On the potential use of the Ecosystem Services Valuation Database for valuation in the System of Environmental Economic Accounting

Luke M. Brander[‡], Jan Philipp Schägner[§], Rudolf de Groot[|]

‡ Institute for Environmental Studies, Vrije Universiteit, Amsterdam, Netherlands
§ JRC, Ispra, Italy
| Foundation for Sustainable Development, Wageningen, Netherlands

Corresponding author: Luke M. Brander (lukebrander@gmail.com)

Academic editor: Alejandro Caparrós

Abstract

The System of Environmental Economic Accounting - Ecosystem Accounting (SEEA EA) provides a framework for quantifying and valuing ecosystem services that is consistent with the System of National Accounts (SNA). As such, monetary estimates for ecosystem services are required to be measured as exchange values. The environmental economics literature on the value of ecosystem services has expanded consideralby over the past two decades and the Ecosystem Services Valuation Database (ESVD) currently provides the most comprehensive collection and synthesis of this information. The primary valuation studies included in the ESVD, however, measure a variety of value concepts including welfare values, exchange values and others. This raises a challenge for using existing value data as input to SEEA EA applications. This paper explores potential approaches to using the ESVD for value transfers that are consistent with SEEA EA, specifically for the estimation of meta-analytic value functions that can be used to reflect spatial variation in supply and demand of ecosystem services and proxy exchange values. It identifies avenues for future research and development of the ESVD to operationalise and test this approach.

Keywords

cosystem service valuation, value transfer, Ecosystem Services Valuation Database, meta-analysis

Introduction

The recently published System of Environmental Economic Accounting—Ecosystem Accounting (SEEA EA) framework represents a significant step towards making visible the contributions of nature to the economy and people (Edens et al. 2022). The SEEA EA is a spatially-based, integrated statistical framework for organising biophysical information about ecosystems, measuring ecosystem services, tracking changes in ecosystem extent and condition, valuing ecosystem services and assets and linking this information to measures of economic and human activity (U.N. Statistical Division 2021). SEEA EA builds on a synthesis of the current knowledge of ecosystem accounting and serves as a platform for further development at national and sub-national scales. It provides a common set of terms, concepts, accounting principles and classifications and an integrated accounting structure for ecosystem services, in both physical and monetary terms (U.N. Statistical Division 2021).*[1] The framework is consistent with the structure, definitions and accounting rules of the System of National Accounts (SNA), which enables the integration of information on natural capital and ecosystem services with existing measures of economic assets and activity.

Following the adoption of the SEEA EA, the United Nations Statistical Commission (UNSC) encourages all countries to implement the framework with a view to mainstreaming the accounts into policy-making and stimulating further development of technical capacities and methods (Edens et al. 2022).

The purpose of developing ecosystem accounts, both physical and monetary, is to quantify and communicate the economic importance of natural capital and ecosystem services to decision-makers in order to improve the management and sustainable use of these resources. The comparative advantage, or added value, of monetary accounts as information for decision-making is that the importance of environmental change is conveyed in a common unit of account (i.e. money), so that values can be directly compared across other goods, services, investments and impacts in the economy and to society. There remain, however, a number of practical challenges for the monetary valuation of ecosystems services (ES) in the SEEA EA. The first challenge is the requirement to ensure consistency with the SNA, that monetary values for ES are measured as exchange values. This concept of value is explained in detail in the following section but, to put it briefly here, exchange value is a monetary measure of the magnitude of economic activity, primarily in evidence through market transactions and market prices. Many ES, however, are not traded in markets due to their public good characteristics (non-excludability and non-rivalry) and do not have observable market prices. To address this absence of information, considerable research effort in the field of environmental economics has developed and applied methods to estimate values for non-marketed ES (Freeman et al. 2014, Groot et al. 2012). To a large extent, ES valuation has focused on the estimation of welfare values as opposed to exchange values (Caparrós et al. 2017).

The second challenge is that the values of ES are highly spatially variable, reflecting context-specific determinants of demand for and supply of each service (Bateman et al. 2002, Hein et al. 2006, Schaafsma 2015). The supply side is largely determined by ecological processes and characteristics that may be influenced by human activities, such as ecosystem area, biodiversity, fragmentation, disturbance, soils and climate. Spatial factors that affect demand for ecosystem services include the number of beneficiaries, culture and preferences, accessibility and the availability of substitutes and complements. Since the determinants of both the supply and demand of ES are spatially variable, ES values are also inherently spatially variable. The spatial dimension of some services is further complicated by the geographic separation of the ecosystem unit producing the service and the beneficiaries of the service. In consequence, the use of fixed unit values in ES assessments or accounting is not valid (Schägner et al. 2013). The estimation of appropriate values therefore requires that account is taken of spatial heterogeneity in biophysical and socioeconomic conditions.

