cost functions in which the environmental input is a variable influencing the outputs of costs of some economic activity. However, they are heavy on data requirements to relate relevant ecosystem processes and/or economic outputs to measures of ecosystem extent and condition. Regulating services can be also valued based on observed market transactions for similar services, such as in payments for ecosystem services schemes and emissions trading schemes. However, there will be limits to where this approach can be used, particularly as these values probably seldom reflect true market values due to the institutional arrangements involved or the way in which services are quantified (often using management actions as a proxy).

Regulating services are also valued using stated preference methods. This approach is more challenging, because the link between ecosystems and the benefits that people receives might be more difficult to understand by broader public. Some studies have tried to get around this by spending more time in explaining how the service links to a benefit that is more familiar to the individuals (Polasky and Segerson, 2009)

Valuation of regulating services is highly dependent on the understanding and quantification of the services in physical terms. This requires complex biophysical modelling in order to quantify the risks avoided as a result of the service. These are typically GIS-based models, in which the effects of ecosystem changes on service provision can be estimated, taking spatial variation of relevant driving factors into account. These models vary in their complexity, data requirements and degree of assumption, but have made considerable advances in recent years. In order to quantify and value the ecosystem service, the present situation (e.g. water quality, sedimentation rates, average annual losses from disaster events) is often quantified relative to a hypothetical baseline "no ecosystem service" situation, even where total loss or conversion of an ecosystem may be unlikely. The models can also quantify smaller, more plausible, changes when used for scenario analysis. How changes in value are derived is pertinent to the extrapolation of values over large spatial scales, since marginal values are likely to change in a non-linear fashion, also depending on how passive values are dealt with (Turpie et al. forthcoming). This issue is discussed further in section 5 on value transfer.

4.5 Cultural or amenity services

Cultural services are a difficult group of services to define. They include the active or passive use of ecosystems and their components (e.g. fish stocks) for a range of human pursuits including education, science, recreation, relaxation, exercise, social interaction, cultural activities, religious activities and spiritual fulfilment. In addition, their valuation is challenging since values are often derived from the attributes of ecosystems in conjunction with man-made and human capital. Cultural values are also highly context specific, in that context is likely to be a greater predictor of value than the extent, condition and characteristics of the ecosystem assets themselves.

Although most studies emphasise the recreational component of cultural value (including the working group papers), it should be noted that in reality it is difficult to isolate "recreation" from all of the above-listed motivations for the use of natural and semi-natural outdoor spaces, as these uses are often in combination. The term "cultural services" is considered somewhat misleading (for example among certain social scientists and policy makers), and this group of services might be better labelled as "amenity services[50]", which conveys a sense of "desirable and useful features of ecosystems".

The amenity services provided by ecosystems are partly within the SNA boundary. In the SNA, these values are manifest in a portion of the transactions relating to property markets (including related financial market transactions) and in transactions relating to transport, retail and services relating to recreational activities and tourism. To some degree these can be considered as additive (i.e. not double counting), in that people may either invest in property in order to be closer to ecosystem amenities, or they may travel to use them, or in the case of holiday home owners, they do both. Thus, the amenity

[50] Note this is a broader conceptual understanding of amenity than in the figure in WG paper 10.

values in general may be covered to a large extent by the combination of property price premiums estimated from hedonic pricing methods, and tourism values. A more difficult task is to clearly allocate the benefits of the amenity ecosystem services to the wright beneficiaries in the production boundary. As stated in (UNSD, 2017), the task of the accounts is to measure the benefits to the economic unit more immediately in the value chain. Hence, when an individual visit a place with free entrance, and enjoys the natural landscape, the household is the immediate beneficiary. However, when an individual visit a hotel in a nice nature surrounded location, the amenity value is embedded in the output produced by the services sector. In addition, the individual might use other services and goods during his trip, that are produced by other sectors. Hence, the benefits of the amenity services are usually embedded in many economic units at the same time. So, amenity services might be embedded in mechanisms (1) and (2) in Figure 1.1, but also in mechanism (3). Note that properties and tourism trips may be purchased for any of the reasons listed above, not just for recreation.

While property and tourism-related transactions are already measured in the SNA, the ecosystem contribution to these values still needs to be isolated in the ecosystem accounts. Hedonic pricing methods are used to estimate the contribution of ecosystems to property value. First stage hedonic analysis is compatible with SNA accounting, and the main challenges relate to data needs, definition of the environmental variable, and identification in the econometric analysis. Hedonic studies may underestimate the value of nature, however, as a result of data and computational limitations, especially with regard to scaling up. For example, they seldom capture the additional premium associated with the choice of city as a result of its overall greenness and pleasant commuting, a value that would require multi-city hedonic pricing studies. In the case of tourism value, which is often separately accounted in tourism satellite accounts, this means identifying the contribution of nature-based tourism as an essential first approximation, and then if possible, attributing the contribution of ecosystems to this value. Survey data or spatial data on tourism intensity are two potential means of disentangling tourism values. However, this is conceptually difficult for any point in time, and ultimately it will be more important to examine how changes in ecosystem extent and condition affects tourism value.

Much of the cultural or amenity value of ecosystems lies outside the SNA boundary, and requires estimation using non-market valuation methods. This includes the use of amenities for which entry is free and unrecorded, and/or which is not captured in property markets[51], and also includes non-use values such as the existence or bequest value associated with landscapes and biodiversity. These use and non-use values are mostly estimated using travel cost methods or stated-preference methods such as contingent valuation or choice experiments. The details of these methods vary considerably, and have evolved to deal with a range of situations, such the use of time instead of travel costs where people reach sites on foot. Revealed and stated preference methods are designed to estimate willingness to pay, which not a suitable measure for accounting, since under most institutional context assumptions it would include consumer surplus. However, the outputs of stated preference methods can be used to generate simulated exchange values for use in accounting. This is a critical innovation, which also brings accounting systems one step closer to incorporating welfare values, in that it allows for the inclusion of some intangible benefits. While the estimation of simulated exchange values does

[51] This could be because of an absence of well-functioning property markets, such as in communal areas or informal settlements.

require making assumptions about the institutional context, it is probable that this could be done with a reasonable level of accuracy. From a national accounting perspective, one of the main problems with these methods is that they are highly labour intensive and difficult to apply to sufficient locations to allow reliable extrapolation (see section 5.1.4).

4.6 Discussion

It is clear that the valuation of ecosystem services is primarily hindered by perceptions and definition of ecosystem services themselves. For example, in the SEEA EEA WG4 papers, the authors were not consistent in separating out the regulating functions under discussion from the related bundles of services generated by ecosystems. For example, discussions on sediment retention extended to how the soil underlies all ecosystems and therefore has a bearing on all ecosystem services including cultural services. The discussions on “water supply” also extended to all forms of hydrologically-related services as well as the provisioning aspect of water. Until practitioners develop a common understanding on what is being valued in physical terms, perfecting the methods for valuation will be difficult to achieve. Related to this is deciding on how to avoid double-counting in a consistent way.
As important as defining the ecosystem services to value, is to define the beneficiary. The methods and data availability are going to depend on the values of what to who. For values that are already captured within the SNA, the main issue is finding methods to attribute value to the contribution of ecosystems, which is conceptually challenging to do for a particular point in time. The adaptation of valuation methods for accounting has largely been done based on deductive methods (residual and cost based methods) than has been previously associated with non-market valuation. However, national statistical offices produce many primary data collection, that can be helpful to value many of the relationships within the production boundary.

For values not captured in the SNA, non-market methods have to be applied. Since these have mostly been developed to estimate willingness to pay for use in economic and policy decision making, additional steps are required to derive estimates of exchange value. However, these steps are not onerous (see section 3). Ideally, the choice of methods should be inductive (i.e. based on econometric analysis) rather than deductive (as far as possible), should generate exchange values based on supply and demand, should be able to pinpoint the service value in question, and should be designed in such a way that they can be extrapolated to the scales required for accounting. Cost considerations may also be a factor, but are not generalisable up front due to vast differences in data availability and accounting budgets for different countries.

4.7 Conclusions - key messages of this section

- Practitioners need a common understanding on what is being valued in physical terms.
- In the case of regulating services, the biophysical modelling is the main challenge for monetary valuation, not the marginal pricing itself.
- Clear guidelines are required on how to avoid double-counting in a consistent way.
- Methods should be inductive (i.e. based on econometric analysis) rather than deductive (as far as possible). This is a challenge since traditional accounting and economic assessment methods (e.g. residual approach, optimisation, input-output) tend to be deductive.

- There is large potential to use inductive methods to disentangle marginal values from ecosystem services to beneficiaries that are already in the production boundary using data currently produced by the national statistical offices (e.g. agricultural survey, industrial survey, etc.).
- Inductive non-market valuation methods estimate a demand curve that show marginal values. There is a challenge to mix this demand function with a relevant supply function, and apply 'simulated exchange values'.
- Extrapolation by benefits transfer will be an inherent and major part of ecosystem accounting. Methods should therefore be designed in such a way that they can be extrapolated to the scales required for accounting.

SECTION 5. Value transfer in ecosystem accounting

The intent of this section is discuss the options available to extrapolate and scale value estimates from a limited number of study sites to an accounting area. The section is aimed at raising awareness about the conditions in which value transfer can be expected to provide information that is sufficiently accurate and reliable for the purposes of ecosystem accounting.

5.1 The value transfer challenge in ecosystem accounting

Benefit transfers are used when time, funding, data or other constraints preclude the use of primary research to provide site-specific economic information (Johnston et al., 2018). While constraints such as these are ubiquitous within large-scale management and policy evaluation, they are standard practice in national accounting, because valuation is based on samples from a national population. "Value transfer" is used more generally to refer also to extrapolation and interpolation of cost estimates outside their original context.

Challenges facing accounting for ecosystem services are in theory no different from those facing the transfer of any other economic value such as exchange prices. However, the combination of (i) a policy demand for estimation and mapping ecosystem services over large scopes and scales, (ii) spatial heterogeneity in ecosystems and institutional use regimes, and (iii) a tendency to report average values per unit area rather than per household, all lead to a unique set of challenges for spatially distributed benefit transfer, and *ipso facto* for ecosystem accounting.

> *"Many abuses of benefit transfer methods have occurred within the ecosystem services literature, often in an attempt to estimate the value of entire ecosystems at planetary or biome-wide scale [..]. Economists have criticized the conceptual basis for these transfer exercises, particularly the confusion between marginal and total value estimates and the inappropriate scaling of unit-value estimates [..] (p.208, Johnston et al. 2018)"*

Since the 1980s and 1990s, benefit transfer methods using stated and revealed preferences have evolved to better handle site and welfare heterogeneity (Johnston et al., 2015). However, there are still few applications involving the transfer of results from revealed preference methods such as hedonic pricing (Lewis and Landry, 2017). While national accounting follows a (revealed) transaction value convention to pricing changes in assets, most of the findings from benefit transfer research are based on testing of stated preference methods. Findings are nevertheless relevant because:

(i) changes in consumer surplus and changes exchange value offer similar approximations to incremental changes in demand under certain conditions[52] ;

(ii) much of the benefit transfer error for ecosystem services is due to spatial transformations of marginal household values which would occur independent of the type of monetary valuation method.

[52] they are most similar for linear demand curves (Fenichel, 2018)

5.2 Valuation reliability and precision needed for ecosystem accounting

Primary valuation studies are sometimes (not always) designed to address specific policy purposes. In these studies there is accuracy and reliability 'designed' for the study's purpose and methods. Such studies are then possibly used for the secondary purposes of value transfer in accounting. The reliability in the value transfer purpose of ecosystem accounting is determined by the primary studies. When values are transferred to a (national) accounting area they may in effect be "validated" by the accounting authority. Accounting values may then be transferred back from specific map pixels to assess local level projects, without reflection on the origin of the estimates and their repeated spatial transformations. Moving forward with monetary valuation of ecosystem services supply and use accounts it is therefore important that the specific purpose of the valuation is clear, and "health warnings" provided on secondary (or even tertiary) transfers of values from ecosystem accounts.

Part of the benefit transfer literature has been dedicated to testing the accuracy and reliability over time and space required of valuation estimates for the purpose of determining policy priorities (Barton, 2007). Whether we observe a significant difference between an estimate from an onsite study and a transfer/scaling to other basic accounting units, depends also on the precision of valuation estimates (error bars). Accuracy in this accounting context is relevant in terms of the absolute transfer error, measured as the difference between a transferred value and a benchmark value estimated on-site. Of course, the value estimate should be accurate in accounting compatibility terms of capturing exchange value. Reliability in an accounting context refers to whether transfer errors are predictable and consistent over time and space.

