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The value of forest ecosystem services: A meta-analysis at the European scale and application to national ecosystem accounting

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ABSTRACT

A great share of ecosystem services (ES) at the global scale is provided by forest biomes, and acknowledging the value of forest ES is critically important towards sustainable decision making. The literature inventory of forest valuation studies is extensive and thus a significant mass of knowledge is already available concerning the value of forest ES. To this end, meta-analysis is a prominent benefit transfer approach that has been employed in the past to provide value transfers of forest ES taking advantage of contemporary knowledge. For the purposes of conducting a meta-analysis, we collected 158 primary studies, originated in Europe and dated from 2000 to 2017, of which 30 provided relevant information for a statistical meta-analysis, yielding 71 value observations. The results reveal that GDP per capita and the type of ecosystem service are significant determinants in explaining the variation in forest value. We also apply the meta-analysis model results so as to estimate the ES provided by forests in the Czech Republic. We find that the total value of forest is approximately 2842 US $ ha^{-1} $year^{-1}$, with regulation and maintenance ES being the most valuable services. We finally attempt to show the prospects of using this method for accounting purposes and illustrate the supply and use forest accounting tables based on the meta-analysis outcomes. Meta-analysis can potentially form a promising decision support tool for start-up accounts considered as a second best valuation approach. Nonetheless, the method still remains questionable due to the great variation in how primary valuation studies are reported and the lack of guidelines with reference to its application in ecosystem accounting as such.

1. Introduction

Forests form a vital source of life for ensuring the flow of a wide range of ecosystem services (ES). They provide raw timber material, non-timber products (resin, medicinal plants, etc.) and wild food (berries, mushrooms, honey, etc.). Forests also regulate local and global climate, improve soil retention and water quality, facilitate pollination, make barriers to natural hazards, enhance biodiversity, and provide recreational and aesthetic values in rural and peri-urban landscapes (Chiabai et al., 2011; Bravo-Oviedo et al., 2014).

Several studies in the past have attempted to estimate the value of forest ES; work by Acharya et al. (2019) reports a thorough literature review of around 1156 forest valuation studies from 1994 to 2017, globally. The study by Costanza et al. (1997), which is one of the first studies in ES valuation, estimated that 38% of the total ES value at the global level comes mainly from forests and wetlands. The study revealed that ES provided by temperate forests alone have an average value of approximately US$ 300/ha/year (in 1994 US$). Ninan and Inoue (2013) reported a literature review of studies that estimated the value of forest ES. The estimates significantly vary across forest sites, countries and regions: from US$ 8/ha to US$ 4080/ha (in 2010 PPP US$) (in Ninan and Inoue, 2013); whereas regulation and maintenance services – watershed protection, carbon sequestration, waste treatment and pollination services – showed higher values than the other services considered.

As in Costanza et al. (1997), several studies have employed benefit transfer (BT) methods to provide estimates for forest ES. BT is a cost and time effective method by which results are extracted from previous studies so as to construct a transferred value. BT practices are eligible for valuing ecosystems as well as specific types of ES (Boyle and Parmeter, 2017). Its utility was recognized in the early 90 s when the U.S. Environmental Protection Agency used simple value transfers from a study site or average of values from several study sites to conduct regulatory impact assessments. Since then, several empirical applications, as well

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as theoretical ones, have led to a BT upgrade aimed at advancing the credibility of BT value estimates (see Johnston and Rosenberger, 2009; Johnston et al., 2015, 2018; Boyle and Parmeter, 2017).

A BT may be applied through different approaches. The literature identifies two main approaches, i.e. that of unit value transfers and that of benefit function transfers (Rosenberger and Loomis, 2003; Johnston and Rosenberger, 2010; Newbold and Johnston, 2020). A unit value transfer involves the transfer (as is or adjusted) of a single number or set of numbers from past primary studies. A benefit function transfer involves an estimated parametric function derived from original studies. The function can be elicited through a single study or through a set of studies. The former is classified as a single study benefit function, where information is gathered by a single primary study, while the latter is classified as a meta-analysis (MA) transfer, where results from prior studies are synthesized through econometric modelling. There is evidence that a MA (also called a meta-regression model analysis) can reduce transfer errors and provide more robust and accurate transfers than other alternative methods (Johnston and Rosenberger, 2010; Kaul et al., 2013).

In the literature there are examples of BT applications for valuing forest ES. The scope ranges in terms of the type of BT employed, i.e. MA transfer (Barrio and Loureiro, 2010; Chiabai et al., 2011; Hjerpe et al., 2015; Lindhjem, 2007; Ojea et al., 2010, 2016) vs unit value transfer (Müller et al., 2019), in terms of scale, i.e. national (Bateman and Jones, 2003; Bateman et al., 1999) vs regional (Zandersen and Tol, 2009; Lindhjem, 2007) vs global (Chiabai et al., 2011; Ojea et al., 2010, 2016), as well as in terms of the types of ES that have been valued. Besides spatial considerations, Zandersen e al. (2005) updated a BT application accounting for temporal effects in the value of recreation ES from forests.

The latest study in the literature concerning a MA transfer approach for eliciting forest ES is that of Ojea et al. (2016). The authors conducted a global MA from studies published during the past 30 years. Their dataset included 52 studies (and 205 observations) from 1995 to 2007. Besides peer review MA studies that employ a systematic literature review to conduct a BT, there are open access datasets that report the economic value of ES for various ecosystems and which can provide data for BT applications. The most widely used databases are the Ecosystem Service Valuation Database (ESVD) (Groot et al., 2012) and the Environmental Valuation Reference Inventory (EVRI) database. With respect to forest studies, ESVD comprises studies dated from 1983 to 2009. EVRI was launched in 1997 and since then is being updated steadily, incorporating studies across all regions of the globe.

In this study we applied a systematic literature review of forest valuation studies conducted in Europe during 2000–2017. Our first objective has been to update the literature as well as the current available datasets by mining the most recent and properly assessed studies. Next, we aim to provide an updated insight on the monetary values of forest ES through the employment of a meta-regression analysis. The use of European studies in the regression model makes estimates comparable and transferable.

Further, we aim to explore the use of BT estimates in ecosystem accounting and carry out an empirical application of value transfers for the Czech Republic in light of ecosystem accounting principles. Ecosystem accounting is a framework for integrating ecosystems with national accounting and reporting systems. This framework was standardized in the System of Environmental-Economic Accounting (SEEA), which has been proposed and supported by the United Nations (UN) since 1993 (UN, 1993). SEEA formed the methodological guidelines of the ecosystem accounting framework. This framework follows the SEEA EEA-Experimental Ecosystem Accounting (SEEA-EEA) Technical Guidelines, released in 2015 to support national efforts at ecosystem accounting (UNEP, 2015 in La Notte et al., 2017a, 2017b). The experimental dimension of the SEEA guidelines has been eliminated as a consequence of the framework being under global consultation, incorporating several findings that have been reported in a range of technical materials on ecosystem accounting during the period 2013–2020 (UN, 2020).