The third challenge relates to the geographic scale at which ES value information is required in accounting applications. The implementation of SEEA EA may be conducted at various scales, including sub-national, national and global. In all cases, this requires ES values for multiple ecosystem units across large geographic areas. Most economic methods that have been developed to estimate values for non-marketed ES, however, are expensive and time-consuming to conduct and are generally only feasible at small scales (e.g. for individual ecosystem units). This "scaling up" challenge describes the need to produce information for large numbers of diverse ecosystem units and, potentially, to also account for changes that occur across the stock of the resource (Brander et al. 2012). While the estimation of ES values for a single ecosystem site is already complex, scaling up values is accompanied by additional complexity and methodological difficulties.

A fourth challenge, which is largely a derivative of the preceding three issues, relates to the level of uncertainty regarding estimated ES values. With respect to uncertainty over ES values, the SEEA EA guidance recommends "*compilers to consider issues of data quality and uncertainty before compiling and disseminating accounts in monetary terms.* (…) *Approaches to limiting these uncertainties and maximising the robustness of the data in ecosystem accounts will need to be further developed"* (U.N. Statistical Division 2021). There is a need to quantify uncertainties regarding ES values and develop methods to improve accuracy of estimation.

The SEEA EA framework suggests a commonly-used approach for scaling-up values while accounting for their spatial variations, which is to conduct value transfer (also known as benefit transfer (U.N. Statistical Division 2021), which involves the use of research results from existing primary valuation studies at one or more sites or policy contexts ("study sites") to predict ES values for other sites or policy contexts ("policy sites") (Brander 2013, Johnston et al. 2018). The successful implementation of value transfer, however, requires primary valuation data in sufficient quantity and quality and still "*there is a requirement for the ongoing expansion of work on estimating spatially explicit primary valuations to support the regular compilation of accounts*" (U.N. Statistical

Division 2021). With more than 7,000 value estimates representing all ecosystem services, biomes and continents, the Ecosystem Services Valuation Database (ESVD) provides the most comprehensive collection and synthesis of this information (Brander et al. 2021).

In this paper we explore the potential of using the ESVD for conducting value transfers that address the challenges described above in implementing monetary valuation in SEEA EA. The structure of the paper is as follows. Section 2 provides definitions of the relevant concepts of value and how these are measured by economic valuation methods. Section 3 describes the ESVD and the representation of different valuation methods in the data. Section 4 proposes an approach to using data from the ESVD for value transfers that address the three challenges outlined above. Section 5 outlines avenues for future development of the ESVD to enable the proposed approach and provides concluding remarks.

Concepts of economic value

Here we provide a brief explanation of the concepts of economic value that are relevant to this paper in order to clarify the distinctions between the requirements of the SEEA EA and the availability of existing data on the value of ES.

In neo-classical welfare economics, the economic value of a good or service is the monetary measure of the well-being associated with its production and consumption. In a perfectly functioning market, the economic value of a good or service is determined by the demand for and supply of that good or service. Demand for a good or service is determined by the benefit, utility or welfare that consumers derive from it. Supply of a good or service is determined by the cost of producing it. Fig. 1 provides a simplified representation of demand (marginal benefit) and supply (marginal cost) for a good traded in a market at quantity ‘Q’ and price ‘P’.

In Fig. 1, area ‘A’ represents the consumer surplus, which is the gain obtained by consumers because they are able to purchase a product at a market price that is less than the highest price that they would be willing to pay (which is related to their benefit from consumption and represented by the demand curve). The producer surplus, depicted by ‘B’, is the amount that producers benefit by selling at a market price that is higher than the lowest price that they would be willing to sell for (which is related to their production costs and represented by the supply curve). The area ‘C’ represents production costs, which differ amongst producers and/or over the scale of production. The sum of areas A and B is the total surplus in this market and is interpreted as the net economic gain or societal welfare resulting from production and consumption with a quantity of Q at price P.

In contrast to societal welfare, exchange value is a monetary measure of the magnitude of economic activity in evidence through market transactions. In Fig. 1, this is represented by areas B and C, or equivalent to price (P) x quantity (Q), and corresponds to a measure of producer surplus plus the costs of production. Under the concept of exchange value, the total outlays by consumers and the total revenue of the producers are equal. For national accounting purposes, this approach to valuation enables a consistent and convenient recording of transactions between economic units since the values for supply and use of products are the same. In order to integrate the values of ecosystem services with values in the system of national accounts, it is therefore necessary to value the total quantity of ecosystem services at the market prices that would have occurred if the services had been freely traded and exchanged. In other words, it is necessary to measure exchange value and not welfare value. See Day (2013) for a detailed explanation of welfare and exchange values.