These are mainly considerations in the academic benefit transfer literature. In policy practice, whether a value transfer error is acceptable requires some consideration of the purposes of valuation for ecosystem accounting for policy-makers and planners (henceforth "stakeholders"). Purposes of valuation specifically for accounting can be summarised as follows:

- **Trend & benchmarking**. Stakeholders may have a non-declining ecosystem asset value policy objective. Policy-makers may want to know if there is a significant change in the physical extent and condition of ecosystem asset in particular locations and in aggregate; if there is a significant change in the physical supply and use of ecosystem services, and how these changes are reflected as a change in 'asset value' from a change in the monetary value of discounted flows of benefits. For this purpose it is not necessary to know the absolute value of the asset, only to have valuation that can identify significant change between accounting periods.
- **Comparison**. Stakeholders may wish to compare the trends in different local accounting areas for differences, perhaps due to local differences in land use regimes. Again, valuation methods must be sensitive to change in ecosystem extent and condition, but are not required to determine the total ecosystem asset value.

There are also a number of policy purposes using economic valuation estimates that may be found in accounts, e.g.

- **Spatial planning**. Stakeholders may want to compare current value of ecosystem services between areas, in order to carry out zoning or spatial targeting of policies
- **Justification of budgets** may be based on capital values, e.g. determining the asset value of urban green spaces.

These are examples demanding absolute asset values rather than change, demanding which presents a challenge. The reliability and precision requirements for valuation for accounting lie somewhere between requirements of valuation for awareness-raising and those of valuation for priority-setting, instrument design and litigation (Figure 5.1; Barton, 2016).

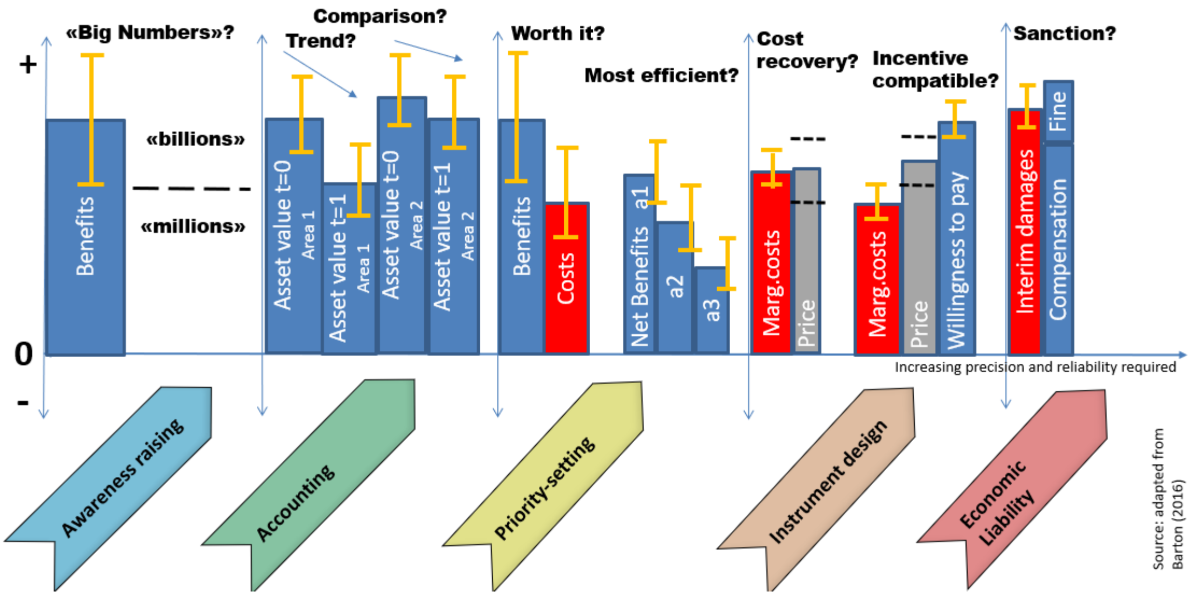


Figure 5.1 Decision support contexts of monetary valuation and conceptual differences in the requirements for precision and reliability. Source: adapted from Barton, 2016.

The least stringent requirements are for valuation for 'awareness raising', which aims to document large absolute values of ecosystem assets (Barton et al., 2015). The accuracy requirement is in an order of magnitude - "millions or billions?" This is superficially what many may see as the purpose of ecosystem accounting. However, the benefit transfer literature has been critical of this purpose for monetary valuation (Johnston et al., 2018). In some cases the motive is to compare ecosystem asset values with those of man-made or financial capital. This purpose is in many cases doomed to disappointment for the "big numbers" proponents because the marginal ecosystem service value is determined using methods based on residual value attribution to ecosystems, or implicit value revealed as a coefficient of market exchanges that are co-determined by a host of other non-ecosystem variables.

In benefit-cost analysis for project screening purposes, projects need to pass the test of "is it worth it?"[53] - are discounted benefit flows greater than discounted costs? For priority-setting – "what is more efficient?" – valuation methods need to be accurate enough to be able to rank alternative policies/projects. The absolute value of the changes in ecosystem service supply and use due to the projects/policies is required. Note that this is the absolute value of the change induced by the policy, not the absolute value of the ecosystem asset itself.

For policy instrument design, there may be several pricing and incentive design principles in play. For example, in estimating a municipal fee for ecosystem services utilities, fees should recover costs of utility delivery only. Some marginal of cost recovery error may be permitted on an annual basis and

[53] Net present value NPV>0 criterion

refunded to households. In another example, payments for ecosystem services (PES) valuation needs to be accurate enough to distinguish marginal willingness-to-pay from marginal cost of supply in order to determine a financially feasible payment level.

For economic liability and compensation, valuation methods need to stand up in court. The degree of accuracy may be smaller or greater than for instrument design, depending on the legal case. The accuracy needs to be sufficient for a court to calculate economic compensation for interim damages. The court needs to set a compensation amount that, with confidence, is not confounded with any additional fine the court imposes on the responsible party.

Accuracy of valuation may be less of a concern in evaluating trends in asset value, than in cost-benefit analysis where priorities must be ranked. The size of transfer errors determines the probability that an observed trend is significantly different from zero. More importantly, for evaluating changes in asset value it would be a desirable property of valuation that transfer error was constant between accounting periods. In other words, when assessing changes in ecosystem asset values, accuracy (low absolute error) may be less of a concern than reliability (consistent error).

5.3 Types of spatial value transfer

Benefit transfer can involve transfer of estimates (i) from a single study site to a single policy site (one-to-one), (ii) from a few study sites extrapolated to a policy area (few-to-many), or (iii) from one accounting area to another (many-to-many) (Fig.5.2).

The first type (i) is common in the literature testing benefit transfer reliability, where unit value and benefit function transfers have been tested between *as similar sites as possible*. Per person or per household unit values for single services are transferred, often adjusted for differences in purchasing power parity if transfers are international. For single ecosystem services, benefit function transfer can make further adjustments for differences in the scope of change, site and household characteristics.
Johnston et al. find that there is insufficient weight of evidence to identify specific conditions under which the benefit function transfer enhances validity and reliability (Johnston et al., 2015). Unit value transfers outperform function transfers in some instances. Unit value transfers may be defensible under some policy analysis conditions where it is the only option, and socio-economic and population are similar.

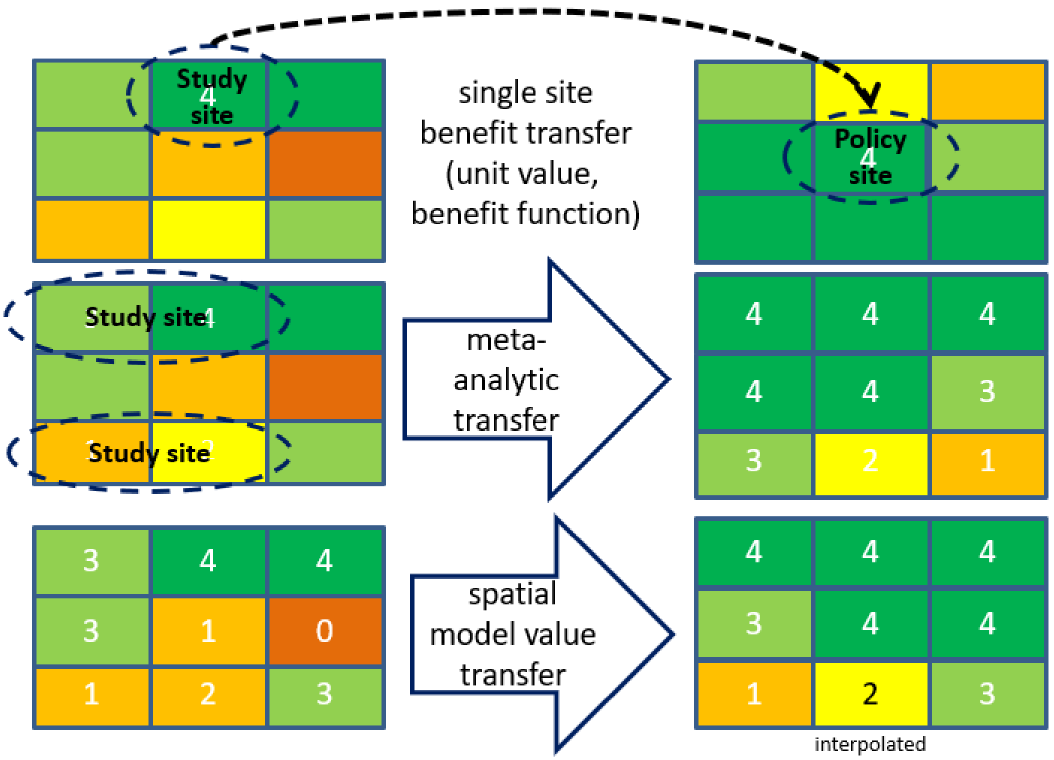


Figure 5.2 From single site benefit transfer to accounting area 'spatial value transfer'

The second (ii) is common for policy analysis situations where one or few primary study sites incorporating some variation in local conditions are extrapolated to a larger policy area. This is done using meta-regression-models from meta-analysis. Studies in a meta-analysis will cover some, but often not all the socio-demographic and ecological variation in the policy area to which it is being applied. Applying meta-regression-models outside their input range can result in large transfer errors (see Box 1 below).

The third type (iii), where some spatial valuation model is available covering all the variation found in the accounting area, is the ideal approach for ecosystem accounting. This can be used for ecosystem service mapping where ecosystem services are estimated based on biophysical, population and socio-economic characteristics of each basic spatial unit. Spatial interpolation is often used if the transfer site has some biophysical and socio-economic characteristics not observed in the area where the valuation model originates, but are within the data range. Transfer of per unit hectare ecosystem values is problematic because they constitute a bundle of ecosystem services which cannot be adjusted for differences in site characteristics (because each component ecosystem services depends on different characteristics).

Furthermore, the spatial configuration of the landscape can be important for the availability of substitutes, especially in recreation, but also for directional regulating services. There are few economic valuation methods that account for substitution patterns of ecosystem services across a landscape. Again this can lead to transfer errors for monetary valuation, even where ecosystem service models are judged to be reliable.

How big are transfer errors acceptable for policy analysis? As discussed above, there is no benchmark for the acceptability of transfer errors – it depends on the point of comparison and the decision-support purpose. Useful benchmarks are (i) the uncertainty on the estimated cost of measures, and (ii) the expected magnitude of the biophysical effect of the policy. Johnston et al. (2017) refer to errors of 10-20% in stated preference studies of water quality improvement (between a study site and a policy site). They note that water quality improvements expected by policy measures under the Clean Water Act can be less than 1%. In such cases valuation methods are not accurate enough to identify relevant change in ecosystem condition. Literature testing benefit transfer uncovers transfer from a few percent mean absolute percentage errors to two orders of magnitude (Rosenberger and Stanley, 2006) (Brander et al., 2010). There is a need for updated synthesis of benefit transfer errors to reflect the growth in available valuation studies during the past decade.