In SEEA EEA (UN, 2017) there is a discrete note about the BT method and its use in the absence of resources for primary data collection, but it was not included in the list of appropriate valuation techniques (Table 6.1 in UN, 2017). In light of the recent SEEA updates, the method is under consideration and is discussed in the thematic section 'Spatial variation and value generalization for the purpose of ecosystem accounting'[1] of the updated SEEA draft document (UN, 2020 pp. 173–174). BT can be a promising method in monetary valuation that would accelerate empirical applications of ecosystem accounting on the national scale (Vačkářů and Grammatikopoulou, 2019; Grammatikopoulou et al., 2020). To this end we aim to explore how BT can be of use in developing forest accounts for the Czech Republic.

The paper is structured into 6 sections. Section 2 provides an overview of previous studies that employed MA to value forest ES, Section 3 describes the methodology, i.e. the systematic literature review and the econometric specification, Section 4 reports the results, Section 5 shows how MA results can be applied in ecosystem accounting, and Section 6 incorporates our concluding remarks.

2. How has meta-analysis been applied and performed in past studies? Milestone results

We selected the most recent studies on MA applications in forest ES valuation so as to illustrate how MA has been employed and what are the lessons learnt. Table 1 reports the literature notes. The scope of analysis for the majority of studies covers primary studies from countries around the globe. The number of studies ranges from 22 to 65, and that of observations varies between 21 and 248. Also, the study objectives differ. Barrio and Loureiro 2010 and Hjerpe et al. (2015) apply the MA approach to assess forest conservation programs and not forest ES *per se*. Chiabai et al. (2011) employ a MA to value cultural ES, both for recreational as well as for passive use. Ojea et al. (2010) focuses on the biodiversity values of global forests. The MA function includes different types of forests in the explanatory variables list, such as Mediterranean, boreal, temperate coniferous, temperate mixed, tropical wet and tropical mixed. The study evaluates different sections of ES (i.e. regulating, provisioning, and other services), as well as biodiversity of fauna and flora ES in particular. Ojea et al. (2016) applied MA in the evaluation of forest ES under the REDD initiatives. Both studies by Ojea et al. (2010) and Ojea et al. (2016) seem to be the most inclusive in terms of the number of studies and observations used, as well as in terms of the model specification, also incorporating many explanatory variables, ES, and valuations – including forest specific ones.

Econometrically, studies follow a common approach, employing in most cases a semi-log functional form which is estimated through a linear ordinary least squares (OLS) regression analysis. To correct for heteroscedasticity, studies applied Huber-White robust standard errors. Ojea et al. (2016) also explored a random effects model using data in the form of a panel data structure. Some studies (e.g. Chiabai et al., 2011; Ojea et al., 2010), though, did not provide much detail on the model and analysis specifics.

Studies performed adequately well with a R^2 of approximately 0.5 (e.g. in Chiabai et al., 2011; Ojea et al., 2010, 2016) or even higher of 0.9 (in Barrio and Loureiro, 2010). Some studies performed a transfer application (e.g. Hjerpe et al., 2015; Chiabai et al., 2011; Ojea et al., 2016), but none of them reported the transfer errors of their model estimates.

Outcomes with respect to forest specific ES values are only reported in the Ojea et al. (2016) study. The study reports the estimates of ES in REDD- and non REDD-targeted countries. The full sample model

[1] In the SEEA EA document the term 'value transfer' is used instead of 'benefit transfer'.

Table 1
Previous MA application in forest valuation studies.

Authors	Year	Functional form	Variables	Scale	Analysis	No of studies	Obs
Barrio and Loureiro	2010	Semi-log	Study characteristicsCharacteristics of goods Site and socio-economic characteristics	Global	OLS-Huber-White adjusted standard error	35	101
Chiabai et al.	2011	Semi-log	Site and socio-economic characteristics Type of forest	Global	/	27	59 (for recreational use) and 21 (for passive use values)
Hjerpe et al.	2015	Semi-log and linear-log	Conservation type Conservation scope Valuation characteristics Context characteristics	Europe, Canada and US	OLS-Huber-White adjusted standard error	22	127
Ojea et al.	2010	Linear (with interaction effects)	Forest specific (e.g. forest area, type of forest, protection status, forest ES) Biodiversity indicators Context characteristics (valuation method, income, population density, year of publication)	Global	OLS	65	248
Ojea et al.	2016	Semi-log	Study characteristics (local scale, publication year, impact factor, methods) Forest valuation characteristics (REDD, forest area, ES) Site and socio-economic characteristics (GDP, CO2 emissions, carbon uptake)	Global	OLS, random effects	51	205

revealed that forests provide an average economic value of 1541 US$/ha/year for the category air quality and water regulation, and 1268 US$/ha/year for food and fibre. Wild species diversity showed an average value of 1279 US$/ha/year, while recreation was valued around 218 US$/ha/year. The authors commented that these estimates are comparable with previous findings from the literature, as well as with values provided by *The Economics of Ecosystems and Biodiversity* (TEEB, 2010) initiative.

3. Methodology

3.1. Systematic review

We performed a systematic search in the Scopus and ISI Web of Knowledge science databases using the keywords reported in Table 2. Systematic review is a step-wise methodology that aims to collect, assess and synthesise existing research data. The structure of the systematic review that we followed in the present empirical application is thoroughly described in Vačkářů et al. (2018). We limited our search to European studies only, and also limited the time-span of studies to 2000–2017. Moreover, we excluded grey literature and technical reports, and limited our review to only information published in peer-reviewed journals. We arrived at 158 original studies, of which only 30 were assessed as relevant for incorporation in the BT database. Table 1 in the Appendix presents the selected studies and the number of observations per study.

3.2. Database compilation

After screening primary studies, a database of selected studies was built up and structured in line with the template shown in Table 3 in the Appendix (details of the process are reported in Vačkářů et al., 2018). One of the major challenges in BT applications is structuring the database and organising the data elicited from primary studies. As mentioned in past applications (e.g. Brander et al., 2007; Lara-Pulido et al., 2018), there is a great variation in the way values are reported in primary studies. We noticed a variation in units, i.e. some state economic value per hectare others in biophysical units, or per visit or respondents. This clearly depends on the ES under consideration. There is also diversity in the way forest biome, ES and valuation methods are specified, and hence preparation is required in order for the data to be homogenized. Tables 3–5 report the structured path we followed in order to homogenize the extracted information.

We assigned each of the forest biome studies according to the ecoregion map called Ecoregions2017©Resolve (Dinerstein et al., 2017) (Table 3). Forest valuation studies could be located to different ecoregions and biomes, respectively. As some of the studies were conducted at the local or regional level with higher spatial resolution, they could be located relatively precisely. However, some studies covered whole states or broader regions, and here we assigned them only to the general dominant biome class.

