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Methods

# Methodological aspects of ecosystem service valuation at the national level

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## Abstract

Ecosystem service valuations focusing on the assessment of ecosystem service values in space and time have recently been receiving considerable attention. Ecosystem service valuation data are critical for developing national ecosystem accounts and for assessment of costs and benefits associated with national strategies and plans. In this article, we discuss selected methodological aspects of ecosystem service valuation at the national level for the Czech Republic. We present a classification of ecosystems based on CORINE Land Cover and Consolidated Layer of Ecosystems of the Czech Republic. The focal point of our article is a systematic review of ecosystem service values. A systematic review requires a standardised protocol for incorporation of valuation studies. To illustrate the proposed methodology, we conducted a search of ecosystem service valuation studies at the European level. While there is a significant number of ecosystem service valuation studies, the number of studies which could be used for an effective value transfer is limited. We discuss the limitations of the value transfer approach and suggest further steps for improving the scientific basis for national level valuations.

## Keywords

Ecosystem services, Value transfer, Systematic review, Ecosystem classification

## 1. Introduction

Mapping and assessment of ecosystem services should contribute to the communication of value provided by nature to society (Costanza et al. 2014). Economic valuation of ecosystem services is one of the approaches for the quantification of the importance of ecosystems for human well-being and economic prosperity. According to the EU Biodiversity Strategy, Member States should assess the economic value of ecosystem services and promote the integration of these values into accounting and reporting systems at the European Union (EU) and national level by 2020 (Maes et al. 2012). Thus, a valuation of ecosystem services is clearly linked to the natural capital accounting and assessment of the human appropriation of natural capital (Obst et al. 2015). However, assessment of ecosystem service values and their change at the national level poses several methodological challenges. Project ESMERALDA aims to deliver a flexible methodology to provide the building blocks for pan-European and regional assessments, including national biophysical, social and economic assessment of ecosystem services (Burkhard et al. in prep).

Global, regional and national applications of the mapping and assessment of the economic value of ecosystem services has received close attention (Costanza et al. 2014, Kubiszewski et al. 2013, Schägner et al. 2013, Niquisse and Cabral 2017, Anderson et al. 2017). As these assessments rely on existing information about ecosystem service values, the value (benefit) transfer approach has been applied. Brander et al. (2011) define value transfer as the procedure for estimating the value of an ecosystem of current policy interest (policy site) by assigning an existing valuation estimate for a similar ecosystem (study site). Most global or national studies apply the unit value transfer (see Section 3 for detailed description of approaches). While economic valuation of ecosystem services is undoubtedly context dependent, monetary values can assist the decision-making by expressing the value in common units which people understand and compare different policy options and impacts in terms of human welfare (Brander et al. 2011, Costanza et al. 2014).

Numerous national ecosystem service assessments have been launched, including, for example, TEEB country studies (TEEB 2013) and national assessments in European countries (Schröter et al. 2016). National assessments accumulated an extensive knowledge base about the role of ecosystem services in generating societal benefits, though they are usually not providing a single estimate of ecosystem service value for the nations. The most thorough national assessment, the UK National Ecosystem Assessments (UK NEA), produced many reports and tools illustrating the role of national ecosystems in generating benefits to society. The UK NEA economic valuation report Bateman et al. (2011) presents a comprehensive account of ecosystem service values for different services and sectors. Bateman et al. (2013) demonstrated the use of economic values of ecosystem services in scenario-based analysis of future land use in the UK. This study was based on models providing valuation of 5 ecosystem services. Aspects of economic valuation of ecosystem services have also been considered in the Spanish National Ecosystem Assessment (Quintas-Soriano et al. 2016) where the meta-analysis of valuation studies found 649 economic value estimates within the 150 primary studies. A national study, carried out in the Czech Republic by Frélichová et al. (2014), used a novel C onsolidated Layer of Ecosystems developed in the Czech Republic and comprising 41 land cover categories differentiating natural and human-influenced ecosystems and 17 ecosystem services to estimate the total economic value of ecosystem services by unit value transfer at the national scale.

There are still multiple challenges in national level valuation. As economic valuation studies reveal, there is a trade-off between the number of services valued and data availability for original (primary) valuation. In this article, we focus on improving the procedures for value transfer information to be applied in national level value transfer. The aim of this article is to present methodological aspects for assessing the economic value of ecosystem services at the national level by means of a systematic review. Based on rapidly growing databases and availability of primary ecosystem service valuations studies, value transfer techniques can be used to estimate the total value of ecosystems within the national territories and detect the trends and spatial changes in the ecosystem services values. We present methodological aspects of national studies applying the value transfer approach and illustrate the challenges for national level valuation of ecosystem services based on the example of the Czech Republic.

## 2. Methodological approach to valuation at the national level

Ecosystem service valuation (ESV) utilises various methods and approaches to estimate a monetary value of ecosystem services (Liu et al. 2010). These methods, which can be based on market-based estimates, cost-based estimates or stated and revealed preferences estimates, incorporate conventional as well as innovative approaches to ecosystem service valuation (Nijnik and Miller 2017). National level assessments utilising the value transfer approach can use the available information generated from primary valuation studies to scale-up ecosystem service value estimates to the national scale using value transfer methods (*Brander 2013*).

Estimating economic values associated with ecosystem services at the national level by value transfer follows several steps. First, a comprehensive categorisation of ecosystems containing the distribution of ecosystems in a country is required. In addition to the global land cover maps applied in global valuation studies, more detailed data sources are usually available at the regional or national level. Second, a database of ecosystem service values provides information on the available estimates of economic value. Third, selection and application of the value transfer approach enables the quantification of the ecosystem service value at the national scale. Combination of these databases and application of value transfer enables the quantification and mapping of ecosystem service value (ESV) at the national level (Fig. 1). Below, we provide a description of the methodological aspects for creating these datasets. We present the methodological aspects of classification of ecosystems, the classification of ecosystem services and a systematic search for value transfer.

