Supporting site planning through monetary values for biomass and nature conservation services from ecosystem accounts

Beyhan Ekinci[‡], Karsten Grunewald[§], Sophie Meier[§], Steffen Schwarz[§], Burkhard Schweppe-Kraft[|], Ralf-Uwe Syrbe[§]

‡ German Federal Agency for Nature Conservation, Bonn, Germany
§ Leibniz Institute of Ecological Urban and Regional Development, Dresden, Germany
| German Federal Agency for Nature Conservation (retired), Bonn, Germany

Corresponding author: Burkhard Schweppe-Kraft (burkhard.schweppe-kraft@web.de)

Academic editor: David N. Barton

Abstract

Ecosystem services can be measured physically, but also valued in monetary terms. In public planning and decision-making in Germany, multi-criteria analysis is usually used to inform decision-makers about different impacts of projects, for example, for housing and the siting of industrial or infrastructure projects. Typically, these evaluations are based on various environmental, social and economic impacts using their own specific methods and then juxtapose the different results, without providing further support for weighing various concerns.

Economic evaluations attempt to assess preferences of individuals and society in relation to the outcomes that are relevant for a decision, thereby providing further support to decision-makers. Although so-called welfare values are usually used for this purpose in cost-benefit analysis, it can be shown that, in certain cases, exchange values from environmental economic accounting also fulfil that objective. This is demonstrated for the case of site planning, using maps of economic values of biomass provisioning services and ecosystem services for nature conservation.

The ecosystem service values used for this purpose were determined spatially explicitly nationwide for Germany. Services for nature conservation were calculated as average costs to develop one ´biotope value point´. This unit is used in German planning law to determine ecological compensation measures for impacts on nature. Cost data were calculated from nature conservation measures to fulfil the requirements of the EU Habitats Directive. As a proxy for the biomass provisioning service, hypothetical agricultural land-lease rates with different yield potential were estimated throughout Germany. Due to a lack of other spatially specific data, timber services were valued with the average net profit of forestry businesses.

A comparison shows that, on average, services for nature conservation have higher values than biomass provisioning services. This is the case even for arable land.

Keywords

biomass provisioning services, ecosystem and species appreciation services, site planning, ecosystem accounting, agricultural production, timber production, nature conservation, complementary accounts

Introduction

This article aims to show how values from national ecosystem accounting can be used to support local decisions about the location of housing or infrastructure projects, especially in rural areas.

In Germany, relevant decision-making criteria for the selection of sites for housing, industry and commerce or infrastructure are inter alia quality of the land for agricultural and forestry production and importance for nature conservation; further criteria are, for example, drinking water and groundwater protection, carbon sequestration or recreational land use (BauGB 2017, UVPG 2017, BNatSchG 2021). In general, nationwide monetary values for ecosystem accounting can be used as additional information for site selection in rural areas. However, so far, they only exist for the ecosystem services for biodiversity protection and biomass production (here: agricultural products and timber) and were calculated in the pilot project of Hirschfeld et al. (2020). The following presentation is, therefore, limited to these two ecosystem services.

Cost-benefit analyses, which use monetary values for site selection, are prescribed for some larger measures, such as planning of federal transport routes (BMDV 2014). The criterion of preserving fertile soils is mainly considered here in terms of the purchasing cost for necessary land. Nature conservation concerns have, so far, only been included as additional criteria (ibid.), without being considered in monetary terms. In Germany, most other site planning procedures for location search, for example, for new housing sites, are based on multi-criteria analysis. Here, different aspects to be considered are often only evaluated according to their own specific methods and then just juxtaposed. The evaluative comparison of the various points and their weighting amongst each other, thus, remains with the decision-maker and is not further supported by information about the social and individual values affected by the choice. Valuation methods, including maps that additionally monetise ecosystem service worthiness, are one of several ways to support and facilitate location selection. They offer the possibility to compare and aggregate diverse negative and positive impacts, based on individual and societal preferences. (Schweppe-Kraft and Grunewald 2015, Natural Capital Germany - TEEB DE 2018).

The social benefit or (potential) price, people would pay for an additional hectare of biomass production or nature conservation land, is only marginally influenced by local changes. The situation is different for goods, such as urban green spaces, where the service can only be provided at the place of production and is difficult or hard to replace. With a noticeable reduction, the willingness to pay or the potential price for an additional hectare of green space increases. When assessing a local change in green space provision, this price effect must be considered. In contrast, biomass and conservation services are commodities that are traded on a national or even international scale or where valuation relates to the persistence of populations and ecosystems on a larger spatial scale. For such goods, local changes in quantity usually have only minimal effects on the value per measurement unit. The value per unit taken from national ecosystem accounts can, therefore, be assumed to be largely constant when valuing local changes. An exception would be, for example, if highly endangered endemic species with few other sites were affected. In this case, any local change may affect preferences for conserving the remainder of the population.

In a research project on integration of ecosystem services into environmental economic accounting to fulfil Target 2, Action 5 of the European Biodiversity Strategy to 2020 (EC 2022b), Hirschfeld et al. (2020) determined nationwide, spatially specific monetary values for services of agricultural land for biomass production and for ecosystem services to preserve biodiversity (´appreciation of ecosystem and species services´, according to UN SEEA-EA 2021). These values are supported here by national average monetary figures for ecosystem services of forests for timber production. Economic valuations of ecosystem services are based on UN SEEA-EA (2021). Unlike the other elements of SEEA-EA, they are not yet binding. Some of the valuation methods used here deviate from SEEA-EA recommendations, which is justified in each individual case.

The following sections describe how values for ecosystem services for biomass provisioning and nature conservation were calculated, what results there are nationwide for Germany and how these values can supplement existing methods for location planning. The article ends with a discussion on the approach limitations and with possible steps for a further refinement.

Biomass provisioning services

General approach

According to UN SEEA-EA 2021, the monetary value of biomass provisioning services of ecosystems is not the value of the goods produced, like agricultural goods or timber, but solely the profits made through selling these goods on the market, after deducting all cost for capital, labour and the cost for all intermediate goods, like pesticides. In economic terms, this residual value corresponds to value added minus wages, including entrepreneurs labour inputs and minus an ´adequate´ interest rate for invested capital.

Marginal productivity is the economic concept behind this idea. It results in an exchange value for an ecosystem service when that service is traded on a market and considers additional contribution of a spatial unit (e.g. a hectare) of land to income. Under market conditions, for example, a farmer will try to extend the area under cultivation up to a point where the price of an additional piece of land equals the additional income he can gain from it. As shown in the Discussion, exchange values, based on current marginal productivity, are suitable only for measuring changes that are small, when compared with current supply (Mankiw and Taylor 2014). They are not suited for rapidly occurring large scale (catastrophic) changes, for long-term assessments and for long-lasting changes which can hardly be reversed.

Due to a lack of data on farm profits Hirschfeld et al. (2020) use lease rates as a proxy for biomass provisioning services of agricultural land and estimated spatially specific hypothetical lease rates for all agricultural lands in Germany on the basis of the relationship between lease rates and measures for the relative yield potential that are available for all agricultural lands in Germany. Average proxy data for the biomass provisioning service of forests were added here from official statistics (see below).

Data and methods

UN SEEA-EA (2021) (par. 9.35) proposes net-profits (´resource rents´) from agriculture or forestry as a monetary measure for biomass provisioning services. Since no data on farm profits are available in Germany, agricultural lease prices are used here instead as a proxy for valuing biomass provisioning services of agricultural lands. Lease prices are not available for all agricultural land in detail. Therefore, we used results from Garvert (2017) to assign estimated lease prices to the yield potential of agricultural areas.

This yield potential was determined by an agricultural soil estimate (German: ´Bodenschätzung´, formerly ´Reichsbodenschätzung´; for a brief summary, see Wikipedia 2022) and envelops grass- and arable land. Although for most, it is not available for all agricultural areas in Germany. Another system for the estimation of yield potential is the Müncheberger Soil Quality Rating (SQR). It was developed by Mueller et al. (2007) and adopted to all arable land in Germany by BGR (2013). On the basis of data from the German Federal States Bavaria, Thuringia and Saxony (SLL 1999, TLUBN 2011, STMUV 2014) for which classifications according to both the ´Bodenpunkte´ (soil scores according to the ´Bodenschätzung´) and to the SQR are available, it was possible to determine a function that can be used to convert both systems into the other (Hirschfeld et al. 2020, Grunewald et al. 2021).