What are acceptable errors in the imputation of accounting prices? It may not be possible to document this across large accounting errors. A benchmark for acceptable accounting error could be the revision range of business statistics (3-5%?, this would need a reference). Can revision ranges of GDP be a benchmark for absolute error tolerance of benefit transfers in accounting? GDP revisions can be quite large (e.g. Ghana 60%, China 15%, Netherlands 7%). It may be argued that the magnitude of GDP revisions is not a relevant benchmark for the acceptability of benefit transfer error in accounting. Such revisions will in general be *improvements* because earlier estimates have been based on insufficient data. There is an important difference between a percentage GDP revision due to better data and a percentage of error in value transfers which will probably never be revised.

Further work is needed on benchmarking acceptable extrapolation error of monetary valuation, in order to screen the reliability of available monetary valuation studies. The size of transfer errors determines the probability that an observed annual change in monetary value of ecosystem services is significantly different from zero. We also note that tests of statistically significant difference used in the benefit transfer literature are quite strict. The confidence bounds required in policy decisions can be expected to be more accepting of transfers of monetary valuation studies.

In the rest of this section we address four types of benefit transfer errors relevant for ecosystem accounting, relating to commodity consistency, scope, time and scaling.

5.4 Transfer errors due to commodity inconsistency

According to micro economic theory, the value of intermediate services can only be identified if one can determine the value of the associated final services (Johnston et al., 2015). For regulating services, the final beneficiaries may be in multiple different locations, with willingness-to-pay conditioned by location characteristics. Benefit transfer of the value of intermediate services, implicitly transfers the value of distinct final services. The values transferred are only indirectly associated with the final service. This is called a violation of “commodity consistency” in the benefit transfer literature.

There are also potential violations of 'commodity consistency' in meta-analytic transfers when pooling value estimates from many different primary studies. This is most serious where studies pool ecosystem service values from many distinct services and non-comparable value measures (Johnston et al., 2015) (e.g. pooling producer and consumer surplus and exchange value approaches). Caution must be used with meta-regression-models to only specify (activate) subsets of methods in regression pertaining to accounting compatible values. See an example of such a meta-regression-model where it is possible to control for the types of methods predicting the meta-analytic value to be transferred (Table 1)(Brander et al., 2010).

Table 5.1 – example of a meta-regression-model for wetlands (Brander et al. 2013)

	Variable	Coefficient	p-value
	(constant)	−3.078	0.187
Study variables	Contingent valuation methods	0.065	0.919
	Hedonic pricing	−3.286***	0.006
	Travel cost method	−0.974	0.112
	Replacement cost	−0.766	0.212
	Net factor income	−0.215	0.706
	Production function	−0.443	0.523
	Market prices	−0.521	0.317
	Opportunity cost	−1.889**	0.035
	Choice experiment	0.452	0.635
	Marginal	1.195***	0.008
Wetland variables	Inland marshes	0.114	0.830
	Peatbogs	−1.356**	0.014
	Salt marshes	0.143	0.778
	Intertidal mudflats	0.110	0.821
	Wetland size	−0.297***	0.000
	Flood control and storm buffering	1.102**	0.017
	Surface and groundwater supply	0.009	0.984
	Water quality improvement	0.893*	0.064
	Commercial fishing and hunting	−0.040	0.915
	Recreational hunting	−1.289***	0.004
	Recreational fishing	−0.288	0.497
	Harvesting of natural materials	−0.554	0.165
	Fuel wood	−1.409**	0.029
	Non-consumptive recreation	0.340	0.420
	Amenity and aesthetics	0.752	0.136
	Biodiversity	0.917*	0.053
Context variables	GDP per capita	0.468***	0.001
	Population in 50km radius	0.579***	0.000
	Wetland area in 50km radius	−0.023	0.583

OLS results. $R^2 = 0.49$; *Adj.* $R^2 = 0.43$. Significance is indicated with ***, **, and * for 1, 5, and 10% statistical significance levels respectively.

5.5 Transfer errors due to spatial scale and heterogeneity

Relatively little is known in the benefit transfer literature about the extent to which spatial patterns estimated in one site may be scaled up to spatial patterns observed for a wider policy analysis area. The challenge faced is almost identical to the scaling problems for national ecosystem accountants, although areas may be larger in the former. At the extreme values may be scaled to biomes at global level:

> *"Many abuses of benefit transfer methods have occurred within the ecosystem services literature, often in an attempt to estimate the value of entire ecosystems at planetary or biome-wide scale (e.g. Costanza et al. 1997; De Groot et al. 2012). Economists have criticized the conceptual basis for these transfer exercises, particularly the confusion between marginal and total value estimates and the inappropriate scaling of unit-value estimates (e.g. Bockstael et al. 2000; Brander et al. 2012, Johnston and Wainger, 2015, Turner et al. 1998." (p.208, Johnston et al. 2018)".*

Common approaches in applied benefit transfer include simple transfer of average per household value estimates for a particular location, aggregated over a market extent, and assumed to be valid within a political boundary. The problem with this type of scaling is the lack of adjustment for:

- the **distance of households** from the changes in ecosystems to be valued, and the distance decay in willingness to pay for a service;

- **spatial scale** of the ecosystem service area which is determined by the distance beyond which households cease to have information and/or care about changes in the condition of a location. The scale will typically not confirm to political boundaries if there is mobility across them;
- the availability of **substitutes and complements,** which is determined by distance decay and the spatial scale service area.

Figure 5.3 visualises how land use in an accounting area changes over several accounting periods. The relative scarcity of the different ecosystem assets changes, even though the marginal change in each ecosystem type within the area is constant, as portrayed in the figure. As land use changes the spatial configuration of substitute and complement ecosystem assets also changes; with it we would expect the marginal value of each ecosystem asset to change between accounting periods. Average values per spatial unit determined in t=0 would not be accurate for t=4.

We would expect the values of the ecosystem assets to change in such a scenario because of theoretical expectations of scope, scale and distance sensitivity of valuation of ecosystem services as discussed above:

- Downward sloping demand per household
- Distance decay of willingness to pay (due to both travel cost and less information)
- Reduced demand for a specific site with increase in substitute sites

Figure 5.3 Spatial patterns of ecosystem change challenge benefit transfer. Assume that Ecosystem Type ET2 represents urban, ET3 cultivated ecosystems, ET4 unmanaged forest, ET1 rangeland. Each ET has a different population density and spatially specific access of the population to ecosystem assets within the accounting area. Source: adapted from (UN, 2017)

Value transfer reliability in the presence of spatial scaling challenges could be improved by (i) limiting the selection of source studies to those with similar scales, or (ii) using meta-analytic methods directly accounting for scale.

5.6 Transfer errors due to the scope of ecosystem change and "adding up"

Scope tests in BT refer to whether WTP is sensitive to the *magnitude of change in the level of provision of the ecosystem service*. A challenge in benefit transfer for accounting is the aggregation or scaling over different scopes of change than in the original studies. Some benefit transfer studies are nevertheless conducted with the implicit assumption that marginal values can be averaged or transferred without scope differences (Johnston et al., 2015). Linear in variables valuation functions don't capture patterns of diminishing returns. Micro-economic theory expects diminishing marginal utility of returns, or conversely increasing marginal utility with scarcity, depending on the direction of annual change.

In practice, there is often a divergence between empirical studies' definitions and scope of changes and what is relevant for policy. A publication bias in academic studies has meant that we find mostly values of large changes considered over small geographical areas (Johnston et al., 2015). For large scale policies and ecosystem accounts, primary valuation studies addressing small annual changes over large areas are required.

The challenge for scaling transfers to an accounting area is the spatial variation in the scope of change in ecosystem services across the whole area. Attributes and levels of ecosystem condition may not match well between study and target sites:

> *"Welfare estimates are only well defined for quantified marginal changes in commodity from a known baseline, and it is often unclear how per unit area values relate to underlying marginal changes". (p.211, Johnston et al. 2018).*

In order for valuation estimates to be sensitive to scope of change, and for it to be possible to adjust for diminishing marginal utility of returns, valuation studies must measure changes in physical supply of ecosystem services. A problem in the benefit transfer testing literature has been that changes in environmental quality have been defined in terms that are ambiguous, subjective, or unmeasurable outsides the benefit transfer study (Robert J. Johnston et al., 2018).

Most benefit transfers lack a structural micro-level theoretical foundation that imposes consistency on the use of prior information (Johnston et al., 2015). This is also the case of reduced form meta-analysis models. They can accommodate scope sensitivity and diminishing marginal returns, but they are not consistent with second-order properties of "adding up" (Kling and Phaneuf, 2018). The "adding up" condition tests whether the sum of the estimated willingness to pay (WTP) for each individual part of the package, evaluated incrementally, equals the estimated WTP for the entire bundle—as implied by standard utility theory. The test has failed when valuing stated preferences for annual increments in water quality (Desvousges et al., 2017).

In accounting this amounts to problems with double counting. Failure to comply with the adding-up condition renders benefit function transfer unsuitable for both accounting and policy analysis (Robert J. Johnston et al., 2018).

5.7 Temporal transfer error

There is consensus that value transfer reliability declines over time. Values are only stable over a period of a few years(Johnston et al., 2015). For ecosystem accounting this implies that while accounting prices for ecosystem services do not need to be updated every year, periodic corrections are required. Corrections are needed more frequently in situations where the extent and condition of the ecosystem - and the relative supply of ecosystem services - are also changing rapidly.

5.8 Towards a tool for value transfer in ecosystem accounting ? - meta-regression-models

Meta-analysis identifies location and methodological characteristics of a large number of valuation studies. Meta-regression-models are used to find systematic variation in location, population characteristics and study design that explain variation in values (often stated willingness-to-pay) across study sites. Johnston et al. 2018 report that meta-analytic transfers have found significant effects of geospatial scale on value.

Meta-analytic transfers have used variables that adjust for spatial scale effects in a number of ways (Johnston et al., 2018):

- Type of geopolitical area addressed
- Whether changes affect single or multiple areas
- Relative size categories of areas such as (large, medium, small)
- Measures of site area, e.g.
    - Value per day of recreation
    - Value per hectare for ecosystem service provision
    - Value per kilometre of river for fishing

Can meta-regression models be used for valuation of ecosystem services supply and use in accounting? Because WTP for most ecosystem services decays spatially with distance and is determined by population characteristics such as income, the per hectare value of nearly all ecosystems depends on the size and characteristics of the surrounding population (Turpie et al. 2017). Per unit area meta-analyses struggle to cover the range of population densities and socio-economic conditions that determine per unit area WTP. Johnston et al. (2018) recommends that unit area values should not be scaled without accommodating micro-economic factors such as (i) diminishing marginal utility and (ii) availability of substitute sites, and ecosystem function factors such as (iii) thresholds and (iv) connectivity (Johnston et al., 2018). From a theoretical point of view, meta-regression models in a reduced form that is amenable to value transfer and scaling assume that all studies are nested in a 'mother distribution' - a single demand function - across individual place-based valuation studies. Such an assumption is vulnerable to violation of micro-economic assumptions of each individual study.

The transfer of unit area biophysical estimates of ecosystem service supply is less prone to transfer errors due to these micro-economic considerations. Separate spatial scaling/transfer of physical and monetary values is recommended. Policymakers will be very much interested in good biophysical accounts. This should not be seen as a second best option ("in cases where monetary valuation is not defensible"), but at the very core of ecosystem accounting.

Despite systematic value transfer errors, meta-regression-models are becoming increasingly popular as they provide a transparent approach to systematic use of available valuation estimates, in a form that is amenable to spatial modelling. For example, meta-analyses of wetland valuation studies (Ghermandi et al., 2007) and urban open space (Brander and Koetse, 2011) have reconciled values from different studies in terms of willingness-to-pay per hectare of the ecosystem.

5.9 Example – meta-regression model applied to valuation of urban open space

In this example we tested (Barton et al., 2015) the meta-regression function for willingness-to-pay for urban open space developed by Brander et al. (2011)(Brander and Koetse, 2011). While the model is based on stated preference studies, it provides some experiences that are generally relevant for using meta-regression models to scale values to an accounting area.

Table 5.3 adapted from Brander et al. 2011 shows the independent variables, and marked in red the variables we considered to estimate the willingness-to-pay for recreation in urban open spaces in Oslo. The dependent variable is the log of US$ per hectare per year.

