Ecosystem services of characteristic biotope types in the Ore Mountains (Germany/Czech Republic)

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ABSTRACT
The present transboundary study of ecosystem services (ES) focusses on a section of the Eastern Ore Mountains, a rural low mountain range in Germany and the Czech Republic. Aims of the study were to quantify five biotope types typical for the region (raised bogs, mountain meadows, clearance cairns, near-natural mountain forests, and near-natural streams), to identify some of the specific (not just monetary) values of nature in both countries, and to test appropriate ways to communicate ES aspects to stakeholders and the lay public. The study had to cope with country-specific differences in terms of data availability, valuation methods, landscape peculiarities, and relations between supply and demand aspects. The ES were assessed using both expert-based (‘ecological’) assessments and economic valuations (e.g. calculation of prices and costs, revealed preferences). Among the provisioning ES, particularly biomass/fodder from meadows, wild fruit, and timber were taken into consideration; among the regulating ES, carbon sequestration and water regulation; and of the cultural ES, landscape aesthetics and recreation. The values of (near-) natural ecosystems in terms of regulating and cultural ES exceed those of provisioning ES by far. The results were also prepared for environmental education using new media, such as scavenger games and virtual nature trails supported by mobile devices (smartphones, tablets, or GPS devices).

1. Introduction
While a lot of initiatives to map and assess ecosystem services (ES) exist worldwide, e.g. the Millennium Ecosystem Assessment (MEA 2005), the international TEEB study (The Economics of Ecosystems and Biodiversity, TEEB 2010), various on-going national TEEB studies, and the Strategic Plan for 2011–2020 adopted at the 10th Conference of the Parties of the Convention on Biodiversity (CBD 2010), only few are concerned with transboundary examples, e.g. Roy et al. (2011), Bianchin et al. (2012), Sagie et al. (2013), Orenstein & Groner (2014), Hainz-Renetzeder et al. (2015). Along the border, neighboring countries often share the same (or similar) landscape, species, ecosystems, and the services these ecosystems supply. However, there may be many differences in terms of economic, political, social, and cultural conditions. For example, data availability and data accessibility vary, actors get different support or subsidies for management measures, and protected areas may suddenly end at the borderline. Nature and its processes and flows are not limited by human-made borders between two countries. But the demand for ES, and costs and prices may differ as well as the perception of benefits derived from these ES. This may be due to different perceptions of values, different institutional environment, or various approaches to management of natural resources. All these factors influence the potential ‘direct and indirect contributions of ecosystems to human well-being’ (TEEB 2010) and make transboundary assessments interesting study objects. In this context, according to López-Hoffman et al. (2010) the ES framework can be used as an organizing tool defining mutual conservation goals, which takes stakeholders from all involved countries into consideration, while limiting transboundary tradeoffs.

Due to the amount of data to be collected and processed, it is very costly – and too comprehensive for most research projects – to assess the full range of ES for all ecosystems or biotope types of a region or even just a wide range of them. According to Mertz et al. (2007) valuations can either be done of entire biomes, ecosystems, or of specific ecosystem goods or services. Studies have even been conducted on single species and their services, such as dung beetles (Nichols et al. 2008), the pollination of watermelon plants, the aesthetic value of farmland birds, seed dispersal by jaybirds (Harrison et al. 2010), or the...
benefits of the beaver’s repatriation in the German state of Hesse (Bräuer 2002). The downside of such studies is that they often include only partial coverage of services, sometimes unreliable benefit transfers, and the possible double counting of services, as well as the noninclusion or disregard of important services. Consequently, the use of this data leads to unreliable results of cost benefit analyses (Vejchodská 2015).

Being aware of these risks, the bilateral study ‘Ecosystem Services Ore Mountains’ (ESOM, http://www.esom-project.org) focused its transboundary ES assessment on selected ecosystem (biotope) types characteristic for the study area of the German and Czech Ore Mountains as well as on specifically chosen ES delivered by these ecosystems. Specific questions of the study addressed in this paper include:

(i) What is the distribution of selected ecosystem types characteristic for the Ore Mountains (quantities, differences between both sides of the border)?

(ii) What about the feasibility of valuing various ES, and which methodological particularities must be taken into account?

(iii) In which manner country-specific differences between the two sides of this transboundary study area find expression in the ES assessment, e.g. in terms of data availability, suitable methods, ecosystem and landscape peculiarities, relations between supply and demand aspects?