In order to assess SQR compatible values for grassland throughout Germany, the average values for arable land were also assigned to all grassland areas of a municipality in a first step. These values were then corrected downwards according to the ratios between arable land and grassland, based on the agricultural soil estimates for all counties/districts in each of the above-mentioned German states.

The delineation of arable and grassland is based on data of the land-cover model ´LBM-DE´ Germany for 2012 and 2015 (BKG 2016, BKG 2019). The arable land areas were assigned to SQR values from a relatively coarse dataset (250 m × 250 m) by the BGR (2013). For this purpose, the cropland areas also had to be gridded. The resolution used was 5 m × 5 m to preserve the extent of arable land given by LBM-DE. In some cases, the arable land areas defined by LBM-DE did not coincide with the SQR dataset. In this case, those areas were assigned to the average SQR of that municipality.

Results are site-specific SQR- and ´Bodenschätzung´-compatible estimates for arable land and SQR- and ´Bodenschätzung´-compatible mean values for grassland at municipality level (Fig. 1a, upper legend).

The economic evaluation of the ´Bodenpunkte´ (soil scores) - and indirectly also the SQR values - is based on the information given by Garvert (2017) that, in western and southern states of Germany, a rental income of 4.81 Euro per soil score can be achieved on average. In the six eastern Federal States the average is only 2.74 Euro due to different agricultural and ownership structures. The above factors were calculated on the basis of lease rates from 2010 and 2011. In order to adjust them to the 2018 lease level, we increased them by 49% (Statista 2022). The adjusted factors were then multiplied by the soil scores determined for each area. The result is a nationwide estimate of agricultural rents shown in Fig. 1a, lower legend.

The factors taken from Garvert (2017) are average values per soil score, which Garvert calculated with the help of the hedonic price function he estimated. A more accurate calculation, using the coefficients of the hedonic function themselves, instead of the above averages, would result in: (1) values lower than average for land with low soil scores and (2) higher values for land with high soil scores. However, such a precise calculation would have required an additional effort that was not feasible within the scope of our pilot study. As a result, in Fig. 1a and Fig. 4b, land with a low yield potential tends to be rated too high and land with a high yield potential tends to be rated too low.

Furthermore, the yield potential explains only part of the agricultural land rent (cf. Feichtinger and Salhofer 2016, Garvert 2017). Other factors, such as the size of the agricultural area, can also be partly directly linked to the value of biomass production, for example, through related cost variables. However, additionally, there are influencing factors that have little to do with the value of biomass service. An example would be a high regional demand for land that can be used to dispose surplus manure from animal production, which can also lead to higher lease rates.

So far, there is no study that specifically examines the various influencing factors in terms of their significance for the ecosystem service biomass production. As a result of this circumstance, only the yield potential was considered as an influencing factor in our study. Hence, German-wide lease rates presented in Fig. 1a and those for the Rhine-Sieg County in Fig. 4b tend to be too low when considered as a whole. After comparing our modelled lease rates with statistically determined average values for 2018, an underestimation of approx. 6.95% can be assumed. In few cases, where the areas are currently not being used, values show the biomass provisioning potential.

Figures for timber services of forestry land have been estimated biophysically at the district level by Elsasser et al. (2020) according to the method proposed by SEEA-EA. Economic values presented by these authors, however, are not compatible with environmental accounting because they refer to timber sales that include, for example, wages. According to SEEA-EA, the value for timber services is the timber increment of the respective year converted into the present value of future sales revenues that can be achieved by this increment, minus costs incurred. An approximate value is the (average) annual net profit of forest enterprises per hectare, which was taken here from official statistics (StBA 2020c, BMEL 2021a, BMEL 2021b) as a substitute. These values are not spatially differentiated, which, in this context, is less problematic. Differentiations in production value hardly become relevant for decision-making, since with forests conservation, values account for the overwhelming majority of the total value of both services considered.

Appreciation of ecosystem and species services

General approach

According to UN SEEA-EA (2021), ecosystem services for the national goals and individual preferences for biodiversity conservation cannot be included in environmental economic accounts in monetary terms, as these services are provided without any transaction between an individual and the ecosystem. However, the recording of this service is considered very relevant and it is proposed to include it in the complementary accounts.

Based on setting national and international targets for biodiversity conservation and numerous empirical studies on the willingness to pay for nature conservation (Martin Lopez et al. 2007, CBD 2021, EC 2022a), it can be assumed that goals of conserving species and habitats, without serving any further purpose, are amongst human preferences. Furthermore, in view of the global decline in biodiversity and natural habitats, it can be expected that biological diversity is scarce. With these two characteristics - part of the preference function and scarcity - biodiversity fulfils essential properties of an economic good and, in principle, can be recorded on the basis of scarcity prices and exchange values compatible with other values in environmental economic accounting; just like other goods and other ecosystem services. Whether this takes place in the central area of environmental accounting or as a supplementary valuation appears to be of secondary importance.

Ecosystem services for biological diversity conservation are valued here on both cost and benefit sides. Estimates of costs for a complete implementation of Natura 2000 in Germany (LANA 2016) were used to calculate monetary values for the cost side. An estimate for benefits was derived from studies on the willingness to pay for the implementation of nation-wide biodiversity conservation programmes.

In both cases, the so-called 'biotope value points' (OECD 2016) served as the basis for physical recording of ecosystem services for nature conservation. The derivation of biotope value points takes characteristics, such as naturalness, age, the occurrence of endangered species and threat to the ecosystem itself, into account. In Germany, these points are often used to determine whether impacts on nature and landscape have been compensated by restoring or creating other habitats. Biotope value points can be regarded as physical exchange values for ecosystems that are based on expert knowledge and legal regulations and have a price-like function, albeit on a non-monetary scale.

The cost-based estimate of the value of the appreciation of species and ecosystem service (conservation of biodiversity service) is based on the assumption that investments in nature conservation have a social rate of return (discounted difference between benefits and costs, internal rate of return) that is often used in cost-benefit analysis of public projects (2% to 4%) to show the ´regular´ profitability of other, also private, investments (for details see next chapter).

However, investments in nature conservation only have the same social return as other investments if there is no disproportionate lack of biodiversity compared to other goods. This would be in line with the principle of national accounting, which also uses existing prices and quantities of goods as calculation variables without asking whether they correspond to an optimal allocation, i.e. an optimal distribution of productive resources to the production - and preservation - of various goods.

If, instead, a particularly high scarcity of biodiversity is assumed, an appropriate price would not have to be estimated on the basis of the actual expenditure made, but directly on the basis of the benefits of the measures (e.g. via a contingent valuation).

Willingness-to-pay analyses for conservation of individual species, individual habitat types or for local nature conservation programmes, aggregated over all species, all habitat types or all regions, generally lead to values much higher than values of the willingness to pay for the conservation of all species, all habitats or a programme at national level (cf. Whitehead et al. 1998, Meyerhoff et al. 2012, McFadden and Train 2017). Therefore, two surveys on willingness to pay for national conservation programmes (Hampicke et al. 1991, Meyerhoff et al. 2012) were used here, to determine benefits of nature conservation, each comprising a comprehensive set of measures. The conversion of willingness to pay to individual biotope value points was carried out in the same way as for the cost-orientated consideration. To make results comparable, values were adjusted for inflation.

Data and methods

In the context of a cost-benefit analysis and environmental accounting, market prices would be ideal for calculating the economic value of biodiversity services. In a cost-benefit analysis, these market prices must not be too distorted, i.e. they must be as close to the true economic value as possible. In fact, market prices for biotope value points exist in Germany. They could be determined, for example, at the land agencies that carry out compensation and replacement measures for third parties (cf. BFAD 2022). However, a variety of biotope valuation procedures in Germany at local, regional, state and federal level and in different specialised planning differ in detail. Average prices or price ranges, based on these valuations, are not yet available.