Table 5.3 Example of a meta-regression-model used for value transfer (adapted from Brander et al.2011)

Variable category	Variable	Coefficient	Standard error
	Constant	7.35***	1.13
Land use	Parks and green space	2.25**	0.85
	Agricultural and undeveloped land	1.75	1.07
Services	Recreation	1.44*	0.81
	Preservation	0.82	0.76
	Aesthetic	0.90	0.60
Area	Area (ln)	−0.80***	0.06
Payment vehicle	Entry charge	−0.76	0.81
	Tax	−1.52***	0.56
	Donation	−2.02*	0.83
Elicitation format	Dichotomous choice	−1.42**	0.56
	Payment card	−0.83**	0.44
Socio-economic	GDP per capita (ln)	0.30	0.60
	Population density (ln)	0.49***	0.11
Level 1 (estimate) variance		0.49***	0.10
Level 2 (regional) variance		1.53***	0.43
N		73	
−2 × loglikelihood		191.9	
Pseudo R^2		0.44	

Dependent variable: 2003 US$ per hectare per year (ln).
***, **, * = statistically significant at 1%, 5%, and 10%, respectively.

Population density (per km)	Area (hectare) 0.2	2	10	100	1000	5000	10000	50000
20	7,833,430	1,241,515	342,591	54,297	8,605	2,375	1,364	376
500	37,926,484	6,010,943	1,658,695	262,885	41,665	11,497	6,603	1,822
1500	64,972,863	10,297,505	2,841,555	450,356	71,377	19,696	11,312	3,122
2500	83,452,219	13,226,285	3,649,740	578,445	91,677	25,298	14,530	4,009
6500	133,283,022	21,123,935	5,829,064	923,844	146,419	40,404	23,206	6,404
		Values in table: WTP (US$/ha yr.)						

Figure 5.4 Meta-regression-model predictions of WTP for recreation per ha of urban open space

We noted that the study transformed household WTP values in the original studies into US$/ha of open space by making assumptions about the spatial extent of the population that has positive WTP – the service areas - in each of the original studies. This determined the population density variable in each study in their meta-analysis. To use the Brander et al. model we have to make an assumption about the "service areas" for greenspaces of different sizes in our accounting area. The population density and spatial configuration of "green areas" in the Oslo accounting area (Figure 5.4) is obviously not the same as in the original studies. For a consistent use of the MRM we should use the same definitions of service area as in the original studies.

Another discussion point is that the range in population density was smaller, and sizes of urban open spaces larger in the original studies, than for most of the urban open spaces to be valued in Oslo. The model has no observations of urban spaces <2ha, while there are many of these in Oslo. Population density in Oslo is in places higher than the highest values in the primary studies used in the Brander model. The data range of the model is shown by the dotted line in Figure 5.4. At the limit of this data range the functional form predicts extremely high per hectare willingness-to-pay per hectare. In summary, the model could be used to mathematically predict per hectare values of open space, but should probably not be used at or near the range limit of the observations of ecosystem size and population density in the original data. Also, the lack of information on how WTP/household was scaled to WTP/area in the original data makes its application to new study/accounting areas somewhat of a "black box" exercise. Because the accounting area is small it is possible to do some checks of "reasonableness" regarding per area values relative to e.g. real estate values in the same area. Such local ground truthing is a much bigger challenge for a value transfer to a national accounting area, such checks may not be feasible. The meta-regression model also indicates that there is a difference in willingness to pay for open urban space depending on whether an entry charge, tax, or donation is the payment mechanism articulating values. The payment mechanisms are determined by the property and use rights in the original studies, which may not be the same as for the accounting area. Even at the aggregate and simplified level of the meta-regression-model, value transfer has to adjust for institutional differences between the original studies and the counting area.

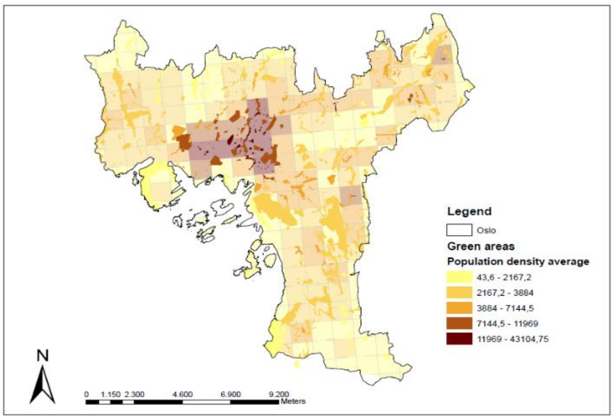


Figure 5.4 Distribution of open spaces (polygons) and population density (grid) in the Oslo urban area

5.8 Conclusions - key messages of this section

Ecosystem accounting can learn from benefit transfer research

Transferring available value estimates from a few study sites to the appraisal of policies covering large geographical areas – also known as benefits transfer - faces challenges related to generalisation and spatial scaling of micro-level valuation. These are also valuation challenges familiar to national accounting. Valuation guidelines for ecosystem accounting can therefore take great advantage of 20 years of research findings from benefit transfer testing for policy analysis[1].

Valuation methods that are sensitive to population characteristics and biophysical change in ecosystem extent and condition more easily scale to an accounting area.

The primary valuation literature available for transfer has generally specified ecosystem services in ways that are difficult to link to monitored biophysical changes in ecosystem extent and condition. The valuation basis is too thin for many ecosystems to offer the variation needed to scale to national accounts. Valuation methods that can link to a wider range of changes in ecosystem condition and differences in population are easier to extrapolate across sites of different condition, and by extension to transfer or scale to a larger accounting area.

Scaling up of biophysical ecosystem functions from research sites to whole ecosystem assets constitutes a potential source of significant error for monetary valuation of ecosystem service flow.

Value transfer errors are potentially large compared to errors in GDP estimates

Quantification of benefit transfer errors shows that they can be so large as to mask normal annual changes in rates of annual GDP growth, and can be an order of magnitude larger than corrections typically observed for GDP prediction.

Transformation of per household or per person marginal values to per ecosystem unit area values is potentially subject to large aggregate transfer error

Meta-regression-models computed across studies from a range of locations are a promising approach to tackle a wider range of ecosystem change across an accounting area. However, meta-regression-models are prone to spatial transformation errors when converting per household or per individual value estimates to per ecosystem unit area values.

Scaling individual/household willingness-to-pay and implicit prices to values per spatial unit of ecosystem are subject to unit value transformation errors when scaled beyond marginal changes, potentially resulting in large aggregate transfer errors. Unit value scaling errors are due to the spatial configuration of the population benefiting from the ecosystem asset and the spatial variation of their preferences.

Economic values are conditional on ecosystem specific governance regimes

Governance regimes of ecosystems specify rights of access, use and rights to environmental quality. These rights condition people's willingness to pay/accept compensation for changes in ecosystem extent and condition. Well-functioning governance regimes are adapted to local ecosystem conditions, resulting in location specific validity of valuation methods, and of marginal values of ecosystem change. Scaling of monetary values in an accounting should aim to be sensitive to these local variations in institutions.

Benefit transfer is not valid for large changes in ecosystem assets that result in non-marginal changes in ecosystem service flow.

An important purpose of monetary accounts is to value *change in* ecosystem service flows and *change in* capitalized ecosystem asset value. For accounts we are required to value ecosystem service flows and ecosystem assets at each point in time, and then compare these to estimate changes over time - what do our models have to incorporate in order to get this right? They have to be sensitive to extent and condition over a broad range. The recognition of the 'safe operating space' of available non-market valuation methods to small changes in ecosystem service supply, has implications for compiling monetary ecosystem asset accounts (see further discussion in DP5.2). For ecosystems where the economic programme is leading to rapid loss of ecosystem extent and condition, projection of marginal values per unit area of ecosystem based on micro-economic valuation methods is (highly) questionable. By extension, benefit transfer of total economic value of assets is not defensible from a micro-economic theory point of view.

Validation of scaled and aggregated monetary values of ecosystem services is often lacking

Monetary use and asset accounts at aggregate accounting level cannot (easily/currently) be validated by ground truthing. 'Common sense' or 'intuition' of micro-level, local outcomes are difficult to apply to higher levels of aggregation, especially when there is no prior experience, cases, or benchmarks values for comparison at aggregate level.

Municipal ecosystem accounting is a necessary step on the way to national ecosystem accounting

An assessment against some benchmarks needs to be carried out at lower spatial scales, where aggregate values can be assessed against known local conditions (e.g. transferred WTP relative to household income). This means that greater attention should be paid to ecosystem accounting at municipal level as a necessary step toward national ecosystem accounting.

Estimate marginal value locally, scale locally, then aggregate

Monetary valuation of non-market ecosystem services use partial equilibrium, micro-economic valuation methods. The valuation outputs from these methods are only transferable to changes in ecosystem extent and condition elsewhere at similar scales.

Because of spatial heterogeneity in ecosystem services, preferences and management institutions, marginal values/accounting prices should be calibrated for local conditions, scaled to local supply and use levels, before being aggregated to the accounting area (Addicot and Fenichel, n.d.).

Specific Guidelines for spatial scaling of monetary valuation estimates to accounting areas needed

Estimating transferable and spatially explicit value functions should become the primary objective for valuation in ecosystem accounting, in order to be politically relevant(Schaafsma, 2015). While research is ongoing best practice guidelines should specify the extent to which certain types of values can and cannot be scaled (and how)(Johnston et al., 2015). In cases where monetary valuation is not defensible guidance should be offered on using biophysical supply-use accounting as the basis for evaluating trends and links to national policy.

SECTION 6. Unresolved and emerging issues

A number of issues emerged during the writing of previous sections, or gave rise to questions and discussions between the co-authors which had no immediate resolution. This section collects these issues as place holders for further work needed on valuation in the SEEA EEA revision.

6.1 Changes or levels - what are the purposes of accounting?

Although there is consensus that variations are important, there is no consensus about the importance of level values in national accounting, and by extension in ecosystem accounting. For arguments supporting the idea that both, variations and levels, are important, see section 3. For arguments supporting that only variations are relevant see discussion paper 5.3. In a nutshell, the argument in favour of using also levels (not only levels!) is that they provide a measure of the relative importance of a sector in an economy, and that they can also be used to provide a measure of the relative importance of ecosystems services in an economy. The arguments against are, among others, that (i) not all goods are valued at marginal prices in an economy, much less for the environment (ii) that summing up demand functions in absolute values vertically is more problematic than summing them up horizontally, because the law of one price does not apply, (iii) that uncertainty in absolute values in physical supply and use tables, and uncertainty in the absolute value of simulated prices is not estimated (through analysis of variance or sensitivity analysis of assumptions). This implies that level values of ecosystem service flows to the economy are difficult to compare with each other and with absolute values of economic sectors.

Further secondary purposes of ecosystem accounting are illustrated in Figure 6.2.

6.2 Prices and values - do environmental economists and accountants understand them the same way?

(Environmental) economic researchers and national accountants often employ "prices" and "values", and "marginal", differently. The SNA would seem to assume that all marginal prices (P) are also average prices. This assumes that value (PxQ) is linear in quantity (Q). This solves problems associated with adding up values obtained from different methods and markets. However, this is a simplifying assumption in SNA that leads to misunderstanding with the economic research community. Prices researchers consider to be marginal and relevant only for marginal changes in Q, are applied to non-marginal changes by accountants. The use of price estimates outside their credible range is discussed in detail in Section 5.

Is this merely a communication issue? Is the extrapolation of marginal valuation estimates to non-marginal changes in physical ecosystem services a convention that limits the policy usefulness of monetary supply-use accounts?

6.3 Plural values – is ecosystem accounting a plural valuation approach?

Ecosystem accounts capture a (limited) portion of plural values as discussed in Section 2. However, the system of ecosystem accounts, when considered together, captures a number of dimensions of values. In this framing of ecosystem accounts, the information can be used for a number of purposes 'beyond GDP'. We suspect that the knowledge that ecosystem accounting is not only monetary is poorly communicated outside the SEEA EEA community (e.g. IPBES). Communicating the multiple purposes of ecosystem accounts to other valuation communities, including the fact that "accounts" are used by ecosystem accountants to mean both biophysical and monetary indicators, requires further effort.

The relative theoretically expected magnitude of different value metrics in national and ecosystem accounts could be illustrated in a version of Figure 6.1. below. Here recreation services serves as an example. In an empirical illustration the surface area of the rings could be roughly proportional to the relative value to GDP as illustrated in the bridging table 6.1 below. A similar proposal formatted as a bridging table is discussed in Section 6.5 below.