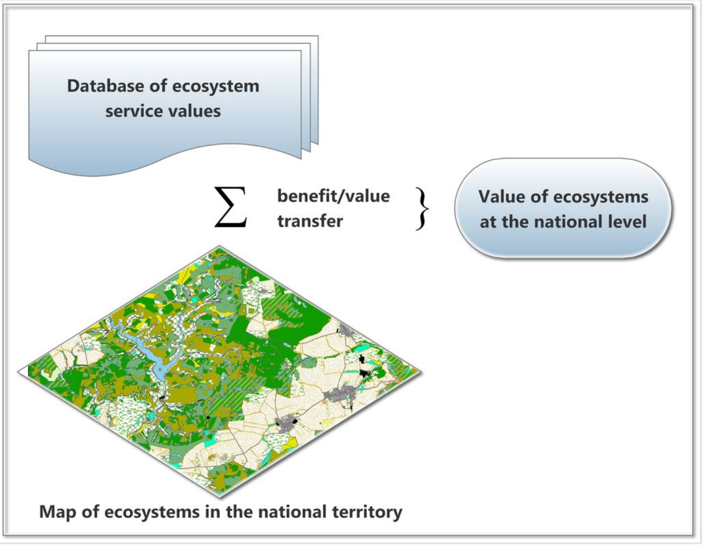


Figure 1.

Scheme of ecosystem service valuation at the national level.

## 2.1. Classification of ecosystems

In European countries, various ecosystem mapping sources are available. At the pan-European level, CORINE Land Cover dataset presents one of the possible sources for mapping the extent of ecosystems and detecting changes in the land cover.

The CORINE Land Cover (Coordination of Information on the Environment Land Cover, CLC) is referring to a European programme establishing a computerised inventory on land cover of the EU Member States and other European countries. CORINE Land Cover is a component of Copernicus Programme Land Monitoring Service and is coordinated by the European Environment Agency (https://land.copernicus.eu/pan-european/corine-land-cover ). The CORINE Land Cover is provided for the years 1990, 2000, 2006 and 2012. This vector-based dataset includes 44 land cover and land use classes in a hierarchical nomenclature (Kosztra et al. 2017). The time-series also includes a land-change layer, highlighting changes in land cover and land use. Five general categories include artificial surfaces, agricultural areas, forest and semi-natural areas, wetlands and water bodies.

The classification of ecosystems for ecosystem service assessments usually requires some aggregation. Suppl. material 1 presents an example of classification of ecosystems using CORINE Land Cover categories, aggregated into 8 broader classes. We included only categories occurring in the Czech Republic and excluded categories typical of the Mediterranean (olive groves, sclerophyllous vegetation), coastal structures (beaches, dunes, salt marshes, salines), marine (estuaries, seas) and high-mountain areas (glaciers and permanent snow). Artificial and bare land categories are classified as unproductive surfaces and therefore, their ecosystem service value is usually set to zero.

In the Czech Republic, a more detailed map of the ecosystems called Consolidated Layer of Ecosystems of the Czech Republic (CLES) was developed in cooperation with the Czech Nature Conservation Agency. CLES presents a detailed map of the extent of natural as well as artificial ecosystems in the national territory (Fig. 2, Suppl. material 1). CLES was developed by detailed habitat mapping in the Czech Republic and by the availability of other data sources on agricultural land, urban areas and water bodies. The advantage of CLES is the detailed resolution of ecosystems applicable even at the local level. However, in its current form, CLES cannot be used to track the changes in ecosystem service values.

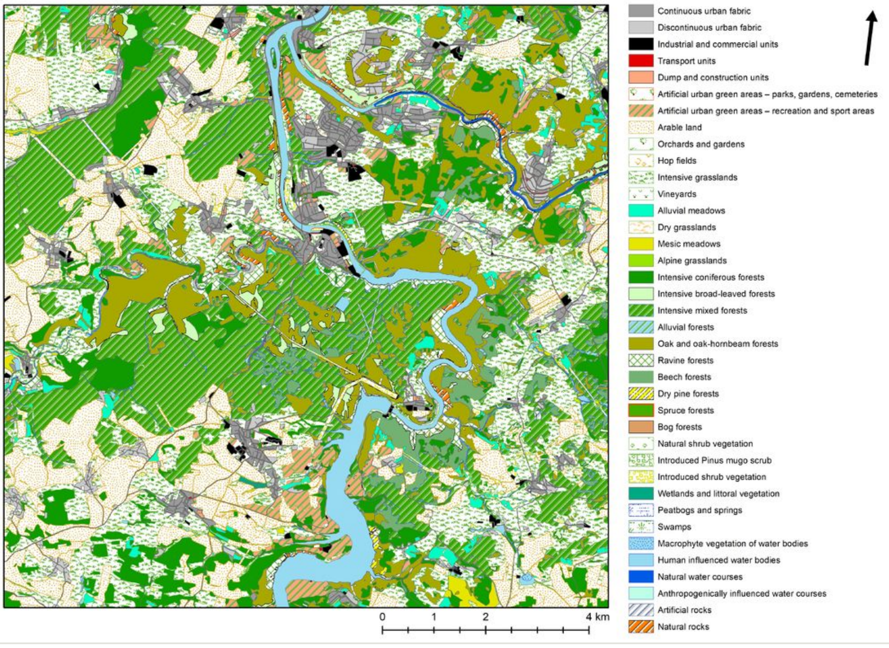


Figure 2.

Illustration map of the Consolidated Layer of Ecosystems of the Czech Republic.

## 2.2. Classification of ecosystem services

For a valuation of ecosystem services at the national level, a comprehensive classification of ecosystem services is required.

We used the classification of ecosystem services CICES (Common International Classification of Ecosystem Services) version 4.3, which was published in 2013 and is a widely used classification of ecosystem service research (Haines-Young and Potschin 2018; Czúcz et al. 2018). There already existed a new updated and extended version of CICES (v5.1, Haines-Young and Potschin 2018) at the time of writing this article, but we decided to continue to use the previous version as it is more straightforward and easier to use. Compared with other recognised and globally used classifications (e.g. MA, TEEB, FEGS-CS, NESCS), CICES provides a higher level of detail amongst ecosystem service categories branched within a solid hierarchical structure (Czúcz et al. 2018).

CICES defines three broad categories (sections) of ecosystem services – provisioning, regulation and maintenance and cultural, which are subdivided into three fixed levels (division, group, class) and one open sub-level (class type). To provide an overview of the classification content and structure, the following table shows the first three levels of the classification (Table 1).

Table 1.