Instead, an average monetary value per biotope value point, that applies to all ecosystem types, was calculated. This was based on a detailed cost estimate of various habitat restoration measures; these will be required in the coming years to meet the obligations of the EU Habitats Directive (LANA 2016). Development measures for 43 different ecosystem types, for which cost data were available, were considered. These measures cover 1.16 million hectares, which corresponds to 3.2% of the German land cover.

The procedure applied for monetary valuation, explained below, combines methods for estimating real estate values using construction costs (ImmoWertV 2019, Art. 22) with elements from the habitat equivalency analysis (NOAA 2020). The latter is used to determine compensation for ecological damage considering also time needed for restoration (Schweppe-Kraft 2009). The original form of our method was developed in discussion with German monetary tree assessment procedures (Schweppe-Kraft 1996).

The following data are recorded for each individual restoration measure considered in the calculation:

- value of the initial biotope (in biotope value points),
- time until the target biotope has reached its desired condition,
- value of the target biotope when the desired condition is reached (in biotope value points),
- one-off investment costs including costs of land acquisition, if necessary for biotope development,
- future annual management costs and/or compensation for non-use; profits from the sale of market products are considered, when calculating net management costs.

The present value of investment and management costs could be compared to the value difference between the initial and target biotope. However, this would exclude the fact that the value of the target biotope will only be reached in the future. To take this into account, the future biotope values are discounted and herewith a discounted value difference is calculated, which, depending on the development time, can be significantly smaller than the simple value difference (cf. Fig. 2a).

Dividing the present value of the investment and maintenance costs by the discounted biotope value point difference yields a monetary value for a one-off payment required to achieve a single additional biotope value point. The one-off payment can be converted into a constant annual payment (annuity). The result is an annual payment which, according to our method, is regarded as the annual monetary value of a single additional biotope value point. The internal rate of return of the restoration measure can be calculated from the amount of the investment and management costs and the annual monetary value of the additional biotope value points created. If the same discount rate is used when discounting the future biotope value points and when converting one-off payments into annual payments, the internal (social) rate of return of the restoration measure corresponds exactly to the discount rate used. If this discount rate (roughly) corresponds to the usual profitability of investments, then through the application of the described method one assumes that the considered investment for habitat restoration including annual management cost has a social rate of return that corresponds to the usual profitability of other investments.

As Fig. 2 shows, the monetary value of the biotope value point per restoration measure can differ substantially between different types of measures. It could, therefore, be argued that the highest monetary value found per biotope value point corresponds to society's current marginal willingness to pay. This marginal value could be taken as the price of each biotope value point. However, politicians, when deciding on programme funding, usually do not consider cost-benefit ratios of each individual programme component, but rather they look at the cost-benefit ratio of an overall programme. This suggests that the average cost per additional biotope value point should be taken as the marginal social willingness to pay or simulated price per biotope value point, taking all measures into account. Fig. 2b shows how this average value per biotope value point changes when different discount rates (2%, 3%, 4%) and calculation periods (infinite, 50 years, 25 years) are applied.

As mentioned above, the implicit assumption of a normal social rate of return for habitat restoration measures is only acceptable if the existing amount of biodversity corresponds to social preferences, i.e. from the the point of view of the individuals, the scarcity of these goods is not higher than the scarcity of other goods. If instead, the demand for biodiversity is higher than for other goods, in relation to their relative prices, only a direct estimate of the benefits of conservation measures can correctly reflect the value of biodiversity.

Two surveys on the willingness to pay for national conservation programmes (Hampicke et al. 1991, Meyerhoff et al. 2012), each comprising a comprehensive set of restoration measures, were used here to determine the benefits of nature conservation measures on the basis of Contingent Valuation studies. The willingness to pay for the whole programme was converted to an individual biotope value point. This was achieved in the same way as for the cost-based approach. Adjusted for inflation, the benefit per biotope value point, determined on the basis of both CV-studies, is about twice as high as the benefit determined here on a cost basis. For details, see Hirschfeld et al. (2020). The cost-based assessment may, therefore, underestimate the actual benefits of biodiversity.

In all mentioned cases, biotope value points were assigned to ecosystems according to the biotope value list by Mengel et al. (2018), which was developed for the Federal Compensation Ordinance (BKompV 2020) and has, ever since, been further differentiated, especially in the area of coasts and seas. The 2018 list defines biotope value points for approximately 500 different ecosystem types. Scores range from 0 (sealed areas) to 24 (intact mires and fens, old semi-natural forests). Points listed are average values that can be increased or decreased by a maximum of three points depending on the condition of the specific ecosystem on site.

Like the biomass provisioning service, German-wide recording of ecosystems is based on the ´Land Cover Model Germany´ LBM-DE of the Federal Agency for Cartography and Geodesy (BKG 2019). This dataset characterises land-use and land-cover, applying the three-digit classification of the European CORINE Landcover (CLC) system. LBM-DE has a spatial resolution of at least 1 ha and is updated every three years. For Germany, there are 37 different ecosystem types, for example, salt marshes, land-use types, such as arable land or land-cover, such as forest.

Linear elements of the official topographic-cartographic information system (ATKIS Basis DLM, BKG 2016) were integrated into the LBM-DE. These factors include traffic routes, paths, as well as all watercourses, hedge structures, tree rows and rocks (Grunewald et al. 2020, Grunewald et al. 2021).

From the LBM-DE and ATKIS classes, the importance of the areas for biodiversity can already be determined to a limited extent, but only very roughly. Therefore, the following specific data were used to further assess the CLC classes and linear elements in terms of their composition and average condition:

- data from the reporting on European Habitats Directive (BfN 2020a),
- data from the reporting on the Water Framework Directive (UBA 2020a),
- mapping of biotopes within the agricultural landscape with high nature conservation value (HNV mapping, BfN 2020b),
- data from the Federal Statistical Office on land use and the extent of various types of agricultural land use (StBA 2020a, StBA 2020b) and
- the Federal Forest Inventory (Thünen-Institut 2020).

On the basis of these sources, it was possible to define approx. 300 different ecosystem types and ecosystem condition classes covering the entire area of Germany. These 300 (approximately) different types were each attributed values from the biotope value list. By assigning subclasses to the spatially specific CLC classes and linear elements, the distribution of the total sum of biotope value points represented in the ecosystem subclasses can also be approximated in a spatially specific manner for the entire German area. Fig. 1b shows the nationwide assessment of biotope points (upper legend) and the monetary value of appreciation of ecosystem and species services (bottom legend).

Results for biomass provisioning and appreciation of ecosystem and species services in comparison - applicability for site planning in rural areas

Due to availability, the following monetary values are partly linked to geographical data from different years (2015 and 2018). This results in minor inaccuracies, which can largely be neglected, because geographical data have changed only slightly in relation to each other in the years in question.

The two maps in Fig. 1 contrast the ecosystem services for agricultural biomass production (for food, fibres, energy biomass etc.) and services for conserving of biological diversity on a national scale, each in their own physical unit (SQR and biotope value points, see upper legend), as well as monetary (see bottom legend). Fig. 1 also gives an impression of the range, frequency and spatial distribution of the values for conservation and agricultural biomass production services for each ecosystem and agricultural production site, respectively.

The monetary valuation of the two services allows for comparison and for adding them up for a joint value. This is done in Fig. 3 for highly aggregated ecosystem types. Here, the ecosystem services for timber production are included. For completeness, additional information is provided on the value of ecosystems as a location for settlements, a value that is of particular importance in the context of spatial planning. Sales values for the biomass produced on agricultural and forest lands are added as well. Although these values do not represent ecosystem services, they can likewise become relevant for site planning under certain economic and social conditions.

Fig. 3 and Fig. 1 show that the monetary value of ecosystem services for timber and agricultural production is significantly lower than the monetarily-valued services of the same ecosystems for biodiversity. Furthermore, this applies to agricultural land, even if all particularly nature conservation-relevant land elements, such as hedges, stone walls, ditches, small wetland elements etc., are excluded. This will be further analysed in the Discussion chapter. Due to their high biodiversity conservation value, non-utilised ecosystems are, on average, significantly more valuable than agricultural land and approximately as valuable as forests.