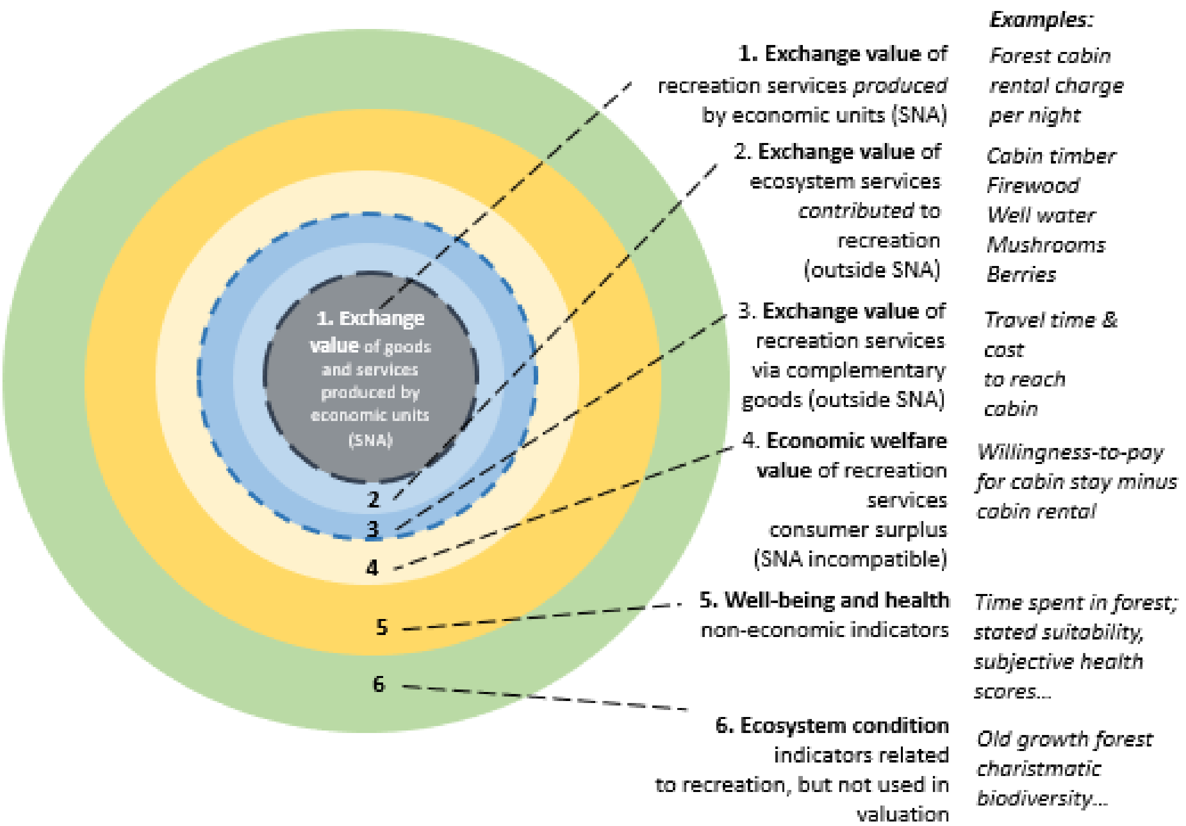


Figure 6.1 *Plural values in the system of ecosystem accounts. Source: adapted from Barton et al., (2017).*

Figure 6.1 illustrates that currently only a small portion of the information available on ecosystems contribution to recreation is used in the system of national accounts (SNA). This is illustrated by # 1 – and the inner dotted line in the Figure 6.1. Ecosystem service mapping and valuation using the exchange-based valuation methods discussed in Sections 3 and 4 will make it possible to expand the scope of national accounts to cover flows not currently recorded, such as ecosystem's contributions to recreation (2), and complementary goods and services to recreation (3) (illustrated by the outer dotted line). Economic welfare measured by consumer surplus from recreation (4) is not accounting compatible, but could be recorded in parallel, along with non-economic indicators of health and wellbeing (5), and indicators of ecosystem condition (6) likely to be important for recreation, but not currently used by recreation demand models.

6.4 Satellite accounts for incommensurate value metrics ?

The 1993 SNA introduced the possibility of satellite accounts, to study certain phenomena without disrupting the central set of accounts. Figure 6.2 illustrates the possibility that instead of discarding valuation information that falls outside the production boundary, it could be captured in parallel thematic accounts. The organization of the information in satellite account would make it possible for policy-makers to evaluate trends, conduct benchmarking and assess 'distance-to-policy' targets in the economy in light of a 'dashboard of plural value indicators'. This is speculative at the current level of development of SEEA EEA, but could be a valid point for future discussion. The use of 'parallel thematic value accounts' may also be a useful placeholder or a way to negotiate valuation debates between accountants and other disciplines that cannot be settled by recourse to historical national accounting convention (in part because conventions themselves are being adapted by SEEA EEA to accommodate ecosystem services).

Figure 6.2 also highlights that spatial data and biophysical and social indicators in the system of ecosystem accounts can potentially be used in a number of disaggregated ways for local environmental and social impact assessment and land use planning. These are what we have called 'secondary purposes' of ecosystem accounting, above. These indicators have been selected to be important for the ecosystem accounting framework. Although they are not monetary, the partial accounts and indicators of a system of ecosystem accounts thus represents a set of 'importances' (Gómez-Baggethun et al. 2017). As such ecosystem accounting can be considered an approach to integrated valuation approach covering a wide range of instrumental plural values.

We propose that for policy makers the "mid-level" in Figure 6.2 (Capacity-condition-supply) will always be the core of ecosystem accounts. In terms of coverage and information content, monetary valuation may in time become not be the rule, but the exception, depending on the strictness of valuation requirements. In any circumstance monetary valuation cannot be better than the quality of our knowledge about underlying biophysical linkages.

At the same time as energies are focused on selecting and testing monetary valuation methods, it is important to communicate the plural values aspects of accounts in dialogue with wider valuation communities such as the IPBES.

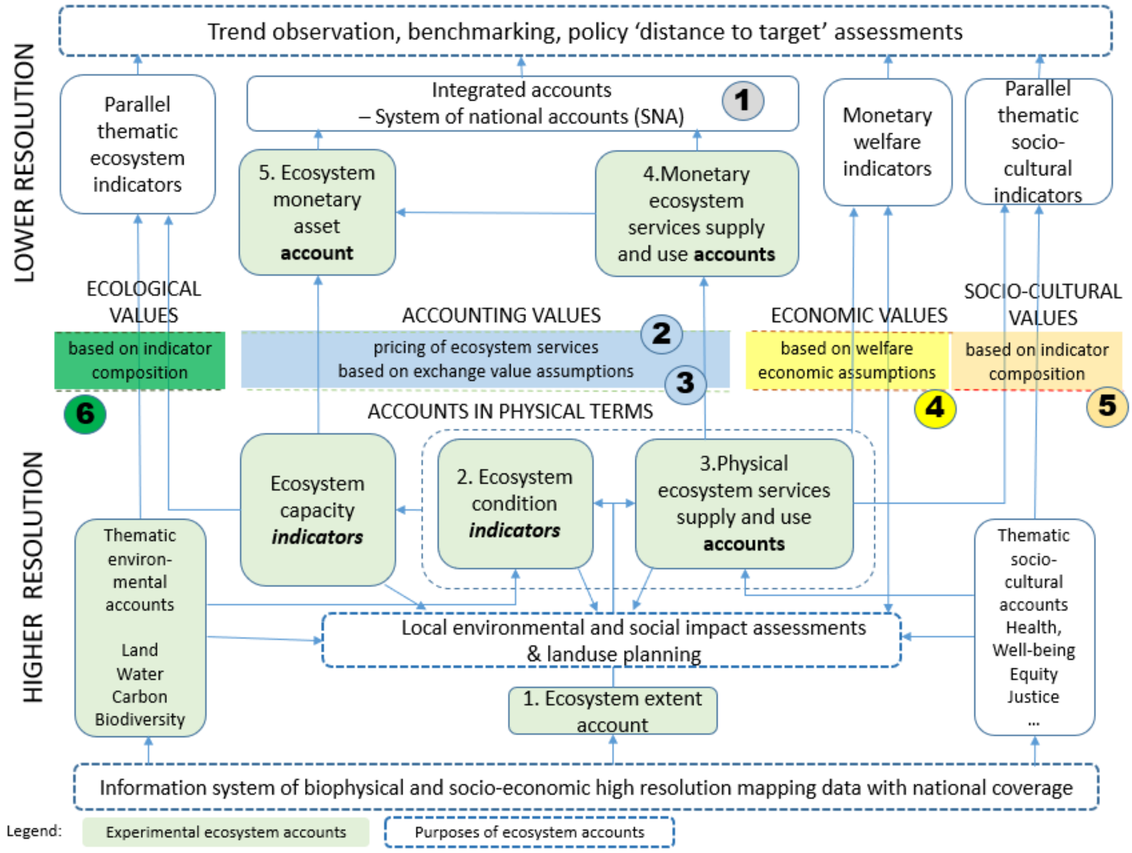


Figure 6.2 The system of ecosystem accounts as an integrated and plural valuation approach. Numbering refers to value concepts in Figure 5.1. Numbers refer to the numbering of concentric circles in Figure 6.1. Source: adapted from OpenNESS (2017)

6.5 Bridging tables to compare different economic value metrics

Another possibility to ease the tension between national accounts and ecosystem accounts (and a fortiori welfare economics) would be to construct a comprehensive bridge table – allowing the comparison of various valuation concepts, and assessment of their differences (this suggestion was actually one of the main outcomes of the valuation expert meeting held in Bonn in 2018). Such a bridge table could be compiled for the economy as a whole (assumed in Table 6.1 below) or for specific ecosystems[54].

Table 6.1 describes a range of values that Nature provides to the economy/society that all seem potentially policy relevant.

[54] Rocky Harris made a similar proposal during the 2017 London Group.

Table 1. Bridge table for various conceptions of ecosystems related value

Value concept	Link with SNA	Purpose	Institutional assumptions	Approach	ES scope	Wealth	Value (for ET)	Comments
Environmental protection expenditures	SNA / SEEA CF	Assess current spending on ecosystems / biodiversity	Current	e.g. BIOFIN -> assess expenditure gaps; typical value 1% of GDP	Channel 1, 2 and 3 (partial)	n/a (liability according to CNCA)	A	
Ecosystem related output	SNA	Demonstrate importance of ecosystems for GDP	Current		1, 2, 3 (partial)	SNA Balance sheet	B	Sometimes by using indirect approach (i.e. RR for all sectors)
Exchange value	Expanded production boundary (use-values)	Make contribution of ecosystems to SNA and non-SNA benefits visible	Simulated exchange values / Marginal value pricing	Market like equivalents if markets would be constructed	1,2,3,4	Compre-hensive wealth	Cxc= ES1+ES2+..	Demand side
			Ibid, but capped at capacity	Assess sustainable yield/production			Ccp <C	Supply side
			Current + WTP; Perfect price discrimination				Cpp=Cxc+ ES1_cs+ ES2_cs	Coincides with welfare based estimates (i.e. for use values)
			Replacement costs	Based on costs of next best alternative			D	WTP > replacement costs can be used as necessary condition
Welfare values	Expanded production boundary (use + non-use values; TEV)	Demonstrate importance of ecosystems for societal welfare	WTP / WTA		1,2,3,4	Inclusive wealth	Cwf = Cpp + ET _nonuse	

The first two metrics would measure environment related output as already captured within the current SNA/SEEA – so no change of the production boundary.

1) *Environmental protection expenditures / env. related transactions:* these are already part of the SEEA CF. They describe the amount societies currently spend on environmental protection / conservation activities. BIOFIN is an example of the interest in such metrics scoped narrowly around biodiversity expenditures. Typically this would be less than 1% of GDP (reference?).
2) *Environment related outputs* (e.g. agricultural products and tourism revenues). This would include all SNA transactions that are dependent on nature. Close to assessing ecosystem services as benefits (and hence not contributions).