Considering that the BT application will be ultimately used for ecosystem accounting purposes, valuation methods (Table 5) were classified in line with the SEEA-EEA framework (UNEP, 2015; UN, 2017). The last column of Table 5 reports the eligibility of the method in accounting and whether or not the exchange value principle is violated.

In order to enable a comparison between economic values, we standardized them to 2016 international US$ dollars per hectare per year. We used the consumer price index and purchasing power parity converters from the World Bank World Development Indicators to standardize values estimated in different years and different currencies.

Finally, the studies were assessed with a score out of 10 according to a set of quality criteria (Table 3, Appendix). The objectives of the primary studies were also incorporated as inputs in the database (Table 2, Appendix; more details in Barton et al., 2018).[2]

3.3. Meta-regression model

Our empirical meta-regression model is specified under a semi-log functional form (Eq. (1)) where the dependent variable (y) is a vector of values in US$ per hectare per year in 2016 prices. In the semi-log part of the model, the coefficients measure the proportional change in the dependent variable for a given absolute change in the value of the explanatory variable. The coefficients in the log–log part of the model correspond to elasticities, i.e. a proportional change in the dependent variable for a given proportional change in the value of the explanatory variable. The explanatory variables are presented in Table 6 and

[2] These elements of the database were not used in our empirical analysis but provide important information about the screening process of the primary studies.

Table 2
Results of systematic review.

Database	Keywords	Timespan	No of studies identified	No of potentially relevant studies	No of relevant studies
Web of Science Scopus EKOSER	"ecosystem service" AND "forest" AND "valuation" AND "Europe" "ecosystem" AND "service" AND "forest" AND "valuation" + EXCLUDE non-European countries	2000–2017	158	66	30

Table 3
Classification of the forest ecoregions and biomes of the valuation studies.

Mediterranean Forests, Woodlands & Scrub	• Iberian sclerophyllous and semi-deciduous forests • Italian sclerophyllous and semi-deciduous forests • Northeast Spain and Southern France Mediterranean forests • Southwest Iberian
Temperate Broadleaf & Mixed Forests	• Baltic mixed forests • Dinaric Mountains mixed forests • European Atlantic mixed forests • Pannonian mixed forests • Western European broadleaf forests
Temperate Conifer Forests	• Alps conifer and mixed forests • Carpathian montane forests

Source: Ecoregions 2017 © Resolve.

grouped into three main parts, i.e. site and socio-economic characteristics (X_{si}), study characteristics (X_{st}), and biome and ES valuation characteristics (X_{es}).

The estimated model is the following:

$$\log y_i = a + X_{si}b_s + X_{sti}b_{st} + X_{esi}b_{es} + \varepsilon_i \tag{1}$$

where α stands for the constant term, β vectors refer to the coefficients associated with the respective explanatory variables to be estimated, ε is a vector of independently and identically distributed residuals, and i corresponds to the study.

We estimated both a linear OLS regression and a random effects model, which assumes that unobserved effects are uncorrelated with explanatory variables. The latter was explored because the dataset contains several observations for some of the studies in the dataset and hence the data could be estimated in a panel data structure. The Lagrange multiplier test statistic resulted in a small value, thus arguing in favour of classical regression with no group specific effects (Table 4, Appendix). Extreme values over 10,000 USD per ha of the dependent variable were excluded. The analysis was performed using the Nlogit 6 software package (Econometric Software, Inc., Plainview, NY, USA).

The coefficient estimates can be used to forecast the values of certain ES or certain forest biomes. The analysist has to select the values of the explanatory factors, multiply them with the corresponding coefficient, and then aggregate them (Johnston et al., 2015). This sum corresponds to the log_{10} of the predicted value of ES of the biome (Eq. (2)), where$\sigma_\varepsilon{}^2$ corresponds to the residual variance from the regression model. The term$\sigma_\varepsilon{}^2/2$ corrects for the log transformation bias.

$$\hat{y} = 10^{(sum\ of\ products + \sigma_\varepsilon{}^2/2)} \tag{2}$$

To explore how accurate the BT values are, value transfer errors are computed. Value transfer may result in transfer errors due to

Table 4
Ecosystem Services classification by CICES.

Section	Division	Group	Class	Example of service	Short description
Regulation and Maintenance Services (biotic)	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of temperature and humidity, including ventilation and transpiration	Regulating the physical quality of air for people	Air quality
Regulation and Maintenance Services (biotic)	Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	Regulation of chemical composition of atmosphere and oceans	Regulating our global climate	Climate regulation
Regulation and Maintenance Services (biotic)	Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats (including gene pool protection)	Providing habitats for wild plants and animals that can be useful to us	Habitat maintenance
Regulation and Maintenance Services (abiotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Liquid flows	Physical barriers to flows	Liquid flows regulation
Regulation and Maintenance Services (biotic)	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Mass flow	Physical barriers to landslides	Mass flow regulation
Cultural ES (abiotic)	Direct, in-situ and outdoor interactions with natural physical systems that depend on presence in the environmental setting	Physical and experiential interactions with natural abiotic components of the environment	Natural, abiotic characteristics of nature that enable active or passive physical and experiential interactions	Ecotourism	Leisure
Provisioning ES (biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials or energy	Fibres and other materials from cultivated plants, fungi, algae and bacteria for direct use or processing (excluding genetic materials)	Harvestable surplus of annual tree growth	Timber
Provisioning ES (biotic)	Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition	Harvestable volume of non-timber products	Non-timber

Source. CICES V5.1 (Haines-Young and Potschin, 2018).

Table 5
Classification of economic valuation methods.

Approach	Type of Valuation method	Appropriate in ecosystem accounting
Price-based	• Market prices	Yes, but under consideration of the market structures
Cost-based	• Avoided damage cost	Yes, under certain assumptions*
	• Replacement cost	Yes, under certain assumptions**
	• Restoration cost	No, since it does not determine a price for an individual ecosystem service.
	• Production function approach	Yes, provided the price refers to a *product rather than an asset*
Production-based	• Net factor income approach	Yes, but under consideration of the market structures.
Revealed preference methods	• Hedonic pricing	Yes.
	• Travel cost	Possibly yes, depending on the actual estimation techniques and whether the approach provides an exchange value
Stated preference methods***	• Contingent valuation	No, does not measure exchange values
	• Choice modelling	No, does not measure exchange values
	• Deliberative group valuation	No, does not measure exchange values

*(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 the potential costs of abatement or replacement.
** (i) that the estimation of the costs reflects the ecosystem services being lost; (ii) that it is a least-cost treatment; and (iii) that it would be expected that society would replace the service if it was removed.
Source. (UNEP, 2015; UN, 2017)
*** stated preference methods may be used for estimating simulated market values which are consistent with exchange values.

incompatible factors from one site to another, or misspecifications of variables reflected in a poorly represented dataset that underlies the value function (Brouwer, 2000). Transfer errors refer to the difference between the model prediction for a policy site and the values estimates from an original study (Rosenberger and Stanley, 2006). An indicator to measure the relative difference is:

$$TE = \frac{Value_{transf} - Value_{obs}}{Value_{obs}} \quad (3)$$

where TE stands for the transfer error, $Value_{transf}$ the estimated value, and $Value_{obs}$ the observed value (Kirchhoff et al., 1997). A small transfer error implies accuracy in transferred values. Transfer errors are categorized in four main scales (Navrud and Brouwer (2007), in Boyle and Parmeter, 2017): errors less than ± 20% suggest a good fit between the policy and study site; errors within ± 50% suggest an adequate fit; errors within ± 100% correspond to poor; while errors over ± 100% imply very poor fits and BT predictions need to be considered with caution. Rosenberger (2015) reports median transfer errors of 36% for benefit function transfers (means of 65%). Nevertheless, the level of transfer errors and the degree of accuracy depends on the policy context (Johnston et al., 2020). Additional research and consensus is required regarding the degree of accuracy that is expected in the context of ecosystem accounting (Grammatikopoulou et al., 2020).