CICES v4.3 classification of ecosystem services, Haines-Young & Potschin 2013.

| Section | Division | Group |
|---|---|---|
| **Provisioning** | Nutrition | Biomass |
| | | Water |
| | Materials | Biomass, Fibre |
| | | Water |
| | Energy | Biomass-based energy sources |
| | | Mechanical energy |
| **Regulation & Maintenance** | Mediation of waste, toxics and other nuisances | Mediation by biota |
| | | Mediation by ecosystems |
| | Mediation of flows | Mass flows |
| | | Liquid flows |
| | | Gaseous / air flows |
| | Maintenance of physical, chemical, biological conditions | Lifecycle maintenance, habitat and gene pool protection |
| | | Pest and disease control |
| | | Soil formation and composition |
| | | Water conditions |
| | | Atmospheric composition and climate regulation |
| **Cultural** | Physical and intellectual interactions with ecosystems and land-/seascapes [environmental settings] | Physical and experienced interactions |
| | | Intellectual and representational interactions |
| | Spiritual, symbolic and other interactions with ecosystems and land-/seascapes [environmental settings] | Spiritual and/or emblematic |
| | | Other cultural outputs |

## 3. Valuation by value transfer

Ecosystem service valuation on larger spatial scales (such as global, regional or national) requires the aggregation of values for different ecosystems and ecosystem services (Costanza et al. 2014). These studies usually apply the value transfer approach, scaling-up values from primary studies to wider policy contexts (Brander 2013). Value transfer has been recognised as a cost-effective method where existing data from original studies are transferred to novel settings.

Value (benefit) transfer is a commonly used method in large-scale ecosystem services valuation studies. There are basically 2 types of value transfer methods (Johnston et al. 2015) with two variations within each:

(1) The unit value transfer:

1.1. Simple, single unadjusted value transfer;

1.2. Adjusted unit value transfer in order to account for factors such as currency values or income.

(2) Benefit function transfer:

2.1 Single-site benefit function transfer, which employs an estimated function from a single primary study;

2.2 Meta-analysis value transfer which gathers information from a set of prior studies.

The unit value transfer has been applied in multiple contexts, including a global valuation of ecosystem services and change in the values (Costanza et al. 1997, Costanza et al. 2014) and national valuations of the contribution of natural ecosystem capital to the economy (Kubiszewski et al. 2013, Frélichová et al. 2014, Niquisse and Cabral 2017).

Meta-analysis value transfer has been applied for thematic assessments of ecosystem services such as wetlands (Ghermandi et al. 2010), forests (Chiabai et al. 2011), mangroves (Brander et al. 2012) and lakes (Reynaud and Lanzanova 2017). Schmidt et al. (2016) developed meta-analysis value transfer functions for 12 ecosystem services based on 194 case studies using 839 monetary values of ES.

The general form of a benefit transfer function can be described as (Johnston et al. 2015):

$$y_{j,s} = f\,(x_{j,s}\ \beta_{j,s})$$

where $y$ is the predicted value estimate for site $j$ and population $s$. The vector of variables $x$ $(j,s)$ represents the factors that explain variations in value estimates $y\ (j,s)$ and $\beta\ (j,s)$ is a vector of parameters that reflect the effect of each factor on $y\ (j,s)$. The explanatory factors can incorporate the type of valuation study and valuation method, the type and abundance of an ecosystem, the socioeconomic characteristics and the geographical context. The meta-analysis value transfer is thus a process of estimation using a regression analysis of many primary study results.

If appropriate data are available, it is possible to combine the unit and meta-analytical approaches in national-scale ESV data synthesis and assessments (Quintas-Soriano et al. 2016). Value transfer requires a systematic search of literature. In the next section, we focus on selected aspects of a systematic review (SR) for value transfer and discuss results and challenges associated with a systematic search for value transfer.

## 4. Systematic review of ecosystem service values

Value transfer approaches require availability of comprehensive datasets capturing the economic values of ecosystem services. The most widely used databases are the Ecosystem Service Valuation Database (ESVD) (de Groot et al. 2012) and the Environmental Valuation Reference Inventory (EVRI) database. In our previous projects focusing on pilot ecosystem value assessment at the national level, we developed the EKOSERV database for unit value transfer at the national level (Frélichová et al. 2014). The EKOSERV database has been updated using the systematic review protocol we tested to collect relevant data for ecosystem service valuation at the national level.

Systematic Review (SR) is a step-wise methodology that aims to collect, assess and synthesise existing research data. SR lays down a priori eligibility criteria and an a priori methodological protocol. The preparation of the protocol is a crucial part of the SR as it ensures that the review is “carefully planned and that what is planned is explicitly documented before the review starts, thus promoting consistent conduct by the review team, accountability, research integrity and transparency of the eventual completed review” (PRISMA Group guidelines in Moher et al. 2015). SR forms one of the basic steps in preparation of the database for national ecosystem service valuation. SR provides information underpinning the value transfer and enables a cost-effective and relatively rapid technique for extracting the ES values when data or resources are limited (Doerr et al. 2014).

We performed a SR to investigate the economic value of ES provided by ecosystems that have been assessed in scientific literature. ESV is a relatively new and popular discipline and the state of the art is evolving rapidly (Abson et al. 2014, Kull et al. 2015). SR methodology has been primarily employed in medical and healthcare disciplines while expanding to other disciplines as well (Tranfield et al. 2003, Haddaway et al. 2015), where organisations were formed in order to establish a formalised procedure for the SR process. In conservation science, the SR is a common method to summarise evidence about environmental management interventions (Cook et al. 2013, Doerr et al. 2014) and it provides an efficient means to facilitate the accessibility of the available knowledge in order to better provide information for decision-making (Pullin and Stewart 2006). A clear and consistent structure of SRs adds another important feature – repeatability (Haddaway et al. 2015).

There are already several studies using the SR method in ecosystem service valuations, e.g. to synthesise evidence concerning ES indicators or ES from specific ecosystems (Czúcz et al. 2018, Shepard et al. 2011). However, to the best of our knowledge, there is no agreed procedure for the SR process and especially meta-analytical ecosystem service valuations and, thus, the SR process is yet to be determined, though, for our investigation, we followed the standards referred in the Cochrane Collaboration review collaborating body (Collaboration for Environmental Evidence 2013). Despite recent methodological developments (Richardson et al. 2015), there are no standardised guidelines for value transfer valuations applicable at the national level.