The situation is only different in the case of settlement areas. Here, the building land value for residential or commercial purposes, which can be seen as a value for an abiotic service (see explanation in the annex of Fig. 3), is significantly higher than the biodiversity value. However, this does not mean that there should be a further expansion of settlement areas at the expense of areas for biodiversity, forestry and agricultural production. In addition to the effects on biodiversity and the availability of agricultural and forestry land, the increase in settlement, industry and infrastructure areas has other negative effects. Depending on the specific planning, these effects can degrade recreational areas close to settlements, can increase the urban heat island and tend to increase traffic volumes along with multiple consequences on the quality of the urban environment, health and climate change. These effects are important for deciding whether or not a settlement or infrastructure project should be carried out. However, in a first planning step, when distinguishing between less and more environmentally damaging sites, the spectrum of environmental impacts to be examined can often be limited. In this paper, the spectrum is limited to the aspects of biodiversity and biomass production, although in Germany also, for example, recreation or flood protection would be considered regularly. This aspect will be addressed further in the Discussion chapter.

Estimating the monetary value of a biotope value point on the basis of willingness-to-pay captured by contingent valuation studies led to values per biotope value point which are proximately twice as high as the valuation based on costs (see above and Hirschfeld et al. (2020)). Although this is a considerable discrepancy, it would hardly change the relative values of the ecosystems shown in Fig. 3; and thus, would not considerably alter site planning decisions, based on these values.

If ecosystem services can only be utilised with a high capital input, ecosystem transformations may not only result in the loss of ecosystem services, but also in the loss of the capital benefits associated with the utilisation of the ecosystem service. An example are farms with high capital inputs, for example, dairy farming. If such a farm cannot lease neighbouring land after the conversion of its own land in favour of an infrastructure project, the economic loss may be higher than the ecosystem service of the converted land. In the worst case, the farm will be closed down. The economic loss corresponds to the value added, if not only employed capital (e.g. through the sale of machinery), but also labour associated with ecosystem service utilisation cannot be applied elsewhere. In the short term, economic losses could, furthermore, occur for producers of the input products. In this case, the total economic loss could include not only the value of the ecosystem service, but also the value of the products produced.

If the turnover of the products is considered instead of the ecosystem services, i.e. if inputs of goods, labour and capital required for production are added to the ecosystem services, the picture outlined above changes. As Fig. 3 shows, production areas then become more valuable than unused or near-natural areas.

However, such a scenario, with completely inflexible capital, labour and product markets, is not at all realistic. In an industrialised country with functioning markets and a shortage of labour, like Germany, the total economic loss associated with a loss of biomass provisioning services will be far closer to the service value than to the product value. Only when major land-use changes, within short periods, coincide with insufficient adjustment possibilities of labour and capital markets value added, or in the worst case sales values, should additionally become relevant for location decisions.

To the authors' knowledge, currently no other study is available that attempts to value biodiversity for an entire country - on the basis of the exchange value concept - and contrasts this evaluation with values for biomass provisioning services. Thus, validating our results against comparable studies is a challenge. Lease prices are influenced by the structure of respective lease markets and do not always correspond to the actual value of the ecosystem service (see also the chapter on ´biomass provisioning services´). However, in the authors' opinions, this cannot be the reason for the considerable difference between the value of provisioning services and the value of ecosystem and species appreciation services. That is evident in our figures. When comparing our results on biodiversity with other studies, for example, on national parks, certain projects or regional conservation measures, we found that our per ha values for nature conservation services are rather low. The reason might be the so-called embedding/scope effect (for an explaination see section ´appreciation of ecosystem and species services´). Specifically, on the values for arable land, see ´Discussion´.

According to the authors, the high values for biodiversity, compared to ecosystem services for biomass production, can be explained as following: biodiversity has increasingly become a very scarce commodity, while technical progress and breeding successes in agriculture have meant that biomass can be produced ever more cheaply. As a result, the relative value of biodiversity has increased and the political and individual willingness to pay for its restoration is higher and more money per land unit is spent for this purpose than for purchasing of a piece of forest for timber production or leasing land for agricultural use.

These high values assigned to biodiversity, compared to values of biomass provisioning services, must, however, not be misunderstood. They do not mean that converting all agricultural and forestry land into nature reserves is economically and socially beneficial. The willingness to spend large sums of money, in order to achieve an improvement of one biotope value point, can be explained by the current high scarcity of biodiversity. Each restoration measure would reduce this scarcity and, thus, change relative values. At the same time, the value of a biomass production area depends on the current supply and demand for biomass. The demand is dependent, amongst other things, on the international purchasing power for food, which in turn, is determined by global income distribution. Other factors include a possible increase in demand for energy biomass or an expected expansion and preservation of forest stands for climate change mitigation reasons.

In other words, relative prices or values for biodiversity and biomass production presented here are prices and values referring to the current situation. Therefore, they only apply to relatively small changes in relation to the total stock of ecosystems and their services concerned. Policy scenarios, in which an extensive change in the utilisation of ecosystems and ecosystem services is considered for an entire economy, would have to take future expected price and value changes into account. In contrast, relatively small changes - in macroeconomic terms - due to individual settlement or infrastructure projects are not expected to result in widespread price and value changes, so that current prices and values can be used as a proxy for assessing quantity changes.

In the field of biodiversity, however, even relatively small quantitative changes can lead to significant value changes. An example would be destroying the site of a highly endangered species. The biotope value point approach used here is too vague to be able to represent such special features. At the latest, when highly-endangered species are expected to be affected, the procedure proposed here must be underpinned by on-site surveys to support site planning.

Raw data for ecosystem accounting include values for biomass provisioning and nature conservation services that are far more differentiated than those presented in Fig. 1 and Fig. 3. Fig. 4 below shows how these can be used to support existing site planning methods with economic data on the value of ecosystem services. By aggregating monetary ecosystem service values, it is possible to directly identify which areas are most likely to be considered as sites, if the aim is to reduce the total value of all ecosystem services (here reduced to only two) as little as possible.

This procedure would primarily identify areas with a high proportion of arable land as the most suitable locations for settlement, industrial and infrastructure development, if only biomass provisioning and appreciation of ecosystem and species services are considered. In Germany, arable land is often used for new settlements and infrastructure facilities (Tietz et al. 2012: 17). Additionally, in Germany, arable land is frequently used for ecological compensation measures that regularly become necessary in such cases. This pattern corresponds to what Fig. 3 suggests in terms of the economic values shown there. Through development, areas with the lowest total value (arable land) are replaced by areas with a significantly higher economic valuation (settlement areas). Via ecological compensation, areas with a lower total value (arable land) are again converted into areas with a higher value (near-natural areas or forest). Thus, the procedure proposed here to support existing site planning methods with ecosystem service values from ecosystem accounting would seemingly not fundamentally change current decision-making. Rather, it underpins established procedures and decision-making routines with economic data that further strengthen the aspect of biodiversity conservation in location planning.

General discussions, conclusions and outlook

On the basis of ecosystem services for biomass provisioning and for nature conservation, it was shown that a monetary valuation of these services, as it is currently being discussed and developed for an application in environmental accounting, can meaningfully support decision-making processes on the ground with socially-relevant information. Compared to other decision support methods, monetary values for ecosystem services offer the advantage that they can be compared with each other and with other monetary values (Boyd 2011). Thus, they provide an additional basis for weighing up different concerns, which so far, has not been available in a comparable manner. When planning new settlements, transport lines or infrastructure facilities in rural or on the edge of urban areas, the possibility to aggregate values for different ecosystem services (such as for agricultural and timber production and the preservation of biodiversity) can simplify location searches with the lowest overall impairment of ecosystem services.

The fact that values for ecosystem services from environmental economic accounting can be used meaningfully for location decisions does not mean that the decision must automatically be based on values available there. This is the case, for example, when other ecosystem services that have not yet been evaluated on a nationwide basis have to considered, such as values for recreational use of the landscape. If recreation-related services would also be considered, especially near-natural ecosystems in the vicinity of urban areas and areas equipped with special recreational infrastructure, these would gain additional value. Furthermore, many specific impacts, for example, on animal species, require additional on-site studies and cannot yet be assessed on a national data basis. In addition, institutional and legal specifications must be considered in making decisions, such as different protected area categories, which take precedence over monetary evaluations.