4. Results

4.1. Descriptive results

The mean value of forest biomes varies according to the type of biome (Table 7). The mean value of temperate broadleaf and mixed forests was 1204 US$ ha^{-1} $year^{-1}$, which was much larger compared to the corresponding figure for Mediterranean and conifer forest biomes.

Valuation methods were classified in 5 categories, i.e. cost-based, price-based, revealed, stated and other. The data showed that there is a preference in the choice of valuation method given the type of ES under valuation (Fig. 1). For example, over 80% of provisioning services were valued by direct price-based approaches, while the stated preferences method was often selected for valuing cultural services. However, the pattern of selection was not very clear for regulation and maintenance ES.

Table 8 reports the mean values of ES per type of valuation method. Overall, regulation and maintenance services were assessed at a higher level than cultural and provisioning ones. In particular, 'Liquid flows' regulation and maintenance ES were on average valued at 1566 US $ ha^{-1} $year^{-1}$, which is considerably higher than the value of air quality,

Table 6
Description of explanatory variables.

Variable	Description of variable	Mean	Std. dev.	Cases
Site and socio-economic characteristics				
GDP per capita	Log of GDP per capita	4.396	0.189	93
Population density	Log of population density	2.157	0.288	93
Forest area	Log of forest area	4.631	1.182	76
Protected	Dummy: 1 = Protected, 0 = otherwise	0.430	0.498	93
National scale	Dummy:1 = National scale of study, 0 = otherwise	0.183	0.389	93
Regional scale	Dummy:1 = Regional scale of study, 0 = otherwise [R1]	0.387	0.490	93
Study characteristics				
Year	Year of valuation	2010.130	4.852	92
Cost-based	Dummy:1 = Service valued by cost-based method, 0 = otherwise	0.196	0.399	92
Price-based	Dummy:1 = Service valued by price-based method, 0 = otherwise	0.380	0.488	92
Stated preference-based	Dummy:1 = Service valued by stated preference method, 0 = otherwise[R2]	0.239	0.429	92
Biome and ES characteristics				
Temperate conifer forests	Dummy:1 = Temperate conifer forests, 0 = otherwise	0.318	0.468	88
Temperate broadleaf & mixed forests	Dummy:1 = Temperate broadleaf & mixed forests, 0 = otherwise[R3]	0.477	0.502	88
Timber	Dummy:1 = Timber provision, 0 = otherwise [R4]	0.174	0.381	92
Air quality	Dummy:1 = Air quality, 0 = otherwise	0.065	0.248	92
Climate regulation	Dummy:1 = Climate regulation, 0 = otherwise	0.163	0.371	92
Habitat maintenance	Dummy:1 = Habitat maintenance, 0 = otherwise	0.054	0.228	92
Liquid flows	Dummy:1 = Liquid flows regulation, 0 = otherwise	0.098	0.299	92
Mass flows	Dummy:1 = Mass flows regulation, 0 = otherwise	0.109	0.313	92
Leisure	Dummy:1 = Leisure, 0 = otherwise	0.239	0.429	92

R[1]: Reference is Local scale studies.
R[2]: Reference valuation method is Revealed and other methods.
R[3]: Reference is Mediterranean forests.
R[4]: Reference service is Non-timber provision.

Table 7
Mean value of biome (international US$ ha^{-1} $year^{-1}$, constant prices 2016).

Biome	Mean	N	Std. deviation
Mediterranean forests	331.037	24	504.606
Temperate broadleaf & mixed forests	1204.446	42	2291.706
Temperate conifer forests	115.538	30	193.542

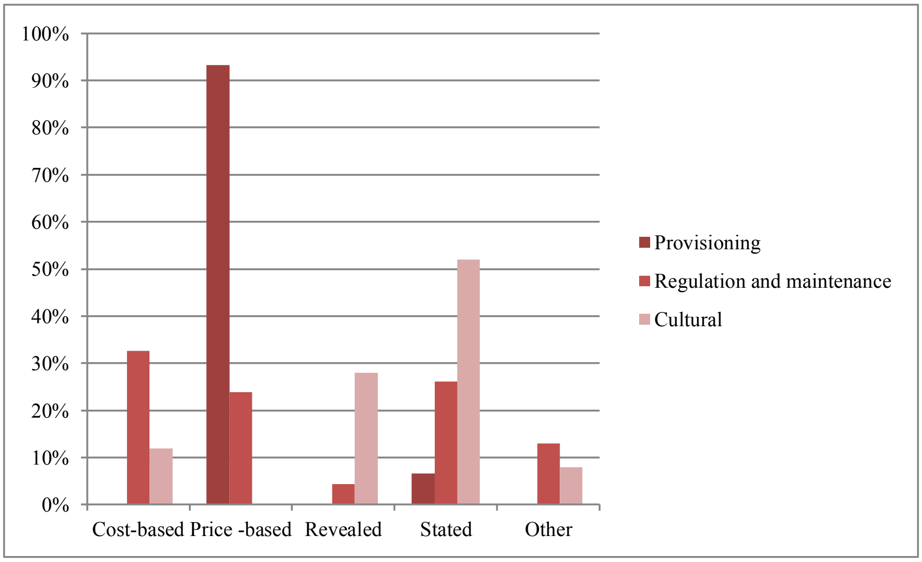

Fig. 1. % ES section valued according to method.

Table 8
Mean value of ecosystem services per applied valuation method (international USD ha^{-1} year^{-1}, constant prices 2016).