(iv) In which way can we communicate the findings to stakeholders and the lay public (tourists, residents) to raise their awareness for ES and values of nature and the landscape in this region?

While emphasizing human welfare, monetary valuation is not required in each case. Various qualitative and (semi)quantitative methods were applied, e.g. physical accountings. ES assessments also have to include the demand side, e.g. by applying preference analyses. To communicate the results, not only popular-science publications (e.g. Bastian et al. 2014a) but also new media for public relations and environmental education (E-learning platforms, nature trails enhanced by virtual contents or GPS-supported scouting games) were created and introduced.

2. The study area and its ecosystems

2.1. Description and characteristics of the study area

The study area is located between Dresden, Germany, and Prague, Czech Republic, and covers 365 km² along the Czech–German border. It comprises a typical part of the Eastern Ore Mountains on both sides of the German–Czech border. It covers the territories of two German municipalities (Altenberg, Hermsdorf) and – at least partly – eight Czech municipalities (among them Osek, Moldava, Dubí, and Petrovice) (Figure 1). The Ore Mountains represent a traditional cultural landscape of European significance particularly marked by its ore mining history. The mountain range is a half-horst with a length of approx. 150 km averages 800–1000 m above sea level. Siliceous rocks and a harsh climate are typical there. The study area’s land-use pattern reveals that it mostly consists of forests – especially on the mountain ridge – grassland, arable fields, and settlements, such as villages and small towns (Figure 2).

For the landscape characteristics and the ES assessment it is very important to consider the different historical development of regions on both sides of the border in the last century (after 1945). On the German side people have been living within the study area continuously over several centuries, local inhabitants have strong local roots, and their
identification with the landscape is very high. In comparison, on the Czech side most German inhabitants were forced to move to Germany after the Second World War. People from other Czech (and Slovak) regions resettled there. Most of the land was nationalized (to public ownership). Today, the Czech side of the study area is lower in population density and land-use intensity than the German side.

The characteristic ecosystem types that were selected to be investigated are especially important for nature conservation: raised bogs, mountain meadows, clearance cairns, near-natural mountain forests, and near-natural streams (Figures 3–7). Some of them are not just valuable ecosystems but also historic cultural landscape elements (Bastian et al. 2013).

2.2. Brief characteristics of the five ecosystem types

2.2.1. Raised bogs
The Ore Mountains’ ridge’s harsh climate enabled the emergence of mainly rain-fed raised bogs (Figure 3). Today, most peat bogs are strictly protected but they were severely affected by peat extraction and drainage in the past. Bogs play an important role for a landscape’s water balance and microclimate balance (Succow & Jeschke 1990). They are an important part of the global carbon cycle. Depending on peat thickness, they are able to store much more carbon than forests (Joosten & Couwenberg 2008; Siuda 2011; Wiesmeier et al.

Figure 2. Typical scenery of the Eastern Ore Mountains near Altenberg, Germany (photo: O. Bastian).

Figure 3. Raised bog in the Eastern Ore Mountains on the mountain ridge near Georgenfeld (photo: O. Bastian).
Peat bogs are also habitats of a remarkable flora and fauna.

In densely populated and industrialized Central Europe, bogs attract visitors by evoking a sense of relatively pristine nature. Protected raised bogs like the Georgenfelder Hochmoor, located directly on the German–Czech border, also fulfill educational purposes if they are accessible to visitors and offer information facilities, such as nature trails informing visitors of landscape history, flora, and fauna.

2.2.2. Mountain meadows

Species-rich mountain meadows (Figure 4) significantly characterize the Eastern Ore Mountains. They occur at sites with an altitude of more than 500 m above sea level. Among others, golden oat grass (Trisetum flavescens) meadows, Meum athamanticum – Festuca rubra meadows, and Trollius europaeus – Cirsium oleraceum meadows can be found here. Depending on soil conditions, location, exposure, and water supply, mountain meadows may also tend to moist or wet meadows, matgrass (Nardus stricta).
meadows, or (semi)dry grasslands (Hundt 1964; Hempel 2009).

Intact mountain meadows feature a high ratio of blossom-rich herbs, and a diverse fauna. Blooming meadows have a great appeal to nature lovers. They provide recreation, wildlife viewing opportunities, and offer unique aesthetic impressions. Several herbs are valuable for medicinal purposes. The different regional distribution of specific grassland types can significantly contribute to the regional character of a landscape.