The above statement that the proposed application of monetary ecosystem service values from national accounting may not fundamentally change planning procedures towards a more sustainable utilisation of ecosystems, along with the explanations of short-term prices and values and their long-term development, highlights the weaknesses of an economic valuation if it reflects only current ecosystem service values. Those present service values alone are not suitable for a more sustainable decision-making, especially if they influence the usability of ecosystems in the long term. In Germany, it is common practice to convert arable land into settlement, industry and infrastructure land and also into ecosystems with high biodiversity to use the latter as an ecological compensation. We argued that, in the short term, this may be economical; however, even considering only two ecosystem services - namely the one for biomass provision and for nature conservation - this practice does not seem to be sustainable in the long term when considering the future demands for food or energy biomass. Furthermore, intensification of agriculture has long since reached its limits due to effects on environmental degradation, for example, by impacts of pesticides and fertilisers on habitats and groundwater (Garcia 2020, Midler 2022). Ongoing expansion of settled areas at the expense of agricultural lands, thus, will result in a shortage of both agricultural land and land for conservation of our biodiversity, as well as other related ecosystem services. It is important to realise that monetary values of ecosystem services from environmental economic accounting only reflect current scarcities and prices. Considering future scarcity would only be possible if, beyond current services, environmental economic accounting would value ecosystems also as capital (stocks). A reliable long-term capital valuation, which captures future developments with sufficient certainty, is currently not apparent. It is, therefore, important to use the window of opportunity (e.g. provided by the Stern Review (Stern 2007) and the currently published report by Dasgupta 2022) and to promote, for example, a concrete valuation of peatlands from a climate protection perspective. The so-called Methodenkonvention (convention of methods) of the German Federal Environment Agency, for example, in the field of CO_2 emission valuation, could provide a good basis for this purpose (UBA 2020b).

The concept of biotope value points, which has been used in this work as a general yardstick for quantifying biodiversity, may not be sufficiently scientifically sound to some readers. This concept can be described as a heuristic method, developed by planners, biologists and practitioners from nature conservation administrations, in order to decide on type and extent of necessary compensation measures on a generally accepted basis. Certain value relations, like a 6 points value for arable land and ´only´ 24 points value for peatlands, can be explained by the fact that a lower score for arable land would ultimately mean that fewer compensatory measures would have to be implemented in Germany. The biotope value points were used here because they represent a socially-accepted metric by which biodiversity is recorded comparatively in practice. It was not the task to scientifically question and discuss the concept of biotope value points. However, the authors see no other scientifically- or socially-sound approach with which it would be practical to define physical and monetary exchange values for biodiversity at this time.

For further development of the monetary valuation of biotope value points nationwide, it would be important to decide the following: first, whether valuation should be based on costs or on willingness to pay and second, whether public restoration measures or impact compensation measures should be used as the basis for estimating costs:

- The rather comprehensive nature conservation programmes, for which willingness to pay per biotope value point was assessed, would increase Germany's total biodiversity, measured in biotope value points, only rather slightly, estimated at about 6% (Hirschfeld et al. 2020). The willingness to pay for additional biotope value points can, therefore, be interpreted as a marginal willingness to pay per biotope value point, in the sense of exchange values. They are twice the values that result from the cost-based approach. Therefore, a decision would have to be made whether to perform a valuation based on costs - and accept the risk of ignoring higher social scarcities - or whether to use values based on surveys – that, however, tend to be more uncertain.
- In Germany, a large, probably even the largest part of measures to restore or develop biotopes are carried out as compensation measures within the framework of impact mitigation regulations under nature conservation and building law. Far fewer restoration actions are carried out as nature conservation measures financed by the public sector or NGOs. Measures under the impact regulation tend to be more expensive per biotope value point created than public nature conservation measures. This is, in part, because of the frequent small-scale impact compensation measures compared to the larger-scale public nature conservation projects. Putting the calculation of costs per biotope value point on a broader basis in the future, thus, seems plausible. An example can be the random evaluation of the costs for real biotope development measures under consideration of impact regulation and public nature conservation measures.

At this stage, we would like to point out once again that the underlying study was a pilot. The survey was implemented within the framework of the Environmental Research Plan of the Ministry of the Environment, Nature Conservation and Nuclear Safety as part of the implementation of Target 2, Action 5 of the European Biodiversity Strategy until 2020. A larger part of the survey was commissioned by the Federal Agency for Nature Conservation; the remainder was carried out by the Agency´s own staff. The goal was to examine possibilities of integrating ecosystem services into environmental economic accounting in Germany. The first two ecosystem services selected for the Ministry of the Environment are ´biodiversity conservation´ and ´ecosystem services of urban green spaces´, the latter being the subject of another publication by the authors in one ecosystem. One of the main reasons for this choice was that useful preliminary work already exists on both topics. Ecosystem services for biodiversity conservation should be compared with biomass provisioning services, in part because often differing views on the importance of this service in relation to biodiversity exist. Target 2, Action 5 was carried out under the EU-wide agreement that, if possible, no new primary data should be collected for implementation. In addition, research conducted for practical issues of the various sectoral ministries usually has significantly lower budgets than thematically comparable research projects of the Federal Ministry for Education and Research. This is due to the different orientation, namely applied questions instead of research funding.

These framework conditions make it understandable that the work had to concentrate on producing plausible results orientated to political communication. For this purpose, the results were compared with other important data, for example, from the Federal Statistical Office. However, an in-depth statistical analysis of the possible uncertainties of the results had to be omitted for resource reasons. Further research can be supported, for example, by the extensive and detailed databases of the Thünen Institutes affiliated with the Ministry of Agriculture; for example, on forest issues (cf. Elsasser et al. (2020)) or to capture the effects of various ´distortions´ of regional lease markets on the relationship between ´true´ ecosystem services and actual lease prices.

According to the authors, additional information on ecosystem services for recreation, climate change mitigation and flood prevention would be particularly helpful for site planning issues. In the meantime, initial results on climate change mitigation services are available from a follow-up project in which the authors are involved. Due to time constraints, these results could not be included in this article. The same project is currently also working on a German-wide economic evaluation of recreation services. Extensive and complex simulations are required to obtain valid results on ecosystem services in flood protection. Going forward, a project on this topic with pooled resources from the thematically responsible ministries and the Ministry of Education and Research would certainly be beneficial.

Acknowledgements

The authors would like to thank the German Federal Agency for Nature Conservation for funding the research on which this article is based within the framework of the Environmental Research Plan of the Ministry of Environment, Nature Conservation and Consumer Protection and the EU Commission for support in further processing, discussion and presentation of the results within the MAIA research project.