	Cost-based	Price-based	Stated	Revealed	Other methods	N	Mean (Std. dev)
Timber provision	/	144.671	/	/	/	16	144.671 (154.471)
Non-timber provision	/	37.974	/	/	/	9	37.974 (44.996)
Air quality	514.601	/	17.708	/	173.374	6	204.301 (213.726)
Climate regulation	15.416	1948.509	47.963	/	29.876	15	1310 (2727.695)
Habitat maintenance	333.432	/	457.827	/		5	432.948 (356.802)
Liquid flows	1753.342	/	/	70.466	/	9	1566.355 (1688.771)
Mass flow	483.729	/	767.314	66.499	158.881	10	583.799 (588.305)
Leisure	7.417	/	168.182	1617.847	/	22	606.671 (2075.259)

climate regulation, habitat maintenance, and mass flow regulation. The high average of these regulation and maintenance ES was mainly extracted by a cost-based valuation approach, whereas revealed applications resulted in a much lower value. This signals the huge diversity of values given the employed method. The large standard deviations which were recorded in climate regulation, liquid flows regulation, and leisure ES similarly implies this huge heterogeneity in values.

4.2. Meta-regression model results

The regression model results are displayed in Table 9. Overall, the model explains almost 52% of the dependent variable variation as revealed by the adjusted R^2. The linear OLS was performed using White-adjusted standard errors, given that the Breusch-Pagan test indicated that the model is heteroscedastic. [3]

In the group of site and socio-economic characteristics, only the GDP per capita showed a statistically significant effect. GDP per capita had a positive and significant coefficient indicating that if GDP per capital increases by 10%, then the value of ES increases by 15%. This is comparable with earlier BT studies (e.g. Brander et al., 2006) also related to forest valuation (Ojea et al., 2016; Chiabai et al., 2011). As indicated in previous studies (Ojea et al., 2010; Chiabai et al., 2011), the size of forest area has a negative coefficient indicating decreasing returns of scale for the forest area, although our study coefficient was not found to be significant. This implies weak sensitivity to marginal changes in values with respect to the scope of change. In ecosystem accounting terms where the scope of change refers to an accounting period, the values of ES will not respond to marginal changes in forest extent values. This coefficient can be interpreted as the elasticity of the forest area, and is rather small compared to the findings of Ojea et al. (2010) and Chiabai et al. (2011), where elasticity was approximately 0.5. Studies in protected, local areas would result in higher ES values, as the protected and local scale indicators denote. However, neither indicators were statistically significant.

Among the study characteristics, no explanatory variable was able to explain value variation at a statistically significant level. The results of the valuation methodology dummy variables showed that value estimates from price- and stated preference-based approaches were higher than the estimates from other valuation methods, yet not at a

[3] Multicollinearity was checked by examining the coefficients of the pairwise correlation matrix. The coefficients of the site and socio-economic characteristics seemed to be correlated, but when regression was performed – omitting some of the related explanatory variables – the results and model performance did not markedly change.

Table 9
Linear OLS model results.

	Coefficient	Std. err.	Prob.
GDP per capita	1.509	0.834	0.075
Population density	−0.034	0.685	0.960
Forest area	−0.053	0.118	0.658
Protected	0.045	0.240	0.853
National scale	−0.702	0.487	0.154
Regional scale	0.080	0.309	0.798
Year	0.014	0.025	0.577
Cost-based	0.137	0.333	0.682
Price-based	0.841	0.586	0.156
Stated preference-based	0.442	0.371	0.237
Temperate conifer forests	0.054	0.371	0.885
Temperate broadleaf & mixed forests	0.423	0.408	0.303
Timber provision	0.716	0.273	0.011
Air quality	1.740	0.638	0.008
Climate regulation	0.749	0.305	0.017
Habitat maintenance	2.102	0.678	0.003
Liquid flows	2.149	0.601	0.001
Mass flows	1.944	0.636	0.003
Leisure	1.053	0.620	0.094
Constant	−34.549	50.427	0.495
N	71		
R^2	0.655		
R^2 adjusted	0.527		
Breusch-Pagan test (prob)	33.69 (0.02)		
F (19, 51)	5.113		
Prob > F	0.000		
Standarderrorofε	0.601		
Transfer error: Mean	107.76%		
Transfer error: Median	55.23%		

R[1]: Reference is Mediterranean forests.
R[2]: Reference is Local scale studies.
R[3]: Reference service is Non-timber provision.
R[4]: Reference valuation method is Revealed and other methods.

statistically significant level. Ojea et al. (2010 and 2016) reported similar findings, particularly in reference to the effect of stated preference methods.

Among forest type biomes, temperate broadleaf and mixed forests were associated with higher values per ha by as much as 42% compared to Mediterranean forests. Ojea et al. (2010) and Chiabai et al. (2011) used comparable classifications of forest biome, but those studies covered global data. Ojea et al. (2010) commented that temperate conifer forests were related with higher economic values than Mediterranean forests. In line with Chiabai et al. (2011), our results did not support a strong relation between forest type and ES valuation. With respect to ES coefficients, we observed that all categories have a positive and significant sign with respect to the omitted variable, i.e. non-timber ES. Regulation and maintenance ES, i.e. habitat maintenance, liquid flows, mass flows and air quality ES, showed the highest coefficient estimates. Hence the value of ES would be almost 4 times larger when the estimated service involved regulation and maintenance. Similar findings are indicated in Ojea et al. (2016), though for a smaller list of ES.

The mean and median transfer errors are 108% and 55%, respectively, which are lower compared to other value transfer exercises that refer to ecosystem valuation of a different scope and scale (e.g. in Brander et al., 2007). Still, these estimates conclude to an adequate (based on median) or poor (based on mean) fit with BT predictions.

4.3. Value transfer

Table 10 illustrates how the MA results can be employed to estimate the ES provided by forest at a national scale (as in Johnston et al., 2015). We report the case of the Czech Republic. In the example, we use the value of site and socio-economic specific variables (e.g. GDP) with respect to the Czech case, and controlled for several dummy variables such as the type of biome and ES. The predicted values are indicated in US$ per hectare per year, corrected for log transformation bias according to Eq. (2). The example focuses on valuation of the 'Air quality' service, but the same process can be iterated for all ES by changing the selected dummies. Since this exercise was undertaken for the underlying purpose of ecosystem accounting, the selection of valuation method was made in line with SEEA EEA requirements (see Table 5). The ES valuation was processed controlling only for cost- and price-based valuation methods.

Table 10
Value transfer example.