## 4.1. Structure of systematic review

Fig. 3 illustrates the methodology of a systematic review in line with the Cochrane standards. The abbreviations P, I and O refer to process, input and output, respectively. Each process results in an input for the next process and/or an output. A protocol defines the steps (processes) in the revision. The research team first enters the keywords and decides which search engines to use for the literature scoping (P1). Several keyword selections may be performed in order to capture as many as possible relevant (by quick scanning of title) references. Different datasets (e.g. Scopus vs WoS) may lead to different outcomes based on the phrasing of the keywords or based on a similar wording of the keywords. Keeping track of the efforts is advisable for the final decision of selected keywords.

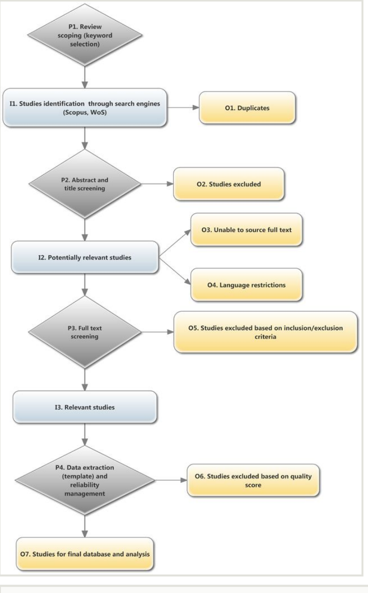


Figure 3.

Stages of the systematic review process. Adapted from Collaboration for Environmental Evidence 2013.

P1 leads to a great number of eligible studies. If more than one dataset is used, then a cross-check between the inputs should be performed in order to exclude references that are captured in both datasets, i.e. duplicates. Then the research team should go through the abstract and the title of studies and exclude those that do not fit the subject of research.

Hence, P2 concludes with a number of relevant studies which need to be read through. Sometimes the studies cannot be sourced or are written in a language other than English and, as such, need to be excluded from the list of studies.

In P3, the research team revised all the studies extracted from P2 based on certain inclusion and exclusion criteria (Table 2). The inclusion criteria are set as criteria that can be regarded as the reasoning for including a study in the final dataset and the exclusion criteria as the reasoning for rejecting it. P3 concludes with a semi-final list of studies.

Table 2.

Eligibility criteria for inclusion of studies in systematic review.

| | **Inclusion** | **Exclusion** |
|---|---|---|
| **Study** | Empirical study (primary data) | Meta-analysis study |
| | Peer reviewed studies | Methodological or conceptual study |
| | Studies in English | Web articles |
| | Studies that have been published after year 2000 | Grey literature |
| | Studies where site and valuation of ES refer to European countries | Large scale: Global scale studies |
| **Valuation** | Economic valuation is one of the study objectives | Studies that assess ES but not in monetary terms |
| | Valuation of ES* | Valuation of biome/ecosystem |
| | | Not clear and or eligible valuation method |
| | | Value range without mean value |

* In some cases, it is also important to restrict searching in studies that value certain ES or studies that value ES using certain methods (e.g. cultural ES using stated preference methods). The latter is to avoid discrepancies in welfare measures i.e. only Hicksian or Marshallian values. This requirement has been discussed in literature (e.g. Johnston and Moeltner 2013).

The last process, P4, aims to set up a database and to perform a reliability assessment of the studies. The reliability assessment is based on certain quality criteria, considering that the studies vary in quality and the final list of studies should only include the most reliable sources (Michel and Hudon 2015). Based on the research objectives, the team created a database with information taken from the semi-final list of studies. The database includes the quality criteria according to which the studies should be scored. A final revision follows based on the scoring of the studies. The final output is a database for analysis where the data are acquired from the final/most relevant studies. The processes P2 and P3 (Fig. 3) were based on pre-defined eligibility criteria which are shown in Table 2.

After screening, a database of selected studies was built up and structured in line with the template shown in Table 3 (P4). The studies were assessed with a score of 10, corresponding to the following five criteria:

Table 3.

Data extraction template for ecosystem service valuation database.

| | |
|---|---|
| **Study info** | Authors |
| | Publication year |
| | Reference |
| **Site and country specifics*** | Scale: Local, regional, national |
| | Area in hectares |
| | Latitude |
| | Country |
| | Population density |
| | GDP per capita |
| | Purchase parity power conversion factor |
| | Consumer price index: of valuation year and of current year |
| **Biome and Ecosystem service (ES) details** | Biome type |
| | ES classification (by CICES): Section, group, class |
| | ES classification as described on the study |
| **Valuation details** | Value reported** |
| | Units |
| | Currency |
| | Year of valuation |
| | Method: Price-based, Cost-based (all subcategories), Production function-based (all subcategories), Revealed preference (all subcategories), Stated preference (all subcategories), Benefit transfer (all subcategories) |
| | Valuation approach: : Direct market value, Stated preference, Revealed preference, Benefit transfer |
| **Study objectives** | Objectives of valuation |
| **Quality** | Quality score: 1-10 |
| **Other comments** | Other |

* The site and country specifics are necessary inputs for meta-regression analysis or adjusted value transfer.

** For value transfer, the value reported should be converted in the same currency per hectare of ecosystem per year. Even for cultural services, where values are usually reported in value/respondent per visit, the same conversion is necessary (as in Ojea et al. 2010).

1. Description of biome and ES classification by classification system
2. Description of policy context of valuation
3. Description of study area (location, hectares of biome valued, latitude)
4. Description of valuation method
5. Description of valuation output (units, currency, year of valuation)

Each criterion was given a score of 0, 1 or 2, meaning weak, moderate or strong. To distinguish between papers of different quality, those that scored less than 4 were given a "Low quality" score; those scoring between 4 and 7 were considered of "Reasonable quality" score; and papers with a score above 7 were considered of "High quality".