Conflicts of interest

References

- BauGB (2017) Baugesetzbuch in der Fassung der Bekanntmachung vom 3. November 2017 (BGBl. I S. 3634), das zuletzt durch Artikel 2 des Gesetzes vom 20. Juli 2022 (BGBl. I S. 1353) geändert worden ist.
- BFAD (2022) Bundesverband der Flächenagenturen in Deutschland e.V.: Der Bundesverband der Flächenagenturen in Deutschland e.V. - BFAD stellt sich vor! https://www.verband-flaechenagenturen.de/%C3%BCber-uns/. Accessed on: 2022-3-20.
- BfN (2020a) Bundesamt für Naturschutz: Nationaler Bericht 2019 gemäß FFH-Richtlinie. https://www.bfn.de/themen/natura-2000/berichte-monitoring/nationaler-ffh-bericht.html. Accessed on: 2020-3-24.
- BfN (2020b) Bundesamt für Naturschutz: High Nature Value Farmland-Indikator - Ein Indikator für Landwirtschaftsflächen mit hohem Naturwert in Deutschland. https://www.bfn.de/themen/monitoring/monitoring-von-landwirtschaftsflaechen-mit-hohem-naturwert.html. Accessed on: 2022-3-24.
- BGR (2013) Bundesanstalt für Geowissenschaften und Rohstoffe: Ackerbauliches Ertragspotential der Böden in Deutschland. Bewertet nach dem Müncheberger Soil Quality Rating (1:1.000.000) auf Basis der BÜK1000N. https://www.bgr.bund.de/DE/Themen/Boden/Ressourcenbewertung/Ertragspotential/Ertragspotential_node.html. Accessed on: 2020-3-25.
- BKG (2016) Digitales Basis-Landschaftsmodell (AAA-Modellierung). Basis-DLM (AAA). Stand der Dokumentation: 01.04.2016. Bundesamt für Kartographie und Geodäsie (BKG), Frankfurt/Main. [In German].
- BKG (2019) Bundesamt für Kartographie und Geodäsie: Digitales Landbedeckungsmodell für Deutschland. LBM-DE 2018, Stand der Dokumentation 15.02.2019. Bundesamt für Kartographie und Geodäsie, Frankfurt/Main.
- BKompV (2020) Verordnung über die Vermeidung und die Kompensation von Eingriffen in Natur und Landschaft im Zuständigkeitsbereich der Bundesverwaltung (Bundeskompensationsverordnung - BKompV). Bundesgesetzblatt I S.1088. URL: https://www.gesetze-im-internet.de/bkompv/BKompV.pdf
- BMDV (2014) Bundesministerium für Digitales und Verkehr - Überblick zur methodischen Weiterentwicklung des Bewertungsverfahrens für den Bundesverkehrswegeplan 2015. https://www.bmvi.de/SharedDocs/DE/Anlage/G/BVWP/bvwp-2015-kurzbeschreibung-methodik.pdf?__blob=publicationFile. Accessed on: 2022-8-23.
- BMEL (2021a) Bundesministerium für Ernährung und Landwirtschaft: Statistik und Berichte des BMEL. Forst, Holz. Tabellen zur Forst- und Holzwirtschaft: Betriebsergebnisse in Forstbetrieben nach Besitzarten. Waldfläche nach Eigentumsart und Baumartengruppe. https://www.bmel-statistik.de/forst-holz/tabellen-zu-forst-und-holzwirtschaft/. Accessed on: 2021-1-17.
- BMEL (2021b) Bundesministerium für Ernährung und Landwirtschaft: Statistik und Berichte des BMEL. Forst, Holz. Tabellen zur Forst- und Holzwirtschaft:

Forstwirtschaftliche Gesamtrechnung. https://www.bmel-statistik.de/forst-holz/tabellen-zu-forst-und-holzwirtschaft/. Accessed on: 2021-1-17.
- BMEL (2021c) Bundesministerium für Ernährung und Landwirtschaft: Statistik und Berichte des BMEL. Landwirtschaft. Landwirtschaftliche Gesamtrechnung: Verkaufserlöse der Landwirtschaft nach Erzeugnissen, Produktionswert des Bereichs Landwirtschaft, Wertschöpfung der Landwirtschaft. https://www.bmel-statistik.de/landwirtschaft/landwirtschaftliche-gesamtrechnung/. Accessed on: 2021-1-14.
- BNatSchG (2021) Bundesnaturschutzgesetz vom 29. Juli 2009 (BGBI. I Seite 2542), das zuletzt durch Artikel 1 des Gesetzes vom 18. August 2021 (BGBI. I Seite 3908) geändert worden ist. .
- Boyd J (2011) Seminar 3: Valuation of Ecosystem Services. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwijy5Cz3eH5AhVuxQIHHcw papers%2FEcosystem-Services-Seminar-3-Valuation.pdf&usg=AOvVaw1Feoe1aPQd4Dgle9M4fEfp. Accessed on: 2022-8-23.
- CBD (2021) Convention on Biological Diversity – First draft of the post – 2020 global biodiversity framework. https://www.cbd.int/article/draft-1-global-biodiversity-framework. Accessed on: 2022-8-23.
- Dasgupta P (2022) The Economics of Biodiversity: The Dasgupta Review. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962785/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf. Accessed on: 2022-8-23.
- EC (2022a) European Commission - EU Biodiversity Strategy for 2030. https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_de. Accessed on: 2022-8-23.
- EC (2022b) European Commission: EU Biodiversity Strategy to 2020. https://ec.europa.eu/environment/nature/biodiversity/strategy_2020/index_en.htm. Accessed on: 2022-3-28.
- Elsasser P, Altenbrunn K, Köthke M, Lorenz M, Meyerhoff J (2020) Regionalisierte Bewertung der Waldleistungen in Deutschland. Thünen Report 79. Johann Heinrich von Thünen-Institut, Braunschweig. [In German]. URL: https://literatur.thuenen.de/digbib_extern/dn062592.pdf
- Feichtinger P, Salhofer K (2016) The FischlerReform on the Common Agricultural Policy and Agricultural Land Prices. Land Economics 92: 411-432. https://doi.org/10.3368/le.92.3.411
- Garcia A (2020) The Environmental Impacts of Agricultural Intensification. CGIAR Advisory Services Technical Note N. 9 URL: https://cas.cgiar.org/spia/publications/environmental-impacts-agricultural-intensification
- Garvert H (2017) Determinanten der Pachtpreise in Deutschland –Biogasförderung und Direktzahlungen im Fokus. Institut für Agrarpolitik und Marktforschung, Justus-Liebig-Universität Gießen, Giessen. [In Germa]. URL: http://geb.uni-giessen.de/geb/volltexte/2017/13142/pdf/GarvertHendrik_2017_07_28.pdf
- Grunewald K, Schweppe-Kraft B, Syrbe R, Meier S, Krüger T, Schorcht M, Walz U (2020) Hierarchical classification system of Germany´s ecosystems as a basis for an ecosystem accounting - methods and first results. One Ecosystem 5 https://doi.org/10.3897/oneeco.5.e50648
- Grunewald K, Hartje V, Meier S, Sauer A, Schweppe-Kraft B, Syrbe R-, Zieschank R, Ekinci B, Hirschfeld J (2021) National accounting of ecosystem extents and services in

Germany: a pilot project. In: La Notte A, et al. (Ed.) Ecosystem and ecosystem services accounts: time for applications. Publications Office of the European Union, Luxembourg, 14 pp. [In English]. URL: http://dx.doi.org/10.2760/01033

- Hampicke U, Horlitz T, Kiemstedt H, Tampe K, Timp D, Walters M (1991) Kosten und Wertschätzung des Arten- und Biotopschutzes. Umweltbundesamt, Berichte, 3/91. Erich Schmidt Verlag, Berlin, 629 pp. [In German].
- Hirschfeld J, Hartje V, Pekker R, Grunewald K, Meier S, Sauer A, Syrbe R-, Zieschank R, Schweppe-Kraft B (2020) Integration von Ökosystemen und Ökosystemleistungen in die Umweltökonomische Gesamtrechnung. Theoretische Rahmenbedingungen und methodische Grundlagen. Research report commissioned by the Federal Agency for Nature Conservation, publication planned.
- ImmoWertV (2019) Immobilienwertermittlungsverordnung vom 19. Mai 2010 (BGBl. I S. 639), geändert durch Artikel 16 des Gesetzes vom 26. November 2019 (BGBl. I S. 1794). https://www.gesetze-im-internet.de/immowertv/. Accessed on: 2020-3-24.
- LANA (2016) LANA (Bund/Länder Arbeitsgemeinschaft Naturschutz, Landschaftspflege und Erholung) Expert Group on ´EU Nature Conservation Financing / GAP 2020´: Effectiveness of the current EU Nature Conservation Financing in Germany, and Requirements for the next Funding Period post 2020. https://www.lpv.de/fileadmin/user_upload/Position_paper_EU_nature_financing_LANA_Expert_Group_Germany.pdf. Accessed on: 2020-3-24.
- Mankiw G, Taylor M (2014) Economics. Cengage Learning
- Martin Lopez B, Montes C, Benayas J (2007) The non-economic motives behind the willingness to pay for biodiversity Conservation. https://www.researchgate.net/publication/222659195_The_non-economic_motives_behind_the_willingness_to_pay_for_biodiversity_conservation. Accessed on: 2022-8-23.
- McFadden D, Train K (Eds) (2017) Contingent Valuation of Environmental Goods. A Comprehensive Critique. Edward Elgar Publishing, Cheltenham, UK; Northampton, MA, USA. [In English]. https://doi.org/10.4337/9781786434692
- Mengel A, Müller-Pfannenstiel K, Schwarzer M, Wulfert K, Strohtmann T, von Haaren C, Galler C, Wickert J, Pieck S, Borkenhagen J (2018) Methodik der Eingriffsregelung im bundesweiten Vergleich. Naturschutz und Biologische Vielfalt, 165. Bundesamt für Naturschutz, Bonn-Bad Godesberg. [In German].
- Meyerhoff J, Angeli D, Hartje V (2012) Valuing the benefits of implementing a national strategy on biological diversity - The case of Germany. Environmental Science & Policy 23: 109-119. https://doi.org/10.1016/j.envsci.2012.07.020
- Midler E (2022) Environmental degradation: impacts on agricultural production. IEEP - Policy Brief URL: https://ieep.eu/publications/environmental-degradation-impacts-on-agricultural-production
- Mueller L, Schindler U, Behrendt A, Eulenstein F, Dannowski R (2007) Field manual for detecting and assessing properties and limitations of soils for cropping and grazing. https://www.zalf.de/de/forschung_lehre/publikationen/Documents/Publikation_Mueller_L/field_mueller.pdf. Accessed on: 2022-3-28.
- Natural Capital Germany - TEEB DE (2018) The Value of Naturefor Economy and Society. A Synthesis of Natural CapitalGermany – TEEB DE. Helmholtz Centre for Environmental Research - UFZ, Leipzig. URL: https://www.ufz.de/export/data/global/212779_Naturkapital-TEEBDE_Synthese_Englisch_BF.pdf