An additional relevant conceptual difference to note in the context of estimating economic values for ES is the distinction between marginal and average values. The marginal value of a good or service is the contribution to well-being of one additional unit. It is equivalent to the price of the service in a perfectly functioning market. Marginal values are relevant for accounting purposes, since they are reflected in prices, and for the welfare assessment of small changes in ecosystem service provision. In contrast, the average value of a good or service represents the aggregate value of a service relative to the scale of provision (defined in terms of units of provision, area of ecosystem or number of beneficiaries) and can be calculated as the total value divided by the total quantity of the service provided and consumed. The distinction between marginal and average values is raised here because, in principle, monetary values included in the SEEA EA should be marginal (reflecting prices).

The available literature on the economic value of ecosystem services contains estimates measuring all forms of value concepts (welfare, exchange and other concepts) and both marginal and average values. It is, therefore necessary to address these conceptual dimensions when selecting value data for use within the SEEA EA.

As indicated in Fig. 1, economic theory suggests that total exchange value (area B + C) is typically lower than societal surplus (area A + B). Other demand functions may, however, be possible and to what extent exchange values differ from welfare value (societal surplus) remains to be explored empirically. We undertook a review of 20 published meta-analyses to investigate if the effects of different value concepts have been examined and whether different value measures have a significant effect on estimated value. We found that controlling for different value concepts is far from common practice. In a rare exception, Woodward and Wui 2001 find that estimates of producer surplus are significantly lower than estimates of other value concepts. However, only seven of the value estimates within their data fall in this category, of which five are exchange values. Brander et al. 2006 examine the difference between marginal and average values, also using a meta-analysis of wetland values, and find that marginal values are almost twice as high as average values. There is evidently scope for further empirical analysis of the differences between value concepts.

Ecosystem Services Valuation Database

The ESVD is, to our knowledge, the most comprehensive global collection of the results of economic valuation studies with details on the type of ecosystem, ecosystem services, location, valuation method and beneficiaries (Brander et al. 2021). The ESVD is a successor to the values database developed for The Economics of Ecosystems and Biodiversity (TEEB) initiative (Kumar 2012) and has been substantially expanded in recent years with funding from a number of partners, including the UK Department for the Environment Food and Rural Affairs (Defra), the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) and the United Nations Food and Agriculture Organisation (FAO). The ESVD is developed and hosted by the Foundation for Sustainable Development (FSD) and Brander Environmental Economics (BEE) with support from the Ecosystem Services Partnership (ESP). The objective of the ESVD is to provide reliable and easily accessible information on the monetary value of ecosystem services for every place on Earth and help stakeholders to better integrate the 'full value' of ecosystem services in their planning, management and decision-making. Further information on the ESVD can be accessed at https://www.esvd.info/ and the web-interface can be accessed at https://www.esvd.net/.

To enable comparisons and summaries of value estimates, recorded values are standardised to a common set of units, namely International dollars per hectare per year at 2020 prices levels. The standardisation process involves five steps to address the following five dimensions: price level (accounting for inflation), currency (accounting for purchasing power parity adjusted exchange rates), spatial unit (accounting for variation in size of study sites), temporal unit (accounting for variation in time periods for which values are measured) and beneficiary unit (accounting for variation in level of aggregation across beneficiaries). It should be noted that it is not possible to standardise all value estimates to this common set of units due primarily to missing data (e.g. on the total number of beneficiaries) or the incompatibility of spatial units (e.g. linear features, such as rivers and beaches, cannot be meaningfully converted into hectares).

The ESVD currently contains over 7,000 unique value records from over 1,000 valuation studies representing 15 biomes and all regions of the world (Brander et al. 2021). Fig. 2 represents the locations of valuation study sites included in the ESVD and shows the broad geographic coverage. We note that the availability of value data is global, but not evenly distributed, with a particularly high representation of European ecosystems and relatively little information for Russia, Central Asia and North Africa. The value data contained in the ESVD reflects the underlying focus of funding and research organisations and is, therefore, not necessarily globally representative of biophysical and socio-economic contexts.

Table 1 provides an overview of the coverage of ESVD data by ecosystem service (using the SEEA EA reference list) and valuation method. Note that the total number of value estimates summarised in the Table is lower than the total contained in the ESVD because some have not yet been categorised using the SEEA EA reference list. The distribution of data across ecosystem services is far from even, with some services very well represented in the data (e.g. recreation, wild fish and wild animals, ecosystem and species appreciation, air filtration and global climate regulation) and others with almost no value estimates (e.g. disease control, baseflow maintenance, rainfall pattern regulation).

Regarding the valuation methods used to produce value estimates contained in the ESVD, market prices have been applied in almost a quarter of cases, primarily for valuing provisioning services, but also for recreation. Stated preference methods (choice experiments and contingent valuation) have also been widely used, largely to value cultural services, but also provisioning and regulating services – reflecting the broad applicability of these methods. The damage cost avoided method, including social cost of carbon which is recorded as a separate method, is also extensively used, but to value a narrower set of regulating services (e.g. air filtration and climate regulation). The travel cost method has been used primarily for the valuation of recreation and visual amenity. Similarly, the hedonic pricing method is primarily used to value visual amenity. The replacement cost method is widely used across both provisioning and regulating services.