When extending the production boundary to recognize ES beyond the SNA production boundary, a range of metrics is possible:

3) Exchange value based on the most realistic market exchange mechanism, for instance a SEV or marginal value pricing approach when looking at recreation (see Discussion paper #10 WG4, Barton et al. 2019). When looking at wealth estimates this would likely be the total wealth of nations (as per World Bank approach).
4) Exchange value, however cap the number of beneficiaries to the maximum number that would not degrade the condition of the underlying ecosystem. This is closely associated with the concept of capacity that has been proposed in the Technical Recommendations. So the value of the ecosystem would present sustainable use (or carrying capacity) of the ecosystem.
5) Perfect price discrimination could be assumed, which would make the consumer surplus non-existent. In this case exchange and welfare values would by construction be equal. The appeal of the perfect price discrimination assumption is of course that this would make it accounting compatible to use the welfare based values from the valuation literature. In practice a realistic market assumption should be the basis for simulated exchange, giving policy-makers insights into additional value that could be created/appropriated within current institutional regimes and technology (see 6.9-6.11 below).
6) Replacement costs in case ecosystem services would be lost. WTP (as in 7) would be used as a check that society would be willing to spend this amount.
7) TEV - this would be a pure welfare based valuation. The difference with (7) could be that here we would use the TEV framework i.e. also allow for non-use values, so the scope would be wider than assessing use-values. When looking at wealth estimates this would be the Inclusive Wealth.

6.6 Asset valuation – is the total economic value (TEV) concept useful?

The TEV framework has become a popular approach (e.g. TEEB, 2016) to estimate the 'total' economic value of an ecosystem or specific environment.

However a number of criticisms have been formulated as well, such as 1) confusion about the typology it uses (e.g. direct use, indirect use, and non-use). For instance authors seem to disagree where option values are situated. Footnote *For instance, the SEEA 2003 did refer to TEV in para 10.149 (although not explicit) – interestingly, the interpretation there was that existence values are the only non-use values, and option and bequest values are interpreted as indirect use values.* 2) that TEV mixes flows and stocks e.g. direct use values are normally identified as flows, whereas existence, bequest and option values are stock values, and indirect values may be changes in stocks, or resource flows used to manage stock). 3) partly as a result of the above, that there is risk of double counting.

Section 2 therefore concludes that TEV framework is not a suitable for defining ecosystem service values, especially as part of a process to incorporate ecosystem service and ecosystem asset values in an extended SNA (SEEA) framework. It is fair to say that other parts of the paper however do refer to TEV categories. TEV is not perfect by any means, but some overarching framework is needed for communication about the range of values addressed (or not) by accounts.

The discussion is a) whether we agree that TEV is not a suitable framework in the context of SEEA EEA b) if so, whether we still need to be able to explain how SEEA EEA relates to it (or possible interpretations of it), given that it seems widespread. Further, does the IPBES framework of instrumental, relational and intrinsic value provide any additional communication advantages relative to the TEV framework?

6.7 Ecosystem disservices

Some ecosystem services are positive externalities. The SEEA EEA arguably internalizes these externalities by an expansion of the production boundary (at least in part, as externalities are commonly defined with regard to utility functions hence in a welfare based setting). A natural question arises whether the SEEA EEA follows a symmetrical treatment regarding negative externalities, by internalizing these as well. At this point it is important to distinguish between two different types of negative externalities: ecosystem disservices i.e. flows from ecosystems to society (e.g. pests such as malaria), and ecosystem degradation i.e. flows from society to the environment (e.g. pollution).

Some ecosystem disservices are already reflected in economic output. For instance, when a farmer is sick due to malaria, he works reduced hours and as a result has lower yield and hence revenue. It would in theory be possible to make such externalities visible by introducing a disservice transaction (e.g. in the form of negative ecosystem output) which would be intermediately consumed by (in this case) the agriculture sector, raising its value added. In the income distribution accounts the additional income could be returned to the ecosystem. Although a notion of negative outputs feels pretty awkward for national accountants, something along these lines was proposed in the SEEA 1993. It would at least result in a symmetrical treatment of externalities. Degradation will be discussed in issue paper 5.4. Ecosystem disservices will be discussed further in a forthcoming Discussion Paper of the SEEA EEA Revision process.

6.8 Estimates based on provision costs and other cost-based methods

It is an exaggeration to say that the SNA is fully based on prices that reflect exchange values. Over a quarter of the National Accounts of all countries are made up of government expenditures that are not valued on that basis but on the cost of provision of goods and services, which have a substantial public good character[55]. The use of cost data, however, does not mean that levels of provision are unrelated to values; the link comes about through the political process that determines the level of provision. Thus a given level of spending on health, education, transport etc. reflects societies´ collective willingness to pay for these services through taxes and user charges. If provision were to be Pareto optimal the total cost divided by the quantity provided would be equal to the sum of the marginal willingness to pay of each individual (vertical summation), which is also equal to the exchange value. In practice, however, public provision is nowhere near that, and studies of collective decision-making indicate the likelihood of such outcomes is remote.

Bearing that in mind, one could argue that ecosystem services could also be valued in terms of the cost of provision. This is not as straightforward as it is for public goods provided by the government, but there are parallels. A public park provides recreational and other services and is paid for through municipal maintenance, as well as through the implicit value of the land services. The latter would be imputed, but could be taken from the opportunity cost of that land -- i.e. what it would rent for if not used for recreation.

One could also question why we are going for models to determine exchange values with respect to ecosystem services when we are quite content to use cost based-approaches to value important components of National accounts such as health and education. In fact, even accepting that in the case of ecosystem accounts (simulated) exchange values would frequently be larger than costs, knowing the costs involved in providing those ecosystem service would always be relevant information. In addition, this information would in fact be needed also for an ecosystem accounts based on (simulated) exchange value (see section 3.6).

However, if the goal is to extend the practice used for education and health, and in general services provided by governments, one should stick to the practices used in these sectors. That is, one should restrict attention to cost actually spent, potentially including clearly defined opportunity costs such as the rental value of land devoted to a park (as mentioned above).

That said, the argument discussed above that cost actually incurred by the government should (in theory) be related to societal preferences, does not apply to all cost-based methods. Replacement costs have no connection to preferences and avoided costs are also problematic. An argument in favor of the latter is that one should at least be willing to pay the cost avoided, but in a world with limited resources there are many costs that could be avoided and societal preferences are needed to decide when a particular cost is acceptable. It can be argued that societal preferences for impacts avoided by ecosystem services could be observed in environmental regulation - for example in safe minimum standards or environmental liability rules. Assuming cost-effective technology, such regulation and rules could be used as a basis for computing avoidance cost. Where avoidance levels are not specified

[55] reference?

by regulation, one could in theory compare cost-effective replacement or avoided costs, with society's WTP, and incorporate only those which would be covered according to societal preferences. Note, however, that this would imply estimating the demand for the related ecosystem services and would bring this practice close to the simulated exchange value method discussed in section 3, as the main difference would be that the supply function would be a point estimate calculated using cost-based methods. This would provide a preference-based foundation, but would increase the data intensity and complexity of the method.

6.9 Cost-based approaches where credible market institutions cannot be simulated?

Are there any consequences for the transparency of accounts when prices and possibly quantities are simulations and not based on observations of actual exchange? Non-experts will normally take figures in the accounts at face value, regardless of the underlying process.

In order not to simulate quantity, simplifying assumptions are needed. For example, in a simulated exchange value approach assuming monopolistic competition (discussed in Section 3) users of open access greenspace are recorded in physical use accounts, but only users that would visit under a simulated exchange price, would be assigned a positive price in monetary use accounts. This accounting convention would be technically feasible, but is it counterintuitive ? A portion of the actual visits are assigned a zero value.

In what situations can we argue that simulated exchange values assuming linear demand and monopolistic competition better represent preferences than cost-based approaches?

6.10 Incomplete property rights and partial equilibrium exchange prices

Another unresolved issue is whether prices observed in an economy come from a set of complete markets which leave out no relevant goods and services. In a Coasean world it suffices to establish property rights. Agents will then find prices that maximize their welfare within the existing institutional context (other authors support this same idea[56]). This may yield prices equal to zero for some goods, but only because those goods have no value under the current institutions. One may argue that ecosystem accounting and simulated exchange values are meaningless in this world, as there are observable market prices for all relevant goods and services, and all of them are, or should be, included in conventional SNA.

Alternatively, one can assume that transaction costs and incomplete property rights imply that some relevant goods and services are currently outside of the market, and therefore that the maximization that markets generate within existing property rights is not necessarily welfare maximizing. In other words, markets are not complete in this vision of the world, and exchange prices are not necessarily equal to the prices that maximize welfare. In this world one might be interested in simulating the prices that would occur if the world was closer to the Coasean world described above. Ideally, this should be done in a general equilibrium context, but applied work will probably need to do this in a partial

[56] References?

equilibrium framework, accepting that this implies missing important general equilibrium effects. The SEV method is only meaningful in this context. In fact, at an abstract level it can be seen as an attempt to find the prices that would occur in the Coasean world described above (if we are already in the Coasean world, we are done).

Finally, an important aspect of the 'Coasean world' was to describe market institutions where transaction costs are substantial. In a world with transaction costs the market internalises transaction costs giving rise to firms rather than atomistic producers (with perfect property rights). Further discussion is needed about the technology and transaction cost assumptions that define "realistic" simulated markets.

6.11. Credible simulated markets and transaction costs

The credibility of the institutional context is a general requirement of valuation methods positing hypothetical markets, such as stated preference methods. What constitutes a "credible" institution is not only a technical, but also a political question, and so likely to be contended. A vast array of possible institutional structures are possible, in principle, but in practice the benchmarks used to assess simulated exchange are limited to standard models of perfect competition, monopoly and monopolistic competition. The latter option is chosen when it comes to national parks/recreational sites. With this assumption it is possible to construct a specific demand curve and a marginal revenue curve for each recreation site. Assuming the demand curve is linear, and production costs are constant, the price is given by the median of the demand function, and *use* would be equal to 50% of the visitors that access the area when there is no price. A very 'open' institutional situation has thus been narrowed down using calculable assumptions. What criteria can we use to judge whether this can be regarded as a reasonable institution in many applications? When does convenience, the need to make calculation possible, outweigh doubt about the technical feasibility (e.g. segmentation, exclusion) and political credibility (e.g. rights appropriation) of the institution?

For example, open access local recreation in some countries and locations may be a constitutional right. It may be technically feasible to estimate a simulated exchange value, but assumptions about markets may be unconstitutional, in conflict with the existing governance regime, or excessively costly to enforce.

Can we identify the institutional 'boundary conditions' in which transaction costs of excluding users from current public goods and common pool resources, exceed/don't exceed the simulated exchange value that could be captured by the simulated institution?

6.12. Revising exchange prices - marginal versus non-marginal changes

There is disagreement about whether welfare and exchange prices are the same in the context of using them to compute changes in ecosystems contributions to GDP. For marginal changes in ecosystems contributions to GDP differences are minimized and marginal changes in GDP approximate reasonably well changes in welfare. For large changes in the economy, variations in GDP and variations in surpluses are not even similar.

How do we reconcile that using exchange prices to value incremental changes over one accounting period approximate change in GDP and welfare well, while using the same exchange prices to value larger changes over several accounting period would not? In a market we would expect exchange prices to respond to changing scarcity and substitution possibilities. In non-market situations an explicit decision to re-value would need to be made between accounting periods. This means that for ecosystem services where non-marginal changes are observed over accounting periods, valuation methods would need to be recomputed.

6.13 Expectations regarding accuracy

Is there is a difference in the expectations about accuracy and reliability of valuation methods, depending on whether primary or secondary data are used? Environmental economists working in research with mostly primary data tend to favour data rich *inductive methods*, which also allow for greater statistical accuracy. Practitioners using existing data and value transfer/extrapolation will tend to favour *deductive methods* which use less data and are more amenable to extrapolation on a few observable variables.

In accounting less emphasis may therefore be placed on absolute estimation error of methods than in valuation research. As long as the error and bias are constant over accounting periods, uncertainty about estimates only needs to be small enough to observe trends. This approach to uncertainty documentation is often deemed as insufficient by valuation researchers. The documentation of uncertainty is one of several reasons why accountants and economics researchers may differ in their recommendations for valuation methods (See Section 7).

6.14 Challenge to impute spatial variation in exchange prices

Inductive valuation methods that use large data sets from spatially distributed transactions to impute exchange prices are discussed as ideal in Section 4.