## 4.2. Results of systematic review of valuation studies

We performed a systematic search in Scopus and ISI Web of Knowledge science databases using keywords "ecosystem service" and "valuation", complemented by keywords indicating the ecosystem type, i.e. urban, forest, wetland and water. The inclusion and exclusion criteria were selected in line with details presented in Table 2. We limited our search to European studies only and also limited the time span of studies to 2000 – 2017. Another limitation of the scope of systematic review stems from the classification of ecosystems occurring in the territory of the Czech Republic. Based on the above-described SR process, our illustrative exercise concluded in the findings presented in Table 4. The details of primary studies are presented in Suppl. material 2. Reliability assessment and output O7 (final list of studies for building the database and analysis, Fig. 3) are not reported here as it was considered that these are out of the scope of the paper. However, during this stage, we excluded grey literature and technical reports and limited our review to only information published in peer-reviewed journals.

Table 4.

Summary of systematic review results.

| **P1: Review scoping** | | | | | **P2: Abstract and title screening** | **P3: Full text screening** |
|---|---|---|---|---|---|---|
| **Ecosystem** | **Database** | **Keywords** | **Timespan** | **I1: Studies identification** | **I2: Potentially relevant studies** | **I3: Relevant studies** |
| Urban green | Web of Science<br>Scopus<br>EKOSERV* | "ecosystem service" AND "valuation" AND "urban"<br>"Europe"** | 2000-2017 | 97 | 23 | 9 |
| Agricultural | Scopus<br>EKOSERV* | "ecosystem service" AND "valuation" AND "agriculture" + limit to European countries | 2000-2017 | 78 | 28 | 13 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Permanent crops | Scopus EKOSERV* | “ecosystem service” AND “valuation” AND “orchard” + limit to European countries | 2000-2017 | 3 | 2 | 2 |
| Pasture and grasslands | Scopus EKOSERV* | “ecosystem service” AND “valuation” AND “pasture” + limit to European countries “ecosystem service” AND “valuation” AND “grassland” + limit to European countries | 2000-2017 | 29 | 20 | 4 |
| Forest | Web of Science Scopus EKOSERV* | “ecosystem service” AND “forest” AND “valuation” AND “Europe” “ecosystem” AND “service” AND “forest” AND “valuation” + EXCLUDE non-European countries | 2000-2017 | 158 | 66 | 30 |
| Wetland | Web of Science Scopus EKOSERV* | wetland AND “ecosystem service” AND valuation + EXCLUDE non-European countries In EKOSERV exclude coastal wetlands | 2000-2017 | 58 | 18 | 9 |
| Water | Scopus EKOSERV* | “water” AND “ecosystem service” AND “valuation” + EXCLUDE non-European countries “lake” AND “ecosystem service” AND “valuation” + EXCLUDE non-European countries “pond” AND “ecosystem service” AND “valuation” + EXCLUDE non-European countries “river” AND “ecosystem service” AND “valuation” + EXCLUDE non-European countries “water-body” AND “ecosystem service” AND “valuation” + EXCLUDE non-European countries | 2000-2017 | 216 | 22 | 8 |

*Selection for European studies, timespan 2000+, excluding coastal wetlands
**European countries were later included in the final results by country/region

We found 75 original relevant studies in total after stage P3, including 344 observations of ecosystem service values (Table 4). At the initial stage I1, we identified 639 studies. During the stage P2 (abstract and title screening), the number of potentially relevant studies was reduced to 179. The number of published original valuation studies has increased substantially during the last years (Fig. 4), with the highest number of studies published in 2016 and focusing on valuation of forest ecosystem services.

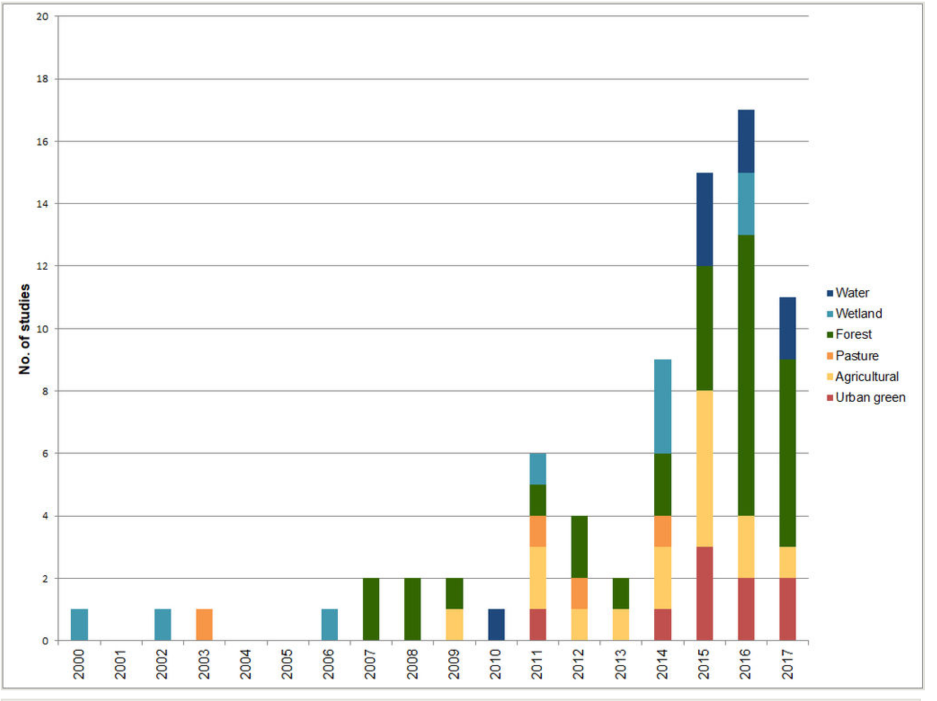


Figure 4.

Number of original ecosystem service valuation studies found in the systematic review process.

## 5. Transferability of results and limitations

The value transfer approach poses multiple challenges and imposes limitations. The valuation method, the presence of agents that will benefit from the service, the level of supply of the service, the time of the analysis and the contextual variables describing the socioecological system in space, can influence the value of the ES and need to be controlled (Troy and Wilson 2006). The majority of ecosystem services valuations conducted at the national level have been based on the simple unit value transfer. Basic value transfer still requires extensive databases capturing ecosystem service values, such as ESVD (de Groot et al. 2012).

Despite the rapid progress in national ecosystem assessments (Schröter et al. 2016), national ecosystem service valuations are scarce. The reason could lie in the limitations of the value transfer techniques. Detailed long-term ecosystem service valuation studies based on biophysical modelling or assessments have only been performed at the regional level (Jiang et al. 2013). Indeed, a review by Malinga et al. (2015) concluded that the majority of ecosystem services mapping has only been conducted at the municipality or province level. Only one-fifth (19%) of the mapping studies were conducted at the national level.