- NOAA (2020) US Department of Commerce & National Oceanic and Atmospheric Administration: Damage Assessment Remediation and Restoration Program. https://darrp.noaa.gov/economics/habitat-equivalency-analysis. Accessed on: 2020-2-21.
- OECD (Ed.) (2016) Biodiversity Offsets: Effective Design and Implementation. OECD Publishing, Paris. [In English]. https://doi.org/10.1787/9789264222519-en
- Schweppe-Kraft B (1996) Bewertung von Biotopen auf der Basis eines Investitionsmodells - eine Weiterentwicklung der Methode Koch. Wertermittlungsforum 14 (1): 1-11. [In Germa].
- Schweppe-Kraft B (2009) Natural Capital in Germany – State and Valuation; with special reference to Biodiversity. In: Döring R (Ed.) Sustainability, natural capital and nature conservation. Metropolis, Marburg. [In Englis].
- Schweppe-Kraft B, Grunewald K (2015) Approaches to the Economic Valuation of Natural Assets. In: Grunewald K, Bastian O (Eds) Ecosystem Services - Concept, Methods and Case Studies. Springer, Berlin, Heidelberg, 85 - 104 pp. [ISBN 978-3-662-44142-8]. https://doi.org/10.2760/01033
- SLL (1999) Sächsische Landesanstalt für Landwirtschaft: Die Landwirtschaftlichen Vergleichsgebiete im Freistaat Sachsen. https://publikationen.sachsen.de/bdb/artikel/13524. Accessed on: 2022-3-28.
- Statista (2022) Durchschnittliche Pachtpreise für landwirtschaftlich genutzte Flächen nach Nutzungsart in Deutschland in den Jahren 1991 bis 2020. https://de.statista.com/statistik/daten/studie/953408/umfrage/pachtpreise-fuer-landwirtschaftlich-genutzter-flaechen-in-deutschland/#:~:text=Diese%20Statistik%20zeigt%20den%20durchschnittlichen,lag%20bei%20rund%20375%20Eur . Accessed on: 2022-8-15.
- StBA (2020a) Statistisches Bundesamt: Genesis-Datenbank. Wohnen und Umwelt. Flächennutzung. Flächenerhebung nach Art der tatsächlichen Nutzung. Bodenfläche (tatsächliche Nutzung). https://www-genesis.destatis.de/genesis/online. Accessed on: 2020-12-29.
- StBA (2020b) Statistisches Bundesamt: Genesis-Datenbank. Anbaufläche (Feldfrüchte und Grünland): Deutschland, Jahre, Fruchtarten. Tabelle 41241. https://www-genesis.destatis.de/genesis/online. Accessed on: 2020-12-19.
- StBA (2020c) Statistisches Bundesamt: Umweltökonomische Gesamtrechnungen. Waldgesamtrechnung. Berichtszeitraum 2014 – 2018. https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/UGR/landwirtschaft-wald/Publikationen/Downloads/waldgesamtrechnung-tabellenband-pdf-5852102.pdf?__blob=publicationFile. Accessed on: 2020-11-16.
- StBA (2021a) Statistisches Bundesamt (2021b): Genesis-Datenbank. Wirtschaftsbereiche. Land- und Forstwirtschaft, Fischerei. Landwirtschaftszählung Haupterhebung. Gepachtete Fläche, Pachtentgelt je ha, Code 41141-0010. https://www-genesis.destatis.de/genesis/online. Accessed on: 2021-1-14.
- StBA (2021b) Statistisches Bundesamt: Genesis Datenbank, Tabelle 61511-0104: Kauffälle, Veräußerte Fläche, Durchschnittlicher Kaufwert für Bauland: Deutschland, Jahre, Baulandarten, Gemeindegrößenklassen. https://www-genesis.destatis.de/genesis/online. Accessed on: 2022-3-28.
- Stern N (2007) The economics of climate change: The Stern Review. Cambridge University Press https://doi.org/10.1017/CBO9780511817434

- STMUV (2014) Bayrisches Staatsministerium für Umwelt und Verbraucherschutz: Vollzugshinweise zur Anwendung der Acker- und Grünlandzahlen gemäß §9 Abs. 2 Bayrische Kompensationsverordnung (BayKompV). https://www.stmuv.bayern.de/themen/naturschutz/eingriffe/doc/vollzugshinweise_acker_gruenlandzahlen_baykompv.pdf. Accessed on: 2022-3-28.
- Thünen-Institut (2020) Dritte Bundeswaldinventur 2012. https://bwi.info/?lang=de. Accessed on: 2020-6-30.
- Tietz A, Bathke B, Osterburg B (2012) Art und Ausmaß der Inanspruchnahme landwirtschaftlicher Flächen für außerlandwirtschaftliche Zweck und Ausgleichsmaßnahmen. [Type and extent of use of agricultural land for non-agricultural purposes and compensatory measures]. VTI Institut für Ländliche Räume URL: https://literatur.thuenen.de/digbib_extern/bitv/dn050574.pdf
- TLUBN (2011) Thüringer Landesamt für Umwelt, Bergbau und Naturschutz: Umwelt regional. Standortbedingungen. https://umweltinfo.thueringen.de/umweltregional/thueringen/06_lw_standortbedingungen.html. Accessed on: 2022-3-28.
- UBA (2020a) Umweltbundesamt: Ökologischer Zustand der Fließgewässer. https://www.umweltbundesamt.de/daten/wasser/fliessgewaesser/oekologischer-zustand-der-fliessgewaesser#okologischer-zustand-der-flusse-und-bache. Accessed on: 2020-6-30.
- UBA (2020b) Umweltbundesamt - Methodenkonvention 3.1 zur Ermittlung von Umweltkosten - Kostensätze . https://www.umweltbundesamt.de/publikationen/methodenkonvention-umweltkosten. Accessed on: 2022-8-23.
- UN SEEA-EA (2021) System of Environmental-Economic Accounting – Ecosystem Accounting: Final Draft (2021), prepared under the guidance of the SEEA Experimental Ecosystem Ac-counting Technical Committee under the auspices of the UN Committee of Experts on Envi-ronmental-Economic Accounting (UNCEEA), version 5 February 2021. https://seea.un.org/ecosystem-accounting. Accessed on: 2022-3-28.
- UVPG (2017) Gesetz über die Umweltverträglichkeitsprüfung in der Fassung der Bekanntmachung vom 24. Februar 2010 (BGBl. I Seite 94), das zuletzt durch Artikel 2 des Gesetzes vom 8. September 2017 (BGBl. I Seite 3370) geändert worden ist.
- Whitehead JC, Haab TC, Huang J- (1998) Part-Whole Bias in Contingent Valuation: Will Scope Effects Be Detected with Inexpensive Survey Methods? Southern Economic Journal 65: 160-168. [In English]. https://doi.org/10.1002/j.2325-8012.1998.tb00135.x
- Wikipedia (2022) Bodenschätzung. https://de.wikipedia.org/wiki/Bodensch%C3%A4tzung . Accessed on: 2022-9-17.