The point of reviewing the methods underlying the value estimates contained in the ESVD is that they give a first insight into the value concepts that are measured and therefore compatibility with the SEEA EA requirement for exchange values. On this first assessment, it appears that a large proportion of the ESVD data are compatible since market prices are generally used to derive exchange values. The valuation method, however, may only be a weak proxy for value concept since most methods can be used to estimate a variety of value concepts. For example, discrete choice experiments can be used to estimate both implicit prices and welfare changes (Grilli et al. 2022). (See Suppl. material 1 for an overview of the correspondence across valuation methods and value concepts.) The specific value concept obtained from a study is determined by the specifics of the analysis and the results that are reported. It is therefore necessary to assess each application in detail to determine the value concept that is estimated.

Potential use of ESVD in SEEA EA applications

The ESVD may support the implementation of monetary valuation of ES in SEEA EA by providing a basis for value transfers that are compatible with SEEA EA concepts and data. The number of primary valuation studies included in the ESVD is substantial and growing, which means that there is an expanding body of evidence to draw on for the purposes of transferring values for ES accounting applications. With an expanding information base, the potential for using value transfer is improving continuously.

Value transfer methods have already been employed widely in national and global ecosystem assessments, value mapping applications and policy appraisals (Costanza et al. 1997, Bateman et al. 2013, Schägner et al. 2013). The use of value transfer is widespread but requires careful application (Johnston et al. 2021). Three alternative approaches for conducting value transfer are described here.

Unit value transfer uses values for ecosystem services at a study site, expressed as a value per unit (usually per unit of area or per beneficiary), combined with information on the quantity of units at the policy site to estimate policy site values. Unit values from the study site are multiplied by the number of units at the policy site. Unit values can be adjusted to reflect differences between the study and policy sites (e.g. income and price levels).

Value function transfer uses a value function estimated for an individual study site in conjunction with information on parameter values for the policy site to calculate the value of an ecosystem service at the policy site. A value function is an equation that relates the value of an ecosystem service to the characteristics of the ecosystem and the beneficiaries of the ecosystem service. Value functions can be estimated from a number of primary valuation methods including hedonic pricing, travel cost, production function, contingent valuation and choice experiments (Rosenberger and Loomis 2017).

Meta-analytic function transfer uses a value function estimated from the results of multiple primary studies representing multiple study sites in conjunction with information on parameter values for the policy site to calculate the value of an ecosystem service at the policy site. Since the value function is estimated from the results of multiple studies, it is able to represent and control for greater variation in the characteristics of ecosystems, beneficiaries and other contextual characteristics (Rosenberger and Phipps 2007, Schmidt et al. 2016).

The choice of which value transfer method to use to provide information for a specific policy context is largely dependent on the availability of primary valuation estimates and the degree of similarity between the study and policy sites. However, there is no consensus yet on which value transfer method works best in a given circumstance (Johnston et al. 2018). In cases where value information is available for a highly similar study site, unit value transfer may provide the most straightforward and reliable means of conducting value transfer (Ghermandi et al. 2016). Conversely, when study sites and policy sites are different, value function or meta-analytic function transfer offers a means to systematically adjust transferred values to reflect those differences (Kaul et al. 2013). Similarly, in the case that value information is required for multiple different policy sites, value function or meta-analytic function transfer may be a more accurate, practical and consistent means for transferring values.

In the context of SEEA EA, we propose that the ESVD data can be used to estimate meta-analytic value functions that are tailored to approximate exchange values, reflect spatial variation in key determinants of ES supply and demand, enable transfers to large numbers of ecosystem units across large geographic scales and allow the testing of predictive accuracy.

To estimate a meta-analytic value function that enables transfers consistent with exchange values, two alternative approaches are feasible. The first approach is to use only primary valuations that represent exchange values, which has the limitation of greatly reducing the available sample. The second approach is to estimate meta-analytic value functions, including explanatory variables that enable the explicit prediction of exchange values. Implementation of this approach would require the inclusion of a variable distinguishing between exchange values and other value concepts in the data. The estimated coefficient on this variable can be subsequently used in value transfer applications to adjust the predicted values towards exchange values.

In order to account for spatial variation in the determinants of ecosystem supply and demand, a set of spatially defined explanatory variables can be included in the meta-regression models to measure supply (e.g. extent, condition, fragmentation) and demand factors (e.g. population, income, distance, substitutes, complements). When applying these value functions, the corresponding characteristics of ecosystem units are used to predict values that reflect the specific supply and demand context of each ecosystem unit. To some extent, relevant data on explanatory variables may already be available within the accounts (e.g. ecosystem extent and condition).