2.2.3. Clearance cairns

The Ore Mountain’s numerous clearance cairns (Figure 5) occur in a density that is unique to Central Europe and give distinction to this cultural-historical landscape. Clearance cairns are heaps of stones that first emerged during the agricultural development of the Ore Mountains in the twelfth and thirteenth century. Stones were collected from arable lands and piled up at the edge of the fields or the parish bounds.

Often, a very special vegetation with various herbs, shrubs, and trees, found its way onto these cairns. Some of them are void of vegetation or only sparsely covered. Farmers used clearance cairns for a variety of purposes: firewood production through coppicing of shrubs, nutrition enhancement through hazelnuts and blueberries, as well as the production of timber by leaving specific, bigger trees on the cairn.
Clearance cairns belong to most plant species-rich habitats in cultural landscapes (Müller 1998) and are an important shelter for many animal species that also use them as migratory routes. They create positive microclimatic effects for their surrounding environment by reducing wind speed, producing shade, mitigating heat radiation, holding of rainwater, fog water comb-outs, and snow accumulation. At slopes, clearance cairns prevent erosion due to their dense root penetration. The shrub vegetation filters dust and other particles out of the air. Furthermore, clearance cairns divide the landscape, and they significantly contribute to the Eastern Ore Mountains’ beauty and uniqueness. However, as the sometimes not only nonsensitive handling of clearance cairns in the past but also in the present shows, many people, especially on the Czech side, are unaware of the diverse ES they provide.

2.2.4. Near-natural mountain forests

In spite of the large-scale transformations of the Ore Mountains’ forests into monotonous Norway spruce (Picea abies) stands in the eighteenth and nineteenth century, some small forest areas were preserved in a state close to their potential natural vegetation concerning the tree species composition and population structure (Grunewald & Bastian 2015a). They are characterized by lower use intensity than timberland and often contain cavernous trees and patches with old growth. The existing near-natural forests are primarily mixed montane ones predominantly with European/common beech (Fagus sylvatica) (Figure 6) and also ravine and steep slope forests, as well as small patches of mountain spruce forests on the topmost mountain ridges.

Near-natural forests enrich the scenery and are home to numerous rare plant and animal species that serve as forestal genetic resource. They deliver many ES, in particular regulation and sociocultural ones. Forests regulate local and global climates, facilitate pollination, and enhance soil retention and water quality (Chiabai et al. 2011). They are also important for storing carbon. Hence, deforestation is responsible for a huge amount of carbon dioxide emissions at global level. Tree species richness, which occurs in near-natural forests in contrast to the still widely spread timberland monocultures, might positively influence ES, such as the sustainable production of tree biomass, soil carbon storage, as well as berry and game production potential (Gamfeldt et al. 2013).

2.2.5. Near-natural streams

Near-natural streams are for the most part unregulated or show only few artificial impacts (Figure 7). Identifying features are a diverse aquatic and riparian vegetation, changing flow rates, manifold stream bed, and bank structures including steep bank sections as well as shallow and deep places.

Near-natural streams with abundant space deliver a number of ES (e.g. Lowrance et al. 1997; Sweeney et al. 2004): they render valuable services to the groundwater and drinking water formation as well as the moderation of flood crests. Their self-cleaning capacity helps filter pollutants and they are also popular recreational destinations for hiking and fishing.

3. Methodology

3.1. Working steps

The assessment of ES within our research included the following steps (Figure 8, Bastian et al. 2014a):

- selection of characteristic types of ecosystems (biotopes) and relevant, easily measurable, and quantifiable ES from all three classes (provisioning, regulating, and cultural) using ES classification of Bastian et al. (2012, 2014b), Grunewald and Bastian (2015b)
- survey (cartographic representation and quantification) of the five selected types of ecosystems (biotopes)
- survey (qualitative analysis and quantification) of selected ES applying various methodological approaches, among them expert judgements, physical accountings, partly also economic valuation/monetization using travel cost method in the combination with choice experiment; using data from literature and databases, own calculations or frequently by involving external experts and stakeholders, and other preference analyses (questionnaires, interviews) (see Section 3.3.1)
- development of specific bilingual environmental education offers, such as ‘virtual’ hiking paths using smartphone-apps as guides, GPS-supported scouting games and topical guided tours, and publication of a bilingual (German/Czech) popular scientific brochure (Bastian et al. 2014a)