Schägner et al. (2013) reviewed studies focusing on ecosystem service value mapping. Their estimate of the proportion of studies conducted at broader regional or national levels (24%) is similar to that of Malinga et al. (2015). National studies usually cover an area ranging from 10,000 $km^2$ to 100,000 $km^2$. From the methodological point of view, they found that the majority of the ESV mapping studies used the simple unit value transfer approach, combining land cover proxy with the unit value of ES. Only 4% of the studies performed a meta-analytical benefit transfer function.

Another limitation of the value transfer studies is the context within which the ecosystem service valuations are produced. Several studies have developed policy scenarios or targets analysis, for example in the context of cost-benefit analysis (CBA) (Peh et al. 2014). Ecosystem service values are dependent on policy targets and scenarios. Therefore, these values are difficult to transfer to different policy contexts.

A value transfer can be based on transferring values tied to biophysical values which is the standard approach applied in primary valuation studies or model toolkits such as InVEST (Kareiva et al. 2011). An ecosystem service valuation at the national level usually applies to an area of land cover as a spatial biophysical proxy. This approach requires values available per area unit, for example EUR per hectare. However, a vast amount of data in ecosystem service valuation databases is reported in different units, such as population or mass flows (Table 5). Sometimes, a biophysical-based value transfer is a more appropriate method, especially in the context of policy-related measures such as abatement of climate change via reduction of greenhouse gases or policies reducing the flow of nutrients from agriculture and households into water bodies. This is related to the discussion of valuing marginal changes rather than communicating the total value of ecosystems (Fisher et al. 2008, Bateman et al. 2011). Therefore, transferring values per tonne of carbon stored in forest ecosystems or kilograms of nitrogen retained in wetlands can be a meaningful approach to value transfer.

Table 5.

Examples of different units for value transfer.

| Ecosystem service valuation | Biophysical unit | Value |
|---|---|---|
| **Area units** | | |
| Total aggregate value | Area (hectares) | EUR per ha |
| **Mass units** | | |
| Climate regulation | Mg of carbon | EUR per Mg |
| Air filtration | Mg of pollutant | EUR per Mg |

| | | |
|---|---|---|
| Water regulation | Cubic metre of water | EUR per $m^3$ |
| **Non-material units** | | |
| Recreation | Number of visits | EUR per visit |
| Recreation | Person-visit | EUR per person per visit |

Finally, we should mention a controversy in the monetary valuation of ecosystem services. It has been suggested that an economic valuation of ecosystem services cannot capture the complex biophysical and socio-cultural benefits provided by ecosystems (Schröter et al. 2014). Even in countries with readily available data for national ecosystem service valuations, such as the United Kingdom (Bateman et al. 2013) or Spain (Quintas-Soriano et al. 2016), researchers are hesitant to make total economic value estimates for national ecosystems. This can be due to the perceived immaturity of the valuation techniques and their complexity beyond the economic valuation of ecosystems services (Nijnik and Miller 2017) and issues relating to gaps in the understanding of marginal value curves and final ecosystem services and goods (Bateman et al. 2011). Thus, large-scale estimates of economic values of ecosystem services generated by value transfer do not necessarily represent ecosystem service values important to different stakeholders, beneficiaries and participants. Also, ecosystem service valuations have often been reduced to assessments of costs of environmental degradation or benefits of conservation policies and have not been incorporated into consistent ecosystem accounting frameworks at the national level.

## 6. Conclusions

Ecosystem service valuation at the national level is still an emerging discipline. The possible reasons for this are outlined in our paper – limitations of current value transfer techniques or incomplete information in studies serving as inputs for SR valuation studies. However, an increasing societal demand for broader-scale valuations and evaluations of strategies and experimental ecosystem accounting might accelerate progress in the value transfer techniques and in the synthesis of the existing data. Within the ecosystem service assessment community, there is a need for standardised valuation data reporting and presentation. As ecosystems are being valued in significantly varying contexts, with different aims and policy goals, we suggest that the development of unified synthesising frameworks would facilitate the application of the available data on ES valuations. As a consequence, the ecosystem service valuations at the national level could become more frequent and extend the knowledge about the importance of ecosystems for society and human well-being. Information on the value of ecosystems on the national level, as well as quantification of impacts of policy inaction or costs and benefits of strategies and plans, could enhance decision-making processes supported by rigorous ecosystem service science.

## Acknowledgements

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## References

- Abson DJ, Wehrden Hv, Baumgärtner S, Fischer J, Hanspach J, Härdtle W, Heinrichs H, Klein AM, Lang DJ, Martens P, Walmsley D (2014) Ecosystem services as a boundary object for sustainability. Ecological Economics 103: 29-37. https://doi.org/10.1016/j.ecolecon.2014.04.012
- Anderson S, Ankor B, Sutton P (2017) Ecosystem service valuations of South Africa using a variety of land cover data sources and resolutions. Ecosystem Services 27: 173-178. https://doi.org/10.1016/j.ecoser.2017.06.001
- Bateman I, Abson D, Beaumont N, Darnell A, Fezzi C, Hanley N, Kontoleon A, Maddison D, Morling P, Morris J, Mourato S, Pascual U, Perino G, Sen A, Tinch D, Turner K, Valatin G, van Soest DP (2011) Economic Values from Ecosystems. In: UNEP WCMC The UK National Ecosystem Assessment: Technical Report. Cambridge, 1068-1151 pp.
- Bateman I, Harwood A, Abson D, Andrews B, Crowe A, Dugdale S, Fezzi C, Foden J, Hadley D, Haines-Young R, Hulme M, Kontoleon A, Munday P, Pascual U, Paterson J, Perino G, Sen A, Siriwardena G, Termansen M (2013) Economic Analysis for the UK National Ecosystem Assessment: Synthesis and Scenario Valuation of Changes in Ecosystem Services. Environmental and Resource Economics 57 (2): 273-297. https://doi.org/10.1007/s10640-013-9662-y
- Bateman IJ, Harwood AR, Mace GM, Watson RT, Abson DJ, Andrews B, Binner A, Crowe A, Day BH, Dugdale S, Fezzi C, Foden J, Hadley D, Haines-Young R, Hulme M, Kontoleon A, Lovett AA, Munday P, Pascual U, Paterson J, Perino G, Sen A, Siriwardena G, Soest Dv, Termansen M (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 L, Bräuer I, Gerdes H, Ghermandi A, Kuik O, Markandya A, Navrud S, D. Nunes PL, Schaafsma M, Vos H, Wagtendonk A (2011) 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 L, Wagtendonk A, Hussain S, McVittie A, Verburg P, de Groot R, der Ploeg Sv (2012) Ecosystem service values for mangroves in Southeast Asia: A meta-analysis and value transfer application. Ecosystem Services 1 (1): 62-69. https://doi.org/10.1016/j.ecoser.2012.06.003