The use of meta-analytic value functions also provides a practical means to estimate values for large numbers of diverse ecosystem units across large geographic areas, also referred to as mapping ES values. The approach can be implemented within a spatially-referenced database or GIS to compute site specific values for hundreds of thousands of ecosystem units (e.g. Brander et al. (2020)). In addition, using meta-analytic functions that include a parameter for ecosystem scarcity provides a means to account for simultaneous changes in the extent of ecosystems on the value of all ecosystem services, i.e. more accurately measure the effect of changes in the stock of natural capital on ES values (Brander et al. 2012).

The proposed use of meta-analytic value functions derived from ESVD data also enables the computation of statistical measures of fit and transfer accuracy, thereby giving quantitative insights into the uncertainties of ES values included in SEEA EA applications. Such information may be important to guide compilers and policy-makers on how to use and interpret monetary accounts. More generally, the ESVD may help to locate and quantify uncertainties in the available data on ES values. Being the largest open access global database of ES values, the ESVD enables the generation of summaries of the available valuation data for any ES, biome, region or country of interest. Thereby, data gaps can be identified and research priorities can be set to improve the coverage of ES valuations used for SEEA EA applications.

A conceptual specification of the proposed meta-regression model for SEEA EA-compatible value transfers is given in equation (1). The dependent variable (y) in the meta-regression is a vector of values in International dollars per hectare per year in 2020 prices. This is the general set of units used to standardise values contained in the ESVD, but alternative units are possible in meta-regression functions that examine specific ecosystem services; for example, for the estimation of recreational values, the dependent variable could be defined as International dollars per recreational visit. The explanatory variables include a categorical variable indicating exchange value and other value measures X^E; a set of variables indicating the ecosystem services valued X^{ES}; a set of variables representing determinants of supply X^S (e.g. ecosystem extent, condition, fragmentation, protection status); and a set of variables representing determinants of demand X^D (e.g. population, income, distance, complements, substitutes). The vectors β^E, β^{ES}, β^S and β^D contain the estimated coefficients on the respective explanatory variables; α is the constant term; and μ is a vector of residuals.

$$y = \alpha + \beta^E X^E + \beta^{ES} X^{ES} + \beta^S X^S + \beta^D X^D + \mu \qquad (1)$$

The implementation of this proposed approach to value transfer for SEEA EA using data from the ESVD requires empirical testing and we identify a number of avenues for future development in the next section.

Conclusions and avenues for future development of ESVD

In order to improve the usability of the ESVD to estimate ES values for SEEA EA, several developments and advancements of the database are considered here.

Of primary importance is the need to include or complete additional data fields that enable compatibility with SEEA EA concepts and definitions. First, there is the need to include a categorical variable indicating the value concept measured by the underlying primary valuation studies. Currently, valuation methods are recorded in the ESVD but value concepts are not. Second, there is a need to include a field indicating whether estimated values are marginal or average values. Third, the SEEA EA reference list categorisation of valued ecosystem services needs to be added for all records. This is completed to a large extent (for approximately 90% of the data) but the remaining records require careful interpretation of the ecosystem services addressed. Fourth, additional fields on the condition of ecosystem study sites should be added to enable the influence of condition on ES value to be modelled. Condition variables should be consistent with those used in SEEA EA. Information on ecosystem condition from the underlying primary valuation studies has been difficult to extract and standardise, so spatially referenced secondary sources might provide an alternative and more consistent, source of information. In general, there is incomplete and non-standardised reporting of the information required by ESVD within primary valuation studies. The development of a standardised reporting template for valuation results would help to resolve this limitation in the future (see Schägner et al., forthcoming).The spatial representation of the study sites within the ESVD can also be improved by deriving the exact boundaries of the study sites, which are currently only approximated by point locations and areal extent. A more precise spatial description of study sites would potentially improve the coupling of value data to spatially defined measures of biophysical and socio-cultural-economic characteristics for each study site. This, in turn, is expected to improve the statistical fit of meta-regression models and accuracy of value transfers.

In addition to supplementing the existing data in the ESVD with SEEA EA relevant information, there remains a large body of valuation literature and study results to be included into the ESVD. Currently, the repository of collected valuation studies includes more than 5,000 publications that potentially contain value estimates that can be included into the ESVD. On top of this, there are studies that have not yet been retrieved and included in the repository and the continuous flow of new valuation studies that are published every week. Researchers are encouraged to submit their publications to ESVD and the web-interface is to be extended to enable authors to add their own studies to the database. To the extent possible given available funding, the ESVD team plans to continuously update the database and publish new data releases. With a view to supporting implementation of SEEA EA, future updates could target gaps in the data that are of particular relevance to ES accounting.