Variables	A: Parameter estimates	B: Selected variable value	C = A*B
Constant	−34.549	1.000	−34.549
GDP	1.509	4.266	6.438
Population density	−0.034	2.135	−0.073
Forest area	−0.053	6.426	−0.338
Protected	0.045	0.000	0.000
National scale	−0.702	1.000	−0.702
Regional scale	0.080	0.000	0.000
Year	0.014	2016	28.405
Cost-based	0.137	1.000	0.137
Price-based	0.841	1.000	0.841
Stated preference-based	0.442	0.000	0.000
Temperate conifer forests	0.054	1.000	0.054
Temperate broadleaf and mixed forests	0.423	1.000	0.423
Timber provision	0.716	0.000	0.000
Air quality	1.740	1.000	1.740
Climate regulation	0.749	0.000	0.000
Habitat maintenance	2.102	0.000	0.000
Liquid flows	2.149	0.000	0.000
Mass flows	1.944	0.000	0.000
Leisure	1.053	0.000	0.000
Sum of products			2.376
$\sigma_\varepsilon{}^2/2$			0.181
$\hat{y}$			360.501

Calculations were based on the following values:
GDP per capita = 18,463.387 in 2016US$ (*source*: https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=CZ-SI).
Population density = 136.6 in persons per km, 2016 (*source*: http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00003)
Forest land, total: 2,669,850 in ha 2016 (*source*: https://vdb.czso.cz/vdbvo2/faces/en/index.jsf?page=vystup-objekt&pvokc=&katalog=30841&pvo=LES02&z=T#w=)

We employed the same exercise for each of the ES. The results are presented in Table 11. As already expected from the model outcome, regulation and maintenance services such as 'habitat maintenance', 'liquid flows' and 'mass flows' showed the highest estimates. This is an important outcome considering that the value of these services and consequently their contribution to the economy is often neglected. The same table shows the comparison of our model estimates with related earlier studies, i.e. Costanza et al. (1997) and Ojea et al. (2016). These studies, although they refer to global scale BT applications, report estimates of similar ES provided by forests. For ES where pairwise comparison is permitted, we observe that the level of values is of similar magnitude.

The total value of forest according to our estimates is approximately 2842 US\$ ha^{-1} year^{-1}, given the selected variable values of the value transfer exercise and the specified list of ES. The only comparable study from the Czech Republic is that of Frélichová et al. (2014), where the value of forest reached almost 90,000 EUR per ha. The author commented that this value is already higher compared to previous studies, but this can be attributed to the high value of recreation (2191 EUR/ha). The study by Frelichova employed a unit value BT using studies published from 2000 to 2012.

Table 11
Economic value of ecosystem services (international US$ ha^{-1} $year^{-1}$, constant prices 2016) and a comparison of results.

Ecosystem service	Benefit function transfer (regional EU scale, units in 2016 US$/ha/year)	Costanza et al. (1997) (global scale, values for temperate/ boreal forest, in 2010 US$/ha/year)	Ojea et al. (2016) (global scale, values for all type of forests, in 2008 US$/ha/year)
Provision of timber	34.090	37	/
Provision of non-timber	6.558	88	/
Air quality	360.501	/	1541.347*
Climate regulation	36.779	129	/
Habitat maintenance	829.921	/	1279.493
Liquid flows	923.712	/	/
Mass flows	576.483	/	/
Soil formation	/	15	/
Waste treatment	/	128	/
Biological control	/	6	/
Cultural amenities	/	3	/
Cultural leisure	74.110	53	218.629
Provision of water	/	/	/
Total	2842.154	459	3039.469

Source: Own calculation.
*Indicated as 'Air quality and water regulation'.

5. Application of ecosystem services accounts

The SEEA EEA framework[4] describes three main categories of accounts: accounts for ecosystem assets, accounts for ES, and integrated accounts. The core of the SEEA EEA is the compilation of ES accounts, and particularly of ES supply and use tables (SUT) in physical and/or monetary terms. The System of National Accounts (SNA) sets the basis of SUT, which evolved first into the SEEA CF and later into the SEEA EEA. This evolution is thoroughly described in La Notte et al. (2017a) and La Notte et al. (2017b). The purpose of SUT is to show the contribution of ecosystems to economic products and services.

The supply table shows the flow of each service provided by different ecosystem types, following the MAES ecosystem classification (Maes et al., 2012). The use table shows the flow of each ecosystem service to different users, i.e. economic sectors or households consistent with the Statistical Classification of Economic Activities in the European Community (NACE rev. 2). SUT are balanced accounts since both report the actual flow.[5]

The same ecosystem type can provide more than one service and the same ES can be used by different users. Hence the challenge of compiling SUT lies in allocating the supply of ES to different ecosystem types, as well as allocating the actual flow of each ES to different users. For some ES the allocation of ES flow to ecosystem types in the supply table, and to economic sectors and households in the use table, is rather straightforward. In the case of timber provision, for example, "woodland and forest" provides timber provision and the economic sector that uses the timber is the 'Forestry' primary sector. For other ES, ex post processing is needed to incorporate the weight of each ecosystem type in providing the ES. The weight is determined by the literature and/or expert opinion. On the use side, allocation of ES flow is based directly on the spatial model output. The land cover type that corresponds to economic sectors and households and the actual ES flow of demand are revealed in a spatial model (Vallecillo et al., 2019).

5.1. Supply and use accounting tables

Based on the MA model estimates, we illustrate the SUT in monetary terms, focusing only on the forest ecosystem type (Tables 12 and 13). We used the values of each ES in US$/ha/year and the forest area revealed in the ecosystem extent accounts as reported in the study of Vačkářů and Grammatikopoulou (2019). In this example we excluded 'Air quality', 'Habitat maintenance' and 'Mass flows' since we were not able to allocate those ES to different sectors in the use table.[6] A spatial model or literature references from the Czech Republic would be required in order to identify the actual use of these services, but these were not available and their assessment would be beyond the scope of our analysis. Hence these ES were excluded so as to keep the SUT balanced.

For the allocation of 'Liquid flow' ES to different sectors we used as a proxy the inputs from the Vallecillo et al. (2019) study, and in particular Table A12.2 (in Annex 13) showing the use of flood control in physical terms (hectares). In this study the demand for flood control is defined as the area of economic assets located in flood plains. The study reports the number of hectares of demand covered by the ecosystem in a given year. This output was used to extract the allocation shares of ES to different sectors (Table 5, Appendix) and the fact that 75% of this service is provided by forests was taken into consideration.

Forests in the Czech Republic show a value of ES flow of 2992 million US$ in 2016, without accounting for all types of regulation and maintenance ES. Most of this value is generated by the regulation of liquid flows, which is mostly being used by the agricultural sector. The value of timber provision (95 million 2016US$) is allocated to the forestry sector, the value of climate regulation service (102 million 2016US$) is allocated to global society, and non-timber services as well as leisure cultural services (18 million and 206 million in 2016US$ respectively) are used by households.

Compared to the Vallecillo et al. (2019) study, our SUT monetary values of forest ES deviate significantly. For example timber provision for the Czech Republic was valued at 769 million euros in 2012, carbon sequestration for climate regulation was valued at 190 million euros, and flood control service was estimated at 319 million euros. These

[4] We use this framework as a reference considering that the final revised SEEA EEA will be submitted for adoption by the United Nations Statistical Commission at its session in March 2021 (https://seea.un.org/content/seea-experimental-ecosystem-accounting-revision).

[5] An actual flow of ecosystem service (actual flow) is generated when the ES potential interacts with the ecosystem services demand (ES demand) and leads to actual use (La Notte et al., 2019). The actual ES flow requires the assessment of the ES potential and ES demand to delineate the service providing areas (SPA) and service demanding areas (SDA), respectively. The actual use of the ES depends on the spatial relationship between SPA and SDA (La Notte et al., 2019; Vallecillo et al., 2019).