- Brander LM (2013) Guidance manual on value transfer methods for ecosystem services. United Nations Environment Programme, Nairobi, 77 pp. [ISBN 978-92-807-3362-4]
- Burkhard B, Geneletti D, Kopperoinen L, Maes J, Potschin M, Santos-Martín F, Stoev P (in prep) Mapping and assessing ecosystems services in the EU – The ESMERALDA coordination and support action approach of integration. One Ecosystem.
- Chiabai A, Travisi C, Markandya A, Ding H, D. Nunes PL (2011) Economic Assessment of Forest Ecosystem Services Losses: Cost of Policy Inaction. Environmental and Resource Economics 50 (3): 405-445. https://doi.org/10.1007/s10640-011-9478-6
- Collaboration for Environmental Evidence (2013) *Guidelines for Systematic Review and Evidence Synthesis in Environmental Management*. www.environmentalevidence.org/Documents/Guidelines/Guidelines4.2.pdf
- Cook C, Possingham H, Fuller R (2013) Contribution of Systematic Reviews to Management Decisions. Conservation Biology 27 (5): 902-915. https://doi.org/10.1111/cobi.12114
- Costanza R, d'Arge R, Groot Rd, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill R, Paruelo J, Raskin R, Sutton P, den Belt Mv (1997) The value of the world's ecosystem services and natural capital. Nature 387 (6630): 253-260. https://doi.org/10.1038/387253a0
- Costanza R, Groot Rd, Sutton P, der Ploeg Sv, Anderson S, Kubiszewski I, Farber S, Turner RK (2014) Changes in the global value of ecosystem services. Global Environmental Change 26: 152-158. https://doi.org/10.1016/j.gloenvcha.2014.04.002
- Czúcz B, Arany I, Potschin-Young M, Bereczki K, Kertész M, Kiss M, Aszalós R, Haines-Young R (2018) Where concepts meet the real world: A systematic review of ecosystem service indicators and their classification using CICES. Ecosystem Services 29: 145-157. https://doi.org/10.1016/j.ecoser.2017.11.018
- Doerr E, Dorrough J, Davies M, Doerr VJ, McIntyre S (2014) Maximizing the value of systematic reviews in ecology when data or resources are limited. Austral Ecology 40 (1): 1-11. https://doi.org/10.1111/aec.12179
- Fisher B, Turner K, Zylstra M, Brouwer R, Groot Rd, Farber S, Ferraro P, Green R, Hadley D, Harlow J, Jefferiss P, Kirkby C, Morling P, Mowatt S, Naidoo R, Paavola J, Strassburg B, Yu D, Balmford A (2008) ECOSYSTEM SERVICES AND ECONOMIC THEORY: INTEGRATION FOR POLICY-RELEVANT RESEARCH. Ecological Applications 18 (8): 2050-2067. https://doi.org/10.1890/07-1537.1
- Frélichová J, Vačkář D, Pártl A, Loučková B, Harmáčková Z, Lorencová E (2014) Integrated assessment of ecosystem services in the Czech Republic. Ecosystem Services 8: 110-117. https://doi.org/10.1016/j.ecoser.2014.03.001
- Ghermandi A, den Bergh JJMv, Brander L, de Groot HF, D. Nunes PL (2010) Values of natural and human-made wetlands: A meta-analysis. Water Resources Research 46 (12): . https://doi.org/10.1029/2010wr009071
- Groot Rd, Brander L, der Ploeg Sv, Costanza R, Bernard F, Braat L, Christie M, Crossman N, Ghermandi A, Hein L, Hussain S, Kumar P, McVittie A, Portela R, Rodriguez L, Brink Pt, Beukering Pv (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

- Haddaway NR, Woodcock P, Macura B, Collins A (2015) Making literature reviews more reliable through application of lessons from systematic reviews. Conservation Biology 29 (6): 1596-1605. https://doi.org/10.1111/cobi.12541
- Haines-Young R, Potschin MB (2018) Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure. www.cices.eu
- Jiang M, Bullock J, Hooftman DP (2013) Mapping ecosystem service and biodiversity changes over 70 years in a rural English county. Journal of Applied Ecology 50 (4): 841-850. https://doi.org/10.1111/1365-2664.12093
- Johnston R, Moeltner K (2013) Meta-Modeling and Benefit Transfer: The Empirical Relevance of Source-Consistency in Welfare Measures. Environmental and Resource Economics 59 (3): 337-361. https://doi.org/10.1007/s10640-013-9730-3
- Johnston R, Rolfe J, Rosenberger R, Brouwer R (2015) Introduction to Benefit Transfer Methods. The Economics of Non-Market Goods and Resources. https://doi.org/10.1007/978-94-017-9930-0_2
- Kareiva P, Tallis H, Ricketts TH, Daily GC, Polasky S (Eds) (2011) Natural Capital: Theory and Practice of Mapping Ecosystem Services. Oxford University Press, 392 pp.
- Kosztra B, Büttner G, Hazeu G, Arnold S (2017) Updated CLC illustrated nomenclature guidelines. European Topic Centre on urban, land and soil systems. European Environment Agency 124: pp.. URL: https://land.copernicus.eu/user-corner/technical-library/corine-land-cover-nomenclature-guidelines/docs/pdf/CLC2018_Nomenclature_illustrated_guide_20170930.pdf
- Kubiszewski I, Costanza R, Dorji L, Thoennes P, Tshering K (2013) An initial estimate of the value of ecosystem services in Bhutan. Ecosystem Services 3: e11-e21. https://doi.org/10.1016/j.ecoser.2012.11.004
- Kull C, de Sartre XA, Castro-Larrañaga M (2015) The political ecology of ecosystem services. Geoforum 61: 122-134. https://doi.org/10.1016/j.geoforum.2015.03.004
- Liu S, Costanza R, Farber S, Troy A (2010) Valuing ecosystem services. Annals of the New York Academy of Sciences 1185 (1): 54-78. https://doi.org/10.1111/j.1749-6632.2009.05167.x
- Maes J, Egoh B, Willemen L, Liquete C, Vihervaara P, Schägner JP, Grizzetti B, Drakou E, Notte AL, Zulian G, Bouraoui F, Paracchini ML, Braat L, Bidoglio G (2012) Mapping ecosystem services for policy support and decision making in the European Union. Ecosystem Services 1 (1): 31-39. https://doi.org/10.1016/j.ecoser.2012.06.004
- Malinga R, Gordon L, Jewitt G, Lindborg R (2015) Mapping ecosystem services across scales and continents – A review. Ecosystem Services 13: 57-63. https://doi.org/10.1016/j.ecoser.2015.01.006
- Michel A, Hudon M (2015) Community currencies and sustainable development: A systematic review. Ecological Economics 116: 160-171. https://doi.org/10.1016/j.ecolecon.2015.04.023
- Moher D, Group P, Shamseer L, Clarke M, Ghersi D, Liberati A, Petticrew M, Shekelle P, Stewart LA (2015) Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Systematic Reviews 4 (1): . https://doi.org/10.1186/2046-4053-4-1
- Nijnik M, Miller D (2017) Valuation of ecosystem services: paradox or Pandora's box for decision-makers? One Ecosystem 2: e14808. https://doi.org/10.3897/oneeco.2.e14808