Finally, future research is required to implement and test the proposed use of ESVD data to estimate meta-analytic value functions for SEEA EA applications. This could start with ecosystems (e.g. forests, wetlands) and ES (e.g. recreation, wild fish and animals) for which there are large numbers of value estimates. Testing would involve the empirical estimation of value functions and exploration of transfer accuracy across diverse policy site contexts.

In conclusion, there is potential to use the ESVD to develop ready-to-use ES valuation tools that require only a limited number of input variables, several of which can be obtained from the physical accounts. The approach to value transfer proposed in this paper may support the estimation of monetary values for ES that are consistent with SEEA EA concepts, account for spatial heterogeneity in ES supply and demand, enable application at large geographic scales and provide quantifiable levels of certainty. The initial analytical step of estimating meta-analytic value functions will require technical support, but once set-up, consistent value transfers can potentially be conducted by compilers of ecosystem accounts with limited expertise and time for implementing primary ES valuation and/or value transfers. The proposed approach should now be piloted to test its practicality and accuracy.

Acknowledgements

We are sincerely grateful to the members of the ESVD team who have helped to manage and build the database, including Victoria Guisado Goñi, Stefanos Solomonides, Vince van 't Hoff, Alistair McVittie, Florian Eppink, Matteo Sposato, Luat Do, Andrea Ghermandi and Michael Sinclair. We also acknowledge the many colleagues who contributed their time and expertise to reviewing the data, including Leon Braat, Wendy Chen, Rachael Cleveland, Hanna Dijkstra, Davide Geneletti, Liselotte Hagedoorn, Marcello Hernandez, Onno Kuik, Tanya O'Garra, Kirsten Oleson, Paolo Pasquariello, Katrin Rehdanz, Jacob Salcone, Maria de Salvo, Priyanka Sarkar, Marije Schaafsma, Uta Schirpke, Andrew Seidl, Giovanni Signorello, Can Vatandaşlar and Naeema Jihan Zinia. We also thank the reviewers, whose constructive comments greatly improved the paper.

Conflicts of interest

References

- Bateman IJ, Jones AP, Lovett AA, Lake IR, Day BH (2002) Applying geographical information systems (GIS) to environmental and resource economics. Environmental and Resource Economics 22: 219-269. https://doi.org/10.1023/A:1015575214292
- Bateman IJ, Harwood AR, Mace GM, Watson RT, Abson DJ, Andrews B, Binner A, Crowe A, Day BH, Dugdale S, Fezzi C (2013) Bringing ecosystem services into economic decision-making: land use in the United Kingdom. Science 341 (6141): 45-50. https://doi.org/10.1126/science.1234379
- Brander LM, Florax RJ, Vermaat JE (2006) The empirics of wetland valuation: a comprehensive summary and a meta-analysis of the literature. Environmental and Resource economics 33 (2): 223-250. https://doi.org/10.1007/s10640-005-3104-4
- Brander LM, Bräuer I, Gerdes H, Ghermandi A, Kuik O, Markandya A, Navrud S, Nunes PA, Schaafsma M, Vos H, Wagtendonk A (2012) Using meta-analysis and GIS for value transfer and scaling up: Valuing climate change induced losses of European wetlands. Environmental and Resource Economics 52 (3): 395-413. https://doi.org/10.1007/s10640-011-9535-1
- Brander LM (2013) Guidance manual on value transfer methods for ecosystem services. UNEP
- Brander LM, Van Beukering P, Nijsten L, McVittie A, Baulcomb C, Eppink FV, Lelij JA (2020) The global costs and benefits of expanding Marine Protected Areas. Marine Policy 116.
- Brander LM, de Groot R, Guisado Goni V, Schaegner P, Solomonides S, van 't Hoff V, McVittie A, Sposato M, Do L, Ghermandi A, Sinclair M (2021) Ecosystem Services Valuation Database (ESVD. Foundation for Sustainable Development and Brander Environmental Economics
- Caparrós A, Oviedo JL, Álvarez A, Campos P (2017) Simulated exchange values and ecosystem accounting: Theory and application to free access recreation. Ecological Economics 139: 140-149. https://doi.org/10.1016/j.ecolecon.2017.04.011
- Costanza R, D'Arge RS, de Groot R, Farber S, Grasso M, Hannon B, Limburg S, Naeem RV, O'Neill J, Paruelo RG, Raskin P, Sutton P, van den Belt M (1997) The value of the world’s ecosystem services and natural capital. Nature 387 (6630): 253-260. https://doi.org/10.1038/387253a0
- Day B (2013) An overview of valuation techniques for ecosystem accounting. Office for National Statistics
- Edens B, Maes J, Hein L, Obst C, Siikamaki J, Schenau S, Javorsek M, Chow J, Chan JY, Steurer A, Alfieri A (2022) Establishing the SEEA Ecosystem Accounting as a global standard. Ecosystem Services 54.
- Freeman AMI, Herriges JA, Kling CL (2014) The measurement of environmental and resource values: theory and methods. Routledge https://doi.org/10.4324/9781315780917