Addicott & Fenichel 2019 argue that for many ecosystem assets management costs are also specific to the landscape features of the ecosystem and its accessibility. Location is important because most natural and ecosystem assets provide highly localized services that can be hard to arbitrage (Addicott and Fenichel 2019). There is seldom one price across the accounting area due to resource immobility and transport costs. Discussion Paper 5.3 points out that

> *" local scale measurement can be difficult because prices often have to be imputed with statistical analysis. Assessing the asset price or change in value of an asset locally might be ideal, but as analysis is increasingly local, the number of measurements and statistical power often falls."*

Deductive valuation methods will be favoured in accounting situations where it is prohibitively expensive to collect enough local ecosystem service use data for inductive methods to impute significant variation in local prices.

6.15 Determinants of spatial heterogeneity in ecosystem asset value

Due to the difficulty in computing local exchange prices (see 6.13 above), ecosystem accountants practicing value transfer may assume an average price per unit of ecosystem service flow or asset across the accounting area. Deductive methods would then be used to compute physical ecosystem service supply-use. The resulting spatial variation in ecosystem service flows or asset values would be driven by physical ecosystem condition variable, not by spatial variation in scarcity and substitution. In these cases, changes in absolute values between accounting periods will be driven by physical changes in extent and condition, not by variation in prices. In such cases the purpose of ecosystem accounting should be limited to assessing changes in value, rather than absolute value levels.

6.16 Identification of ecosystem condition in valuation methods

Lacking conceptual clarity in the definition of ecosystem services hampers valuation. An example is water supply as an ecosystem services. Inductive methods struggle to relate relevant ecosystem processes and/or economic outputs to measures of ecosystem extent and condition.
Until practitioners develop a common understanding on what is being valued in physical terms, perfecting the methods for valuation will be difficult to achieve.

6.17 Third party criterion and accounting for time in recreation

DP3.10 argues that time spent in recreation is an appropriate metric for recreation service and amenable to valuation. However, the SNA makes clear that a service needs to be carried out by one unit for the benefit for another (sometimes called the 3rd party criterion). Does the introduction of ecosystems as quasi-institutional sectors - allowing the recording a transaction between ecosystem and conventional statistical units – constitute an acceptable exception to the 3rd party criterion ? If so is it relevant to consider other exceptions to the 3rd party criterion accounting convention.

It is proposed to seek a clarification on the interpretation of the 3rd party rule from the AEG (group of SNA experts) on whether the extension of the production boundary allows for the use of time spent as a metric of recreation service flow. A significant part the international research agenda on ecosystem services and biodiversity is focused on human health (WHO 2015). In light of this agenda, would recording time spent by household members' exposure to nature also be an acceptable exception to the 3rd party criterion? Alternatively, could the 3rd party criterion be satisfied by defining individuals as a 3rd party relative to the household accounting unit? Would this be similar conceptually to defining ecosystems as a quasi-institutional third party vis a vis other economic institutions for accounting purposes?

SECTION 7. Conclusions – key messages from this report

Valuation of ecosystem services in national accounts context

1. The purpose of valuation in ecosystem accounts is to make the contributions of ecosystem services to economic activity - which in the SNA itself remain mostly hidden - visible to policy makers. Specifically, ecosystem accounts seek to make visible *changes* in those contributions during an accounting period, as well as make visible the *absolute level* of contributions relative to sectors of the economy already in the SNA. The requirements for reliability and accuracy of valuation are greater for the purpose of making visible levels than they are of changes. Which purpose is most important therefore has implications for which valuation methods to recommend.

2. The approach used in the SEEA EEA to make the contribution visible is to impute exchange prices, i.e. price that would prevail in case a market for the ES in question were to exist.

Accounting in Wider Valuation Frameworks

3. In the **communication of ecosystem accounting values** to other valuation communities, SEEA EEA concerns the definition and estimation of anthropocentric instrumental values. Through a system of ecosystem accounts a limited but plural set of values are represented through biophysical information on ecosystem services, monetary supply and use values and monetary asset values. Although assessment of anthropocentric intrinsic values ('relational' values) and non-anthropocentric intrinsic values is essential to address certain research and policy questions, these types of value may be better expressed in other frameworks than SEEA EEA , such as those used by anthropologists and political scientists. The types of value that are in the domain of ecosystem accounting need to be anthropocentric, quantitative and instrumental, or 'reframable' as such (e.g. by reframing ecological values as ecosystem services with defined beneficiaries). Anthropocentric intrinsic and non-anthropocentric, intrinsic types of value are outside the scope of the present review.

4. The **TEV approach** is not considered a useful classification of values for accounting purposes because it does not properly distinguish stocks and flows. While this is also true for IPBES values typology (instrumental, relational, intrinsic), both valuation frameworks help communicate the boundaries of value concepts included in accounting, in communication with different valuation disciplines that the accounting community may interact with in applied policy. The TEV framework is helpful in understanding of what values are in (direct and indirect use) versus out (option and non-use) in accounting frameworks, but NCA does not apply the TEV concept in its totality.

Value and price concepts in environmental economics in the context of national accounts

5. **Welfare measures** for ecosystem services are inconsistent with the measurements provide by national accounts for goods traded in markets. Welfare measures do not allow comparing levels of ecosystem services with one another or with levels of goods and services in markets. On the other hand, variations in welfare are approximated well by an ecosystem accounting measure based on welfare, but also by a measure based on (simulated) exchange values.

6. For some ecosystem services such as open-access recreation, there are no markets where the same or similar items/services are traded currently in sufficient numbers and in similar circumstances. In these cases it may be possible to simulate the price and the quantity that would have been observed if a similar good would have been traded in a market.

7. To estimate simulated exchange values accounting convention requires that the **most realistic institutional context** be specified. The 'most realistic institutional context' may be defined by whether (i) there is a likely **legal basis** for excluding users, and (ii) whether technology and **transaction costs** make it feasible to charge for access/use of the ecosystem service.

8. For iconic and unique recreational sites, where there is a legal basis to exclude users and charge entry, the institutional assumption of monopolistic competition may be realistic depending on local conditions. Monopolistic competition is amenable to estimation with limited onsite data on management costs. Where management costs are assumed to be fixed, a simulated exchange price at 50 % of median demand maximizes revenue.

9. For non-iconic and homogeneous greenspaces, where there is a legal basis to exclude users and charge and entry fee, an appropriate institutional assumption for simulating a market may be perfect competition. The potential carrying capacity of each site should be identified. It should be evaluated on a case by case basis whether market simulation assumptions are consistent with other information in accounts. For example, homogenous greenspace assumes that only accessibility determines demand (that ecosystem condition and carrying capacity are the same across all sites).

Approaches for assessing valuation methods in the context of national accounts.

10. **Tiered approach to selecting valuation methods.** It is important to develop guidelines for method selection that may be implementable across developed and developing countries. A tiered approach (as in IPCC) differentiates recommended valuation methods based on data availability and technical requirements.

Table 7.1 is a first draft of what such a tiered table could look like. Such a table would need to be validated by testing and further practice.

Table 7.1: Tiered approach to valuation of ES approaches

		(data poor / low tech capacity)		(data rich / high tech capacity)
		Tier 1	**Tier 2**	**Tier 3**
provisioning	crops	fraction of market price*	leases / resource rent**	production function
	timber	fraction of market price	stumpage value	production function
	fish	fraction of market price	resource rent	quota / permits
	water	*(recommended not to be seen as provisioning service)*		
regulating	carbon sequestration	social cost of carbon	..	emission trading schemes
	soil retention	avoided costs (any)	..	avoided costs (least cost alternatives iff <WTP)
	air filtration	avoided costs (any)	..	avoided costs (least cost alternatives iff <WTP)
	water purification	avoided costs (any)	..	avoided costs (least cost alternatives iff <WTP)
	river flood regulation	avoided costs (any)	..	avoided costs (least cost alternatives iff <WTP)
	coastal flood regulation	avoided costs (any)	..	avoided costs (least cost alternatives iff <WTP)
	water flow regulation	avoided costs (any)	..	avoided costs (least cost alternatives iff <WTP)
cultural	tourism	Fraction of tourism revenue spatialized based on accommodation	..	Fraction of tourism revenue spatialized based on geotagged social media data
	nearby use (e.g recreation)	Benefit transfer	Simulated exchange value*** / Protection Exenditures + opportunity costs of land	SEV (intersection of supply and demand curve)
	adjacent use (as reflected in property value)	Expert estimates of premium	Hedonic pricing (survey data - small sample).	Hedonic pricing (property sales data - large sample)****
*	e.g. applying a single fixed percentage based on a research study across all estimates			
**	RR aoporach also covers income less costs methods			
***	using the 50% median approach			
****	Marginal Value Pricing potentially (few applications so far)			

Developing countries could start applying Tier 1 methods, using global data sources and at higher resolution. Without further funding a number of developed countries will also need to start at Tier 1. Developed countries with funding, higher technical capacity and national data sets could start applying Tier 2 (and eventually) Tier 3 methods.

An alternative approach would be to divide methods into A. undisputed, B. conditional and C. rejected methods.

Criteria for selecting methods include the degree to which methods are:

1. based on empirical analysis rather than assumed causal relationships (inductive rather than deductive)
2. identify the individual service
3. compatible with exchange values in SNA
4. allow reliable extrapolation based on biophysical, socio-economic and/or institutional context
5. low cost of input data and ease of computation

Table 7.2. Priority A,B and C methods for ES valuation

A method	Undisputed / preferred	production function; hedonics; simulated exchange value; environmental protection expenditure in combination with opportunity costs of land; Marginal Value Pricing; avoidance costs; (least cost alternatives iff < WTP); quota/leases
B method	Conditional	resource rent; benefit transfer using meta-regression models
C method	Rejected	restoration costs; market prices (for crops); travel costs (in case only direct costs); stated preference (with CS); PES; unit value transfer without adjustment

11. Valuation using several methods is encouraged where possible, also with methods that are not advisable for use as exchange prices. This may help to frame or **benchmark** absolute value levels. For example actual costs of management and opportunity costs of ecosystem protection constitute a lower bound for exchange values, while restoration costs and stated maximum willingness to pay constitute an upper bound.

12. Low or zero monetary contributions of ecosystem services to the economy reflect accounting conventions based on (simulated) exchange prices. 'Low or zero' accounting values of ecosystem service flows may also indicate institutional regimes that are far from efficient markets by policy design, or by negligence.

Value transfer in ecosystem accounting

13. Value transfer/ extrapolation /scaling will be required in <u>most</u> determinations of accounting prices because valuation method estimates will be available in only part of the accounting area.

14. Exchange prices computed for the accounting purpose of evaluating changes may not have the accuracy or reliability to be used for purposes requiring evaluating absolute levels (benefit-cost analysis, instrument design, compensation).

15. Most per unit ecosystem area values are conditional on population socio-economic characteristics and spatial distribution patterns in relation to the ecosystem. Never transfer per unit area values that have not been adjusted for spatial context that determine demand

16. Use spatially explicit meta-analytic transfer approaches that adjust for biophysical location, economic and socio-demographic predictors of use (and marginal value)

17. If spatially sensitive values per unit area of ecosystem are not available, monetary use accounts should not be calculated. (Physical supply and use tables provide a reliable trend signal; no added information value of constant per unit area monetary values)

18. For large change in ecosystem extent and condition over time marginal values per unit area of ecosystem using benefit transfer will be invalid

Given the importance of value transfer for accounting, specific guidelines on spatial scaling of monetary valuation estimates from primary study sites to accounting areas will be needed.