[6] One simple way to address the allocation of these ES is to assume that "air quality" is used entirely by households and "habitat maintenance" by global society. The "mass flow" related to the regulation of erosion could be allocated to the agricultural sector.

Table 12
Supply table for forest ES.

Supply (mil US$, 2016)	Ecosystem types										
Ecosystem services	**Artificial surfaces (urban green)**	**Arable land**	**Permanent crops**	**Pastures**	**Mosaic farmland**	**Forest and transitional woodland shrub**	**Natural grassland and heathland**	**Open space with little or no vegetation**	**Wetlands**	**Water bodies**	**Total**
Provisioning:											
Provision of timber						94.868					94.868
Provision of non-timber						18.250					18.250
Regulation and maintenance:											
Air quality											
Climate regulation						102.350					102.350
Habitat maintenance											
Liquid flows						2570.563					2570.563
Mass flows											
Cultural:											
Leisure						206.238					206.238
Total						**2992.268**					**2992.268**

Table 13
Use table for forest ES.

Use (mil US$, 2016)	Type of economic unit									
Ecosystem services	**Agriculture**	**Forestry**	**Manufacturing and construction**	**Electricity, gas supply**	**Transport**	**Waste management**	**Other Tertiarry sector**	**Households**	**Global society**	**Total**
Provisioning:										
Provision of timber		94.868								94.868
Provision of non-timber								18.250		18.250
Regulation and maintencance:										0.000
Air quality										0.000
Climate regulation									102.350	102.350
Habitat maintenance										0.000
Liquid flows	2096.700		62.851		242.389	9.987	1.137	157.499		2570.563
Mass flows										0.000
Cultural:										0.000
Leisure								206.238		206.238
Total	**2096.700**	**94.868**	**62.851**	**0.000**	**242.389**	**9.987**	**1.137**	**381.986**	**102.350**	**2992.268**

deviations are related to the different valuation methods used, which is glaringly obvious in the case of flood control ES. The authors found a difference in the accounts between the contribution of ES to different sectors in both physical and monetary terms. In physical terms, flood control is used mostly by the agricultural sector, while in monetary terms, 72% is used by other tertiary economic sectors and households. This is due to the estimates of the avoided damage control method, i.e. the estimated cost per square metre of residential areas is much higher than the estimated cost per square metre of agricultural land. Their results are still at the experimental stage, however.

SUT Tables 12 and 13 could be used as pilot ecosystem asset accounts by the Czech Statistical Office (CZSO). Empirical applications are vital in initiating changes in current guidelines as these still remain a work in progress (e.g. SEEA EEA recent updates in UN, 2020). This is even more relevant from a national perspective if we consider the institutional challenges that need to be addressed. For the Czech Republic in particular, applications of ecosystem accounting are still rare, but will gain increasing attention with the initiation and progress in ecosystem accounting in the EU (La Notte et al., 2017a, 2017b).

6. Conclusions

This study provides a comprehensive overview of forest valuation literature dated from 2000 to 2017, updating former BT studies in the same field. Our database facilitates keeping track of the value of forest ES, specifically in the region of Europe. We also aimed to identify the determinants of the value of forest ES. To achieve the latter, a meta-regression analysis was performed. The key result from the meta-regression analysis is that GDP per capita and the type of ecosystem service are significant determinants in explaining the variation in forest value. Among ES, our model indicated that regulation and maintenance services such as habitat maintenance, and flows regulation are valued much higher compared to other ES. This is an important message, considering that forests are mostly accounted for their contribution to timber production and climate regulation, ignoring the leverage of other important regulation and maintenance services, and their contribution toward socio-economic welfare.

Next, the study aimed to explore the potential applicability of BT in ecosystem accounting. The study illustrated how BT can be performed in line with SEEA-EEA principles. We argue that the BT method can build bridges between national accounting and environmental economics communities because it can exploit the long-standing work and expertise of the environmental economics community and make it useful for accounting purposes. This can be of great value, as BT is very cost-effective and allows the faster and broader implementation of national accounting systems, such as SEEA, globally – and in data deficient countries in particular (Grammatikopoulou et al., 2020). Ecosystem accounting at the national level is a periodic exercise looking at large values, requiring a permanent commitment by institutions. While ecosystem services have been valued by multiple methods, in this case BT could complement the current experimental piloting of ecosystem accounts, especially for assessing accuracy requirements relative to policy purposes and testing the standardization of valuation (Barton et al., 2018, 2019; Johnston et al., 2020 in the supplementary material of Grammatikopoulou et al., 2020). From a tier approach perspective, the BT method can be considered as a second-best valuation approach compared to on-site primary valuation approaches.

To a great extent BT performance depends on the quality and selection of the underlying primary studies. In our study we attempted to provide some guidelines for the systematic review process and database compilation, so that BT can be more straightforward and transparent in its subsequent application. Nevertheless, there is a considerable heterogeneity in how primary valuation studies are reported and how values are indicated. One major problem is that values in primary studies or valuation databases are reported in different units (e.g. in units per ha or units per visit), sometimes with no clear relation to the biophysical metrics of the service (Vačkářů et al., 2018). What is definitely missing is a standardized way/protocol for reporting the results of valuation studies (Loomis and Rosenberger, 2006; Richardson et al., 2015). Furthermore, there are certain challenges that may arise when using BT for ecosystem accounting purposes, namely in relation to a) value metrics, i.e. the compatibility between physical and monetary metrics; b) the spatial dimension of accounts; c) the application process of BT; d) accuracy and errors of BT estimates; and e) the reproducibility of accounts and cross country applications. To this end, a conceptual framework for BT application in ecosystem accounting needs to be thoroughly explored and developed (Grammatikopoulou et al., 2020; Johnston et al., 2020).

Finally, we attempted to apply the BT results in compiling supply and use forest ES accounts for the Czech Republic. The Czech Republic has been actively developing environmental statistics and accounts. Nonetheless, despite growing interest in the state of the natural world, ecosystem services and biodiversity, the Czech government has progressed only slightly in the development and implementation of ecosystem accounting (La Notte et al., 2021). This policy deficit has been recently highlighted in the updated version of the National Biodiversity Strategy of the Czech Republic 2016–2025.

In light of the above, several activities have been launched whose purpose is, first, to initiate a discussion with respect to ecosystem accounting and, second, to proceed to the application of accounts in line with the System of Environmental-Economic Accounting (SEEA) framework. Based on some preliminary discussions with the CZSO, agricultural and ecosystem asset accounts – especially in the context of declining arable land – have formed the main priorities in the area of ecosystem accounting. In addition, water thematic accounts and supply and use of forest ecosystem services accounts were also indicated as top priorities in light of climate change and its consequences for the state (La Notte et al., 2021). For the latter, our work provides certain guidelines and assistance in this direction. The meta-regression model can be used as a decision support tool to facilitate some start-up accounts. The same process can be followed for other ecosystems that are relevant for the Czech Republic.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

Table 1
Description of studies.