- Ghermandi A, Sheela AM, Justus J (2016) Integrating similarity analysis and ecosystem service value transfer: Results from a tropical coastal wetland in India. Ecosystem services 22: 73-82. https://doi.org/10.1016/j.ecoser.2016.09.014
- Grilli G, Ferrini S, Luisetti T, Turner K (2022) The role of choice experiments in natural capital accounting approaches: fast track versus simulated exchange value in the Deben Estuary saltmarshes. Journal of Environmental Planning and Management 65 (7): 1281-1300. https://doi.org/10.1080/09640568.2021.1957794
- Groot R, Brander L, Van Der Ploeg S, Costanza R, Bernard F, Braat L, Christie M, Crossman N, Ghermandi A, Hein L, Hussain S (2012) Global estimates of the value of ecosystems and their services in monetary units. Ecosystem services 1 (1): 50-61. https://doi.org/10.1016/j.ecoser.2012.07.005
- Hein L, Koppen K, Groot RS, Ierland EC (2006) Spatial scales, stakeholders and the valuation of ecosystem services. Ecological Economics 57: 209-228. https://doi.org/10.1016/j.ecolecon.2005.04.005
- Johnston RJ, Rolfe J, Zawojska E (2018) Benefit transfer of environmental and resource values: progress, prospects and challenges. International Review of Environmental and Resource Economics 12 (2-3): 177-266. https://doi.org/10.1561/101.00000102
- Johnston RJ, Boyle KJ, Loureiro ML, Navrud S, Rolfe J (2021) Guidance to enhance the validity and credibility of environmental benefit transfers. Environmental and Resource Economics 79 (3): 575-624. https://doi.org/10.1007/s10640-021-00574-w
- Kaul S, Boyle KJ, Kuminoff NV, Parmeter CF, Pope JC (2013) What can we learn from benefit transfer errors? Evidence from 20 years of research on convergent validity. Journal of Environmental Economics and Management 66 (1): 90-104. https://doi.org/10.1016/j.jeem.2013.03.001
- Kumar P (2012) The economics of ecosystems and biodiversity: ecological and economic foundations. Routledge https://doi.org/10.4324/9781849775489
- Rosenberger RS, Phipps TT (2007) Correspondence and convergence in benefit transfer accuracy: A meta-analytic review of the literature. In: Navrud S, Ready R (Eds) Environmental Values Transfer: Issues and Methods.
- Rosenberger RS, Loomis JB, et al. (2017) Benefit transfer. In: Champ PA, Boyle KJ, Brown TC, et al. (Eds) A primer on nonmarket valuation. https://doi.org/10.1007/978-94-007-7104-8_11
- Schaafsma M (2015) Spatial and geographic aspects of benefits transfer. Springer
- Schägner JP, Brander L, Maes J, Hartje V (2013) Mapping ecosystem services' values: Current practice and future prospects. Ecosystem Services 4: 33-46. https://doi.org/10.1016/j.ecoser.2013.02.003
- Schmidt S, Manceur AM, Seppelt R (2016) Uncertainty of monetary valued ecosystem services–value transfer functions for global mapping. PloS one 11 (3).
- U.N. Statistical Division (2021) System of Environmental-Economic Accounting—Ecosystem Accounting: Final Draft.
- Woodward RT, Wui YS (2001) The economic value of wetland services: a meta-analysis. Ecological economics 37 (2): 257-270. https://doi.org/10.1016/S0921-8009(00)00276-7

Endnotes

***1**

The accounting framework and the physical accounts described in Chapters 1-7 have been approved as an international statistical standard, whereas chapters 8–11 on monetary valuation and integrated accounting for ecosystem services and assets and chapters 12-14 on applications and extensions are described as internationally recognised statistical principles and recommendations.

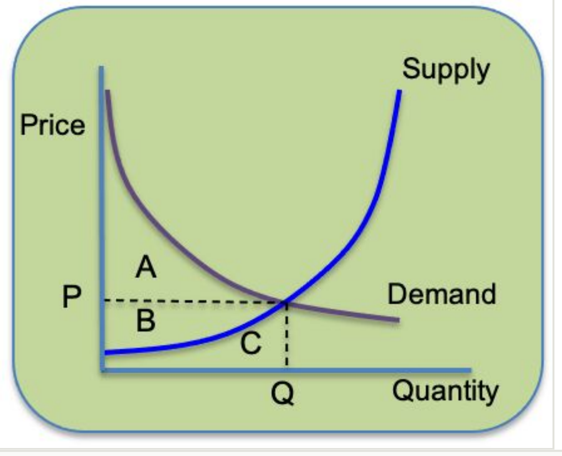

Figure 1.