- Niquisse S, Cabral P (2017) Assessment of changes in ecosystem service monetary values in Mozambique. Environmental Development https://doi.org/10.1016/j.envdev.2017.09.003
- Obst C, Hein L, Edens B (2015) National Accounting and the Valuation of Ecosystem Assets and Their Services. Environmental and Resource Economics 64 (1): 1-23. https://doi.org/10.1007/s10640-015-9921-1
- Ojea E, D. Nunes PL, Loureiro M (2010) Mapping Biodiversity Indicators and Assessing Biodiversity Values in Global Forests. Environmental and Resource Economics 47 (3): 329-347. https://doi.org/10.1007/s10640-010-9381-6
- Peh K-, Balmford A, Field R, Lamb A, Birch J, Bradbury R, Brown C, Butchart SM, Lester M, Morrison R, Sedgwick I, Soans C, Stattersfield A, Stroh P, Swetnam R, Thomas DL, Walpole M, Warrington S, Hughes FR (2014) Benefits and costs of ecological restoration: Rapid assessment of changing ecosystem service values at a U.K. wetland. Ecology and Evolution 4 (20): 3875-3886. https://doi.org/10.1002/ece3.1248
- Pullin A, Stewart G (2006) Guidelines for Systematic Review in Conservation and Environmental Management. Conservation Biology 20 (6): 1647-1656. https://doi.org/10.1111/j.1523-1739.2006.00485.x
- Quintas-Soriano C, Martín-López B, Santos-Martín F, Loureiro M, Montes C, Benayas J, García-Llorente M (2016) Ecosystem services values in Spain: A meta-analysis. Environmental Science & Policy 55: 186-195. https://doi.org/10.1016/j.envsci.2015.10.001
- Reynaud A, Lanzanova D (2017) A Global Meta-Analysis of the Value of Ecosystem Services Provided by Lakes. Ecological Economics 137: 184-194. https://doi.org/10.1016/j.ecolecon.2017.03.001
- Richardson L, Loomis J, Kroeger T, Casey F (2015) The role of benefit transfer in ecosystem service valuation. Ecological Economics 115: 51-58. https://doi.org/10.1016/j.ecolecon.2014.02.018
- 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 A, Seppelt R (2016) Uncertainty of Monetary Valued Ecosystem Services – Value Transfer Functions for Global Mapping. PLOS ONE 11 (3): e0148524. https://doi.org/10.1371/journal.pone.0148524
- Schröter M, der Zanden Ev, van Oudenhoven AE, Remme R, Serna-Chavez H, de Groot R, Opdam P (2014) Ecosystem Services as a Contested Concept: a Synthesis of Critique and Counter-Arguments. Conservation Letters 7 (6): 514-523. https://doi.org/10.1111/conl.12091
- Schröter M, Albert C, Marques A, Tobon W, Lavorel S, Maes J, Brown C, Klotz S, Bonn A (2016) National Ecosystem Assessments in Europe: A Review. BioScience 66 (10): 813-828. https://doi.org/10.1093/biosci/biw101
- Shepard C, Crain C, Beck M (2011) The Protective Role of Coastal Marshes: A Systematic Review and Meta-analysis. PLoS ONE 6 (11): e27374. https://doi.org/10.1371/journal.pone.0027374
- TEEB (2013) Guidance Manual for TEEB Country Studies. Version 1.0. The Economics of Ecosystems and Biodiversity, 94 pp.

- Tranfield D, Denyer D, Smart P (2003) Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. British Journal of Management 14 (3): 207-222. https://doi.org/10.1111/1467-8551.00375
- Troy A, Wilson M (2006) Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. Ecological Economics 60 (2): 435-449. https://doi.org/10.1016/j.ecolecon.2006.04.007

## Supplementary materials

### Suppl. material 1: Annex 1. Classification of ecosystems for national level ecosystem service valuation. doi

**Authors:** David Vačkář
**Data type:** Ecosystem classification
**Brief description:** Classification of ecosystems based on CORINE Land Cover and Consolidated Layer of Ecosystems for the Czech Republic.
**Filename:** Annex 1.pdf - Download file (180.60 kb)

### Suppl. material 2: Annex 2. Results of systematic review of ecosystem service valuation studies. doi

**Authors:** David Vačkář, Ioanna Grammatikopoulou, Jan Daněk, Eliška Krkoška Lorencová
**Data type:** Systematic review of literature
**Brief description:** Results of systematic review of ecosystem service valuation studies in Europe (2000 – 2017) for benefit transfer at the national level .
**Filename:** Annex 2.pdf - Download file (478.22 kb)