Study number	Author (s) and publication year	Year of valuation	Country	Number of obs
1	Hein (2011)	2007	Netherlands	3
2	Manes et al. (2016)	2003	Italy	2
3	Barth and Döll (2016)	2016	Germany	6
4	Caparrós et al. (2017)	2010	Spain	1
5	Goio et al. (2008)	2003	Italy	6
6	Häyhä et al. (2015)	2010	Italy	7
7	Meyerhoff et al. (2012)	2009	Germany	1
8	Matero and Saastamoinen (2007)	2000	Finland	3
9	Ovando et al. (2016)	2010	Spain	15
10	Paletto et al. (2015)	2012	Austria	6
11	Šišák et al. (2016)	2010	Czech Republic	1
12	Grêt-Regamey et al. (2008)	2005	Austria	1
13	Gołos et al. (2009)	2000	Poland	4
14	Bernués et al. (2014)	2013	Spain	8
15	Grilli et al. (2017)	2015	Italy	5
16	Getzner et al. (2017)	2016	Austria	2
17	Fusaro et al. (2017)	2014	Italy	2
18	Schaubroeck et al. (2016)c	2016	Belgium	2
19	Brey et al. (2007)	2006	Spain	4
20	Bastian et al. (2017)	2017	Czech Republic	4
21	Kazak et al. (2016)	2014	Poland	1
22	Grilli et al. (2015)	2012	Slovenia	4
23	Popa et al. (2016)	2011	Romania	5
24	Olschewski et al. (2012)	2011	Switzerland	1
25	Ezebilo (2016)	2007	Sweden	1
26	Hlaváčková et al. (2016)	2013	Czech Republic	1
27	Termansen et al. (2013)	2011	Denmark	2
28	Bastian et al. (2015)	2012	Germany	2
29	Pechanec et al. (2017)	2015	Czech Republic	2
30	Caboun et al. (2014)	2014	Slovakia	1

Table 2
Objectives of primary study.

Explorative	Conduct research aimed at developing science and changing understanding of research peers
Informative	Changes perspectives of public stakeholders
Decisive	Generate action in specific decision problems by stakeholders
Design	Produce outcomes through design and implementation of policy instruments with stakeholders

Table 3
Template and structure of database.

Sections	No	Inputs	Type of input (Data as reported in primary study: DR, Implicit data from primary study: ID, Supplementary data from other dataset: SD, Transformed data: TD)	Transformations
Study info	1	ID (No of observations)	ID	
	2	Study ID	ID	
	3	Authors	DR	
	4	Year of publication	DR	
	5	Reference	DR	
Site and country specifics	6	Site description	DR	
	7	Country	DR	
	8	Latitude	SD	
	9	Area of forest at site level (ha)	DR	
	10	Area of site (ha)	DR or SD	
	11	Area of forest at national level (1000 ha)	DR of SD	
	12	Scale (1=Local, 2=Regional, 3=National)	ID	
	13	Protected area status (1=Yes, 0=No)	ID	
	14	Population density (2015, persons per km^2)	SD	
	15	GDP per capita	SD	
	16	Purchase power parity: PPP conversion factor of GDP (LCU per international $, World bank)	SD	
	17	Consumer price index (2010 = 100) at year of valuation	SD	
	18		SD	

(continued on next page)

Table 3 (*continued*)

Sections	No	Inputs	Type of input (Data as reported in primary study: DR, Implicit data from primary study: ID, Supplementary data from other dataset: SD, Transformed data: TD)	Transformations
		Consumer price index (2010 = 100) at year 2016		
Biome and Ecosystem Services details	19	Description of Ecoregion (tablexxx)	DR or ID	
	20	Description of biome (tablexxx)	DR or ID	
	21	Ecosystem Service as reported	DR	
	22	Ecosystem Services section (CICES class. in tablexxx)	ID	
	23	Ecosystem Services group (CICES class. In table xxx)	ID	
	24	Ecosystem Services class (CICES class. In table xxx)	ID	
Valuation details	25	Economic value_ 1(value/ha/year)	DR	
	26	Economic value_2 (value/person or household or visit ha/year)	DR	
	27	Economic value_ 3(value/tonnes of CO_2/year)	DR	
	28	Economic value_ 4(value/year)	DR	
	29	Currency	DR	
	30	Year of Valuation	DR	
	31	No of visitors	DR	
	32	Carbon sequestration (tonnes/ha/year) on site at year of valuation	DR	
	33	Transformation of value in value/ha	TD	(28)/(9)
	34	Econ.valuation method (tablexxx)	DR	
	35	Econ.valuation approach (tablexxx)	ID	
	36	If other econ. valuation than from tablexxx specify	DR	
	37	Value in international $ at year of valuation (ha/year)	TD	(33)/(16)
	38	CPI2016/CPIyear of valuation	TD	(18)/(17)
	39	Value in constant prices 2016 (international $) (ha/year)	TD	(38)*(37)
Study objectives	40	Study objectives (table 2)	ID	
Quality	41	Quality1: Biome classification	ID	
	42	Quality2: Policy context	ID	
	43	Quality3:Study area	ID	
	44	Quality4:Valuation method	ID	
	45	Quality5:Valuation output	ID	
	46	Total quality score (0 to 10)*	ID	(41)+(42)+(43)+(44)+(45)
Other	47	Additional comments	ID	

*The score of each quality criterion takes the value of 0, 1 or 2 given that the criterion is weak, moderate or strong, respectively.

Table 4
Random effects model results.

	Coefficient	Std. Err.	Prob.
GDP per capita	1.647	0.869	0.058
Population density	-0.057	0.726	0.937
Forest area	-0.047	0.125	0.708
Protected	0.106	0.256	0.678
National scale	-0.613	0.513	0.232
Regional scale	0.048	0.334	0.886
Year	0.011	0.027	0.673
Cost based	0.108	0.327	0.741
Price based	0.789	0.570	0.166
Stated preference based	0.371	0.364	0.309
Temperate conifer forests	0.036	0.387	0.926
Temperate broadleaf & mixed forests	0.370	0.433	0.393
Timber provision	0.705	0.263	0.007
Air quality	1.705	0.617	0.006
Climate regulation	0.733	0.294	0.013
Habitat maintenance	1.992	0.660	0.003
Liquid flows	2.089	0.584	0.000
Mass flows	1.894	0.615	0.002
Leisure	1.040	0.598	0.082
Constant	-29.534	53.808	0.583
N	71		
R^2	0.654		
LM test vs RE model (prob)	1.97 (0.160)		

Table 5
Use of flood control in physical terms in Czech Republic.

	Economic unit						
	Agriculture	Manufacture	Construction	Transport	Waste management	Household	All
Actual flow (in hectares, year 2006)	48,138	1443	26.1	5565	229.3	3616	59,017.4
Share	0.816	0.024	0.000	0.094	0.004	0.0613	1

Source: Vallecillo et al. (2019).

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