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Appendix – Valuation method data needs and challenges

Deductive Method
Residual Methods (Unit resource rent ; The Change in Net Rents; Mathematical Programming Models)
Description Prices determined by deducting costs of labour, produced assets and intermediate inputs from market price of outputs (benefits). Estimates only a single, point equilibrium value marginal product or an estimate of net economic rent, In principle, this method is appropriate but care is needed to ensure that the residual estimated through this approach is limited to the target ecosystem service. Problem when the economic unit uses more than one ecosystem service to produce the same input. E.g. agriculture get benefit from water and pollination. This method do not allow to disentangle them. In those cases, the right interpretation might be the value of the different ecosystem services from the ecosystem asset where the activity takes place.
Data needs • Physical production function (quantities of inputs per output) • Exhaustive list of all relevant inputs • Marginal product per input • Prices of inputs and outputs (inflation adjusted average several years prices would be desirable when thinking about long term planning)
Main challenges Appropriate definition of the physical inputs, output, and revenues. Listing and quantifying the predicted amounts used of all relevant inputs (avoid omitted variables) Aggregation problem (generalize from one productive unit to the whole economy). Empirical measurement of the quantity of the ecosystem services used by the firm Goods produced and sell to cover their costs produced to cover their cost (e.g. public services, like water supply). Forecasting prices when thinking about valuing assets (or long-term planning) Forecasting technological and institutional changes, and ecosystem services scarcity Accounting stance: price distortions can produce biased values. E.g. Some developing countries, have maintained agricultural commodity prices below world market prices with policies designed to keep food prices low to urban consumers, making the imputed values of irrigation water to be accordingly lower than they would otherwise be (or even negative). Owned inputs problem: In many agricultural applications, farmers are not unable or not willing to repay more than a small fraction of the costs of developing an, e.g. irrigation project. Hence, values predicted by the residual method tend to be significantly higher than those found by other formal applications of land value and hedonic property. In additional, inputs owned (non contractual) by the firm are also many times not transacted in the market in the current accounting exercise. Multiproduct firm: to perform these calculations for each of a number of products of a representative firm and determine a weighted average value of the residual claimant, water.
Applicable for the following ecosystem services: Provisioning services involving harvest or abstraction (e.g. concerning timber, fish, crops, livestock, etc.). Firms already in the production boundary.

Deductive Method
Cost based approaches - Damage costs avoided
Description Prices are estimated in terms of the value of production losses or damages that would occur if the ecosystem services were reduced or lost due to ecosystem changes (e.g. as a result of pollution of waterways). Appropriate under the assumptions (i) that the estimation of the damage costs reflects the specific ecosystem services being lost; (ii) that the services continued to be demanded; and (iii) that the estimated damage costs are lower than potential costs of abatement or replacement.
Data needs •
Main challenges These approaches assume that expenditures to repair damages or to replace ecosystem services are valid measures of the benefits provided. However, costs are usually not an accurate measure of benefits. These methods do not consider social preferences for ecosystem services, or individuals' behavior in the absence of those services. Thus, they should be used as a last resort to value ecosystem services
Applicable for the following ecosystem services: Similar to replacement costs, the focus will generally be on services provided by ecosystems that are lost due to human activity impacting on environmental condition, particularly through pollution. Regulating services are likely to be the most commonly estimated using this method.

Deductive Method
Cost based approaches - The Alternative Cost Method (Replacement cost)
Description Value attributable to cost savings from next best alternative source of service (e.g. water supply, electricity, transportation). The method is attractive under the assumptions, valid only in certain limited instances: (1) the alternative must provide the same or equivalent good or service; (2) the alternative must be the least cost alternative way to provide this equivalent good or service; and (3) there must be clear evidence that the services would be demanded from the higher cost alternative (Brown 2017). Because of its computational demands, one would expect this process to be formalized for solution within the framework of optimization modeling. The replacement cost method is a simplified version of the alternative cost method (Brown 2017). With this method the first of the three conditions specified above are met, but there is no empirical check as to whether public or private party would replace the prior investment or that there would actually be sufficient demand or benefit to warrant replacement. Specifically, there can be cases where the cost of replacement exceeds the benefits that would be realized. Using the replacement cost as a measure of benefits assumes that the benefits are at least equal to replacement costs. But as one can see, this is almost circular reasoning, and assumes away the problem of benefit estimation by replacing it by cost accounting. Needless to say, reliance upon the replacement cost method is ill advised (Young and Loomis, 2014).
Data needs • The present values of costs of each alternative are calculated on the basis of a commensurate planning period, price level, and discount rate. • Requirements similar to the residual method.
Main challenges The main weakness is that some alternative can always be conceived which would be more expensive than the project being evaluated, thereby inevitably producing an estimate of cost

savings and positive net benefits. Therefore, the alternative cost method must be supplemented by a study to confirm that the demand for the alternative is sufficient to justify the alternative expenditure.

Applicable for the following ecosystem services: Similar to damage costs avoided, the focus will generally be on services provided by ecosystems that are lost due to human activity impacting on environmental condition, particularly through pollution. Regulating services are likely to be the most commonly estimated using this method.

Deductive Method

Cost based approaches - Restoration cost

Description

Refers to the estimated cost to restore an ecosystem asset to an earlier, benchmark condition. Should be clearly distinguished from the replacement cost method.
Likely inappropriate since it does not determine a price for an individual ecosystem service but may serve to inform valuation of a basket of service.
Is not intended to produce an economic estimate of value, but rather the cost of providing an equivalent resource service flow (Brown, 2017).

Data needs

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Main challenges

Applicable for the following ecosystem services:

Inductive Method

Observations of ecosystem services market transaction

Description

Observed prices from transactions for short-term leases or permanent sales of rights to water.
Possibly appropriate depending on the nature of the underlying institutional arrangements.
This is very important. Usually, PES are not market transactions, but are fixed prices, or just compensations. I think there are in Australia some experiences with audits by landowners to get payments for conservation.

Data needs

- Prices and quantities, plus prices from alternative

Main challenges

The cost of data and the wide variation in production technologies among industries.

Applicable for the following ecosystem services: Given the most common focus of PES schemes, the price information will be most applicable to the valuation of regulating services, e.g. carbon sequestration.

Inductive Method

Production function, cost function and profit function methods

Description

Prices obtained by determining the contribution of the ecosystem to a market based price using an assumed production, cost or profit function.
Appropriate provided the market-based price being decomposed refers to a product rather than an asset – e.g. value of housing services rather than the value of a house.
The advantage regarding residual methods, is that in this method what is established is a statistical relationship between the production (cost) function and the relevant ecosystem services. The estimation can be biased if there are missing variables in the production (cost) function, and these are not well treated statistically.

Data needs

• Primary data (observations from interview surveys emphasizing inputs and production) or secondary sources (e.g. censuses or other government reports). The advantage is that national statistical offices usually already gather agricultural and industrial surveys. • In addition, needs information on the ecosystem services to be valued, as an input of the production function. Usually, this is a measure of the amount of an extractive resource (water quantity, or wood), or the quality of the resource (water quality, air quality). Some papers have related changes in forest cover with different ecosystem services (Tan-Soo et al., 2016; Tibesigwa et al., 2019; Vincent et al., 2015). The challenge is to link the biophysical information and the socioeconomic data.
Main challenges Data intensive. Define the relevant variable to measure the ecosystem services (depends on the benefit and the beneficiary).
Applicable for the following ecosystem services: Prices for all type of ecosystem services may be estimated using this technique provided an appropriate production or similar function can be defined. This will require that the ecosystem services are direct inputs to the production of existing marketed goods and services. It is likely to be of most relevance in the estimation of prices for provisioning services and for certain regulating services that are inputs to primary production, e.g. water regulation.

Inductive Method
Hedonic pricing
Description Prices are estimated by decomposing the value of an asset (e.g. a house block including the dwelling and the land) into its characteristics and pricing each characteristic through regression analysis. Appropriate in principle, if an individual service can be identified. Heavily used in the pricing of computers in the national accounts.
Data needs • Sales price: preferred measure of value, may need to consider selection bias. Can be taken from different sources, and at different aggregation level. • Environmental amenity/disamenity measurement • Appropriate neighborhood and locational variables • Geographic information systems (GIS) database to link the sales prices and the environmental data • Sample frame (time and space). Having repeated observations for the same unit across time can allow to use stronger statistical analysis (e.g. fixed effects)
Main challenges Have joint datasets with both, sales prices and houses attributes (can be alleviated with spatial lad, or quasi-experimental statistical designs). Local vrs. Regional effects.
Applicable for the following ecosystem services: Most commonly applied in the context of decomposing house and land price information and hence will be relevant for those ecosystem services that impact on those prices. Examples include access to green space, amenity values and air filtration. A challenge is attributing the estimated prices to the location of supply.

Inductive Method
Averting behavior
Description

Prices are estimated based on individual's willingness to pay for improved or avoided health outcomes. Possibly appropriate depending on the actual estimation techniques and also noting the method relies on individuals being aware of the impacts arising from environmental changes.
Data needs • Home-produced outcome and on averting behavior: usually a measure of health. Acute morbidity, or short-term illnesses, can be measured by self-reports; by encounters with the health care delivery system such as hospitalizations or by outcomes such as absence from work or school due to illness; chronic morbidity, or long-term illness, is typically measured as presence of physician-diagnosed conditions. Mortality, or death, is more objectively measured than presence of illness because death is a discrete event that is almost universally recorded. Data can be primary or secondary, and individual level, or aggregated, depending on funds and data availability. • Data on environmental conditions. The temporal scale of the required data is dictated by the outcome. Chronic morbidity or mortality in adults would warrant measurement of long-term environmental exposures, but long-term exposure data are rarely available. For acute illness, measures of daily variation in environmental conditions typically would be sufficient, perhaps with allowance for lagged effects of the environment on health and behavior. • Environmental data then must be matched to exposures of people, which is usually done on the basis of residential location. • Inclusion of additional controls for omitted influences that may be correlated with included variables. Where possible, use panel data so that a fixed effects estimator can be used to aid identification of effects of environmental conditions
Main challenges Local vrs. Regional effects.
Applicable for the following ecosystem services: Most commonly applied in the context of environmental pollution on health (e.g. air quality, or water quality). If only cost to avoid the problem re considered they can be a type of channel 1, within the production boundary. However, they can also involve time, not considered in the analysis.

Inductive Method
Travel cost
Description Estimates reflect the price that consumers are willing to pay in relation to visits to recreational sites. Possibly appropriate depending on the actual estimation techniques and whether the approach provides an exchange value, i.e. excludes consumer surplus. A distinction here is that the total of actual travel costs is not a measure of the value of the ecosystem services but it may be appropriate to use the demand profile associated with the travel cost (the estimation of this demand curve is referred to as use of the travel cost method).
Data needs • Identify recreation uses • Identify and define recreation sites • Identify population of users and define a sampling strategy • Define variables including: trip cost, site characteristics (accessibility, environmental quality, etc.), entrance cost (if there is one), and individual characteristics (group size, age, gender, nº children in group, etc.). • Trip count and location (nº of trips taken over a designated time period and the sites visited). These questions can be divided by recreation type, day / overnight, and/or multiple vrs. single purpose. • Measure trip costs (travel, hotel, equipment if needed, other components)

Main challenges Key challenge here is determining the actual contribution of the ecosystem to the total estimated willingness to pay. There are also many applications of this method with varying assumptions and techniques being used with a common objective of estimating consumer surplus. Finally, some travel cost methods include a value of time taken by the household which would be considered outside the scope of the production boundary used for accounting purposes. Also, multi-purpose trips complicate the analysis.
Applicable for the following ecosystem services: This will relate to valuation of recreational ecosystem services.

Inductive Method
Stated preference
Description Prices reflect willingness to pay from either contingent valuation studies or choice modelling. Possibly appropriate. It does not measure exchange values. However, while the direct values from stated preference methods are not exchange values, it is possible to estimate a demand curve from the information and this information may be used in forming exchange values for ecosystem services. The estimated demand function can be a good proxy to a market demand function if it is carefully implemented.
Data needs • Individual survey with description of the changes in the ecosystem services associated to a policy program, vehicle payment, and individual acceptance / rejection to assume an additional cost for the ecosystem service improvement (this can be set in many different ways)
Main challenges Key challenge here is to frame the questionnaire in a way that is perceived by the respondents. Is advisable to spend time on carefully design the program framing. If the benefits of the ecosystem services that is wanted to be valued is very indirect and hardly perceived by the respondent, is advisable to ask for changes in an endpoint related to the ecosystem service, but more noticeable by the respondent as a benefit.
Applicable for the following ecosystem services: Any, including non use

Mixed Method
Simulated exchange
Description Prices are estimated by utilizing an appropriate demand function and setting the price as a point on that function using (i) observed behavior to reflect supply (e.g. visits to parks) or (ii) modelling a supply function. Appropriate since aims to directly measure exchange values. However, the creation of meaningful demand functions and estimating hypothetical markets may be challenging.
Data needs • Demand function estimated based in any of the methods shown below. • Cost function is approached as the cost of supplying the services. (Caparrós et al., 2017) approaches the cost function for the supply of recreational services by forests in Andalucía, Spain, as the cost of maintenance by local government.
Main challenges To estimate a demand function, and an appropriate cost function.
Applicable for the following ecosystem services: In principle, may be applied for many types of ecosystem services but most likely to be relevant in the estimation of values for regulating and cultural services.