Conceptual representation of demand and supply for a marketed good.

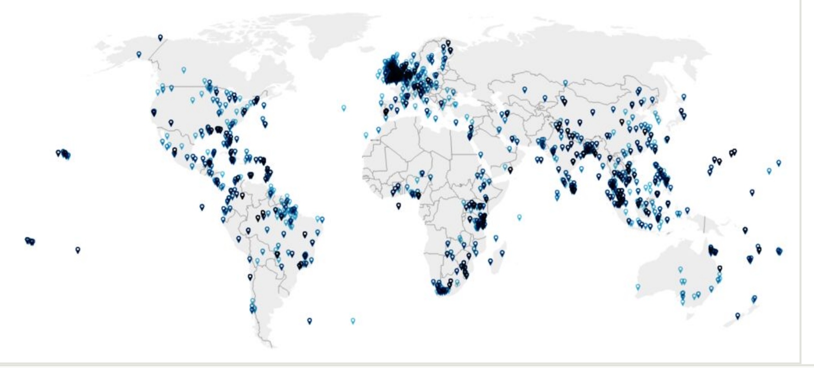

Figure 2.

Locations of valuation study sites included in the ESVD.

Table 1.

Number of ESVD value records by ecosystem service and valuation method (columns ordered by frequency of method use).

Valuation method acronyms: CE = Choice Modelling (Discrete Choice Experiment; Conjoint Analysis); CV = Contingent Valuation; DC = Damage Cost Avoided; DE = Defensive Expenditure; GV = Group Valuation (Participatory Valuation); HP = Hedonic Pricing; IO = Input-Output Modelling; MP = Market Prices (Gross Revenue); FI = Net Factor Income (Residual Value; Resource Rent); OC = Opportunity Cost; PF = Production Function; PP = Public Pricing; RC = Replacement Cost; RT = Restoration Cost; SC = Social Cost of Carbon; TC = Travel Cost; VT = Value Transfer (Benefits Transfer); OT = Other

Ecosystem Service	MP	CE	CV	DC	FI	TC	PF	RC	VT	HP	SC	RT	GV	OT	PP	IO	OC	DE	Total
Crop provisioning services	99		1	3	56			1			1	6	6						173
Grazed biomass provisioning services	28		3		11		10	26	1				1				8		88
Livestock provisioning services	14	2			1														17
Aquaculture provisioning services	23				8		1		1										33
Wood provisioning services	215	1	5		69			1	4				13						308
Wild fish and other natural aquatic biomass	263	52	32		79	2	54		11	59		3	1			10	3		569
Wild animals, plants and other biomass	250	36	11		27		33	14	11				17	1					400
Genetic material services	29	7	27						2					1	2				68
Water supply	26	5	26	59			30	27	5				1	1			2		182
Other provisioning services	209	26	6		7		2	12	9				7	21	1				300
Global climate regulation services	56	44	12	38			2	6	17		116	25	1	3	4		2		326

Rainfall pattern regulation services					3		3		1										7
Local (micro and meso) climate regulation							10	5											15
Air filtration services			4	460				30	1				1	1					497
Soil quality regulation services	7	1	10	13	5			53	5	1			1	4			1		101
Soil erosion control services	7	5	10	14		5	4	38	16	2				2			3		106
Solid waste remediation services	1		1	1			2	4	1										10
Retention and breakdown of nutrients	4	15	4	7			3	43	6				1	2					85
Retention and breakdown of other pollutants		3						9	1			1		1					15
Baseline flow maintenance services	3							4	1										8
Peak flow mitigation services									1										1
Coastal protection services	2	4	4	27			1	6	4										48
River flood mitigation services		40	3	19				15	3										80
Storm mitigation services	1	7	5	21			2	9	5	3			1			2			56
Pollination services	13	1					201		1					1					217
Pest control services				9			21	1	1										32
Disease control services									1										1

Nursery population and habitat maintenance	13	66	38		29		8	6	18			52	3	4	2			2	241
Other regulating and maintenance services	1	14		1	1		3	22	4		1			4					51
Recreation-related services	292	274	369		105	344	7		43	2		1	3	5		12	1		1,458
Visual amenity services	2	91	69	1	1	50			7	72				1	1				295
Education, scientific and research services	37	20	6			5			3				1	1	18				91
Spiritual, artistic and symbolic services	1	1	1		18												2		23
Other cultural services	1	80	9			2		1	2				1		5				101
Ecosystem and species appreciation	6	197	290			2		1	20				8	1	5				530
Total	1,603	994	946	673	420	410	397	334	206	139	118	88	67	54	38	24	22	2	6,535

Supplementary material

Suppl. material 1: Appendix 1: Valuation methods and value concepts

Authors: Brander, L.M.
Data type: Table
Download file (16.78 kb)