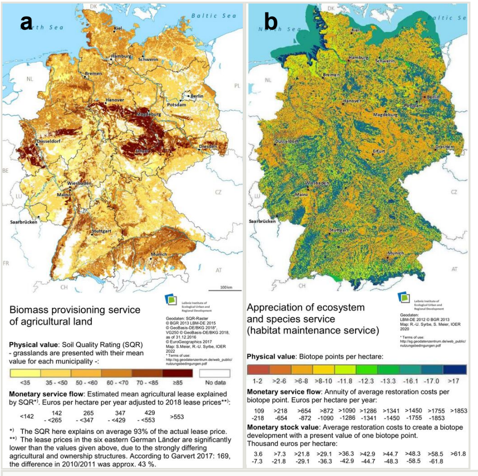

Figure 1.

Ecosystem services for agricultural production and biological diversity (appreciation of ecosystems and species services) presented in physical and monetary units (source: Hirschfeld et al. 2020).

a

Target ecosystem		Source ecosystem		Restoration							Cost per biotope point
	Biotope value points per hectare		Biotope value points per hectare	Time to reach the target (years)	Additional biotope value points after reaching the target per hectare	Additional biotope value points during restoration and after reaching the target, discounted to the begin of restoration (biotope value points per hectare**	Investment cost (euros per hectare	Annual management cost and/or compensation for restrictions (euros per hectare per year)	Present value of investment and management cost (euros per hectare)		Present value of investment and management cost per additional discounted biotope value point (euros per hectare)**
Coastal dunes with *Calluna Vulgaris*	22.00	Meadows and pastures	10.00	100	12.00	3.83	13,650	0	13,650		3,563
Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation	18.00	Natural eutrophic lakes	15.00	80	3.00	1.14	20,116	921	50,808		44,517
Active raised bogs	25.00	Degraded raised bogs	17.00	150	8.00	1.78	30,460	0	30,460		17,110
Stellario-Carpinetum oak-hornbeam forests	25.00	Mixed deciduous forest of moist to fresh sites (age: 10-40 years)	19.00	100	6.00	1.28	0	83	2,750		2,154
Extensiv genutzter Acker	13.75	Acker	6.00	3	7.75	7.21	0	634	21,120		2,929
... Other restoration measures. In total 43 measures covering 1.16 millon hectares Millionen Hektar, which is 3.2 % of German landcover ...											... ...
Surface area weighted mean value:											3,634

* A linear increase in value is assumed
** 3% discount rate, infinite calculation period

b

	Calculation period (years)		
Discount rate	infinite	50	25
2%	4,721	3,556	2,802
3%	3,634	3,178	2,667
4%	3,099	2,900	2,555

Figure 2.

Calculating an average monetary value per biotope value point. For detailed explanation, see Suppl. material 1.

a: Calculation scheme with examples;
b: Calculation result for different discount rates and calculation periods.

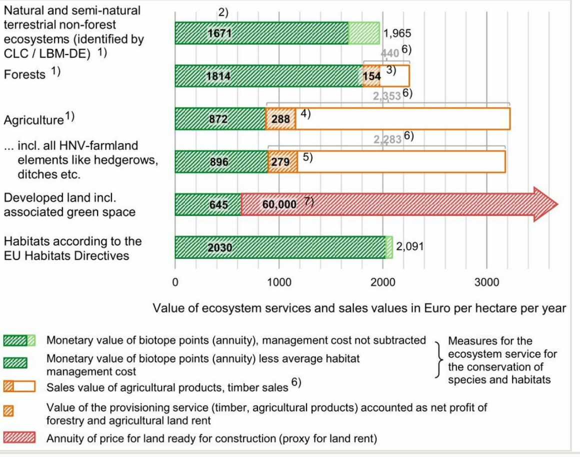

Figure 3.

Ecosystem services for nature conservation, agriculture and timber production; sales values for timber and agricultural products and residential land rent by 2018 (source: Hirschfeld et al. 2020):

1) Including habitats according to the EU Habitats Directive;

2) Monetary values of biotope points according to Hirschfeld et al. (2020);

3) Profits from forestry operations, timber sales: StBA (2020c), BMEL (2021a), BMEL (2021b) ;

4) Agricultural land rent, sales of agricultural products: StBA (2021a), BMEL (2021c);

5) Same as 3), corrected according to the larger area;

6) In the case of marketed products, the value of the ecosystem service is part of the value of product sales;

7) Average sales value for 2018, according to StBA 2021b (200 euros per m^2, interest rate for calculating the annuity: 3%, infinite calculation period).

The value of a site for residential, commercial, industrial or similar use is the land value. Similar to ecosystem services, this value is the difference between the sales value of the final product (e.g. residential rent) minus the total anthropogenic inputs (development costs, construction costs, estate agents etc.). The land value for real estate is, thus, calculated in a very similar way to the value of the ecosystem service.

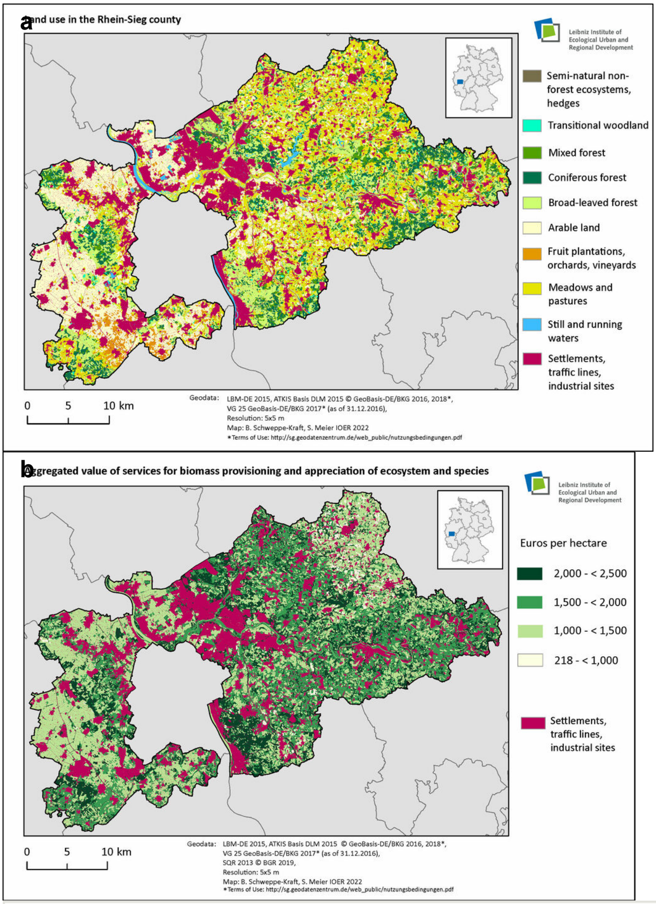

Figure 4.

Land use and aggregated values for biomass provisioning and nature conservation services (appreciation of ecosystem and species services) in the Rhine-Sieg county (source: own illustration).

Supplementary material

Suppl. material 1: Calculation of average cost per biotope value point

Authors: Burkhard Schweppe-Kraft
Data type: Detailed examples for calculating an average monetary value for one biotope value point per hectare.
Brief description: The Excel-file shows the detailed way to calculate monetary values for the appreciation of ecosystem and species services of ecosystems. The file uses examples from the calculation of the cost of habitat restoration measures to fulfil the targets of the European Habitats Directive in Germany.
Download file (52.32 kb)