3.2. Recognition, mapping, and quantification of selected ecosystem (biotope) types

The five chosen ecosystem (biotope) types were mapped using existing geodata for both the German and Czech part of the study area based on the so-called selective mapping of valuable biotopes (German part only) and the habitat mapping according to the Habitats Directive of the European Union (available for both countries but with different specifications). The mapping codes were allocated to the five biotope types as given in Table 1.
In this paper, we use the terms ecosystem (complex interaction of living beings and their environment), biotope (site of a specific community or biocoenosis of plants and animals), and habitat (characteristic site of one or several species) as well. The application of these terms in practice is often not very precise: In so-called biotope mappings being very common in nature conservation and landscape planning, not only the site of a biocoenosis is described but the whole ecosystem including both biocoenosis and its site. Under the influence of Anglo-Saxon literature and EU policy documents (e.g. the EU Habitats Directive) the term ‘habitat’ is also used in the sense of ‘biotope’ or a vegetation type, e.g. ‘Luzulo-Fagetum beech forests’ or ‘Mountain hay meadows’.

The main problem of mapping in Germany was the lacking coverage of biotope geodata. The so-called selective biotope mapping shows composite characteristics of some biotope complexes and is differentiated into woodland mapping, open space mapping, and into patch-shaped, linear and punctual data, respectively. Additionally, patch-shaped and linear data was available for NATURA 2000 habitat types within NATURA 2000 sites. Six of these eight (skipping the punctual) geodatabases had to be combined and recoded (accordingly Table 1, column 1 and 3) with several GIS overlay tools preventing double-counting of biotopes. The mostly small biotope complexes were assigned to the selected biotope types that are encoded in geodata.

So-called ‘mosaic’ biotopes comprise several selected and other biotopes that are not encoded in the geodata in the Czech area. Additional biotope’s characteristics files contain several records for each mosaic that could not be linked to the geodata. The other way round, the geodata’s attribute file (including a recalculated area size) was linked to the biotope’s characteristics file to calculate proportions of the three selected biotope types (according to Table 1).

Table 1. Allocation of geodata to the selected (target) biotope types.

| Biotope Type | EU habitat code (NATURA 2000) | National habitat code (CZ) | Selective biotope mapping (D, Saxony) |
|--------------|-------------------------------|-----------------------------|--------------------------------------|
| Mountain meadow | 6520 T1.2 GB | T2.3 RB | GB |
| Clearance cairns | 6230 | No specific NATURA 2000 habitat code | d |
| Near-natural forests | 9110 L5.4 | L5.1 WLB | WLB |
| | 9130 L4 | WSE, WSL | |
| | 91E0 L2.1, L2.2 | WA | |
| | 9410 L9.1 | WFB, WFS | |
| Near-natural streams | 3260 | d | FBB/FBM, FF(B) |
| Peat bogs | 7110 R3.1, R3.3 | MWH | |
| | 7120 R3.4 | MT (MTW, MTZ, MTP) | |
| | 7140 R2.2, R2.3 | MHB | |
| | 7150 R2.4 | | |
| | 91D0 L9.2, L10.1, L10.2 | | |
| | 91D1 L10.1 | WMB | |
| | 91D3 L10.2 | WML | |
| | 91D4 L9.2 | WMF | |

*a http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/Int_Manual_EU28.pdf.
*b http://www.sci.muni.cz/botany/chytry/Katalog-biotopu-CR-2-obsah.pdf.
*c http://www.umwelt.sachsen.de/umwelt/natur/18492.htm.
*d No data, own estimation (for the project purposes) for the Czech side using topographical data.
3.3. Assessment of ES (supply, exemplary presentation)

3.3.1. Introduction
For the assessment of ES, surveys of relevant scientific literature, both international journals and regional publications, were performed. Also existing surveys (e.g. Sundberg & Söderqvist 2004; MEA 2005; TEEB 2010) were used. The surveys were focused on ES relevant for this study, applicable methods for the assessment of these ES in our study area and the selected ecosystem (biotope) types, and on data/values being representative and suitable to transfer them to our study area or to use them as knowledge basis for further specific valuation steps. The data search included statistics, consultations of experts, authorities, and other regional/local actors (e.g. in agriculture, forestry, hydrology, nature conservation, land care organizations, and tourism associations). Various assessment methods were applied: both expert-based (‘ecological’) assessments (incl. physical accounting) and economic valuations (e.g. calculation of prices and costs, revealed preferences) – see the ES-specific approaches below. The data search was made at two levels (and with the related keywords): one starting from the valuation objects, i.e. the biotope types, the other starting from the ES.

The term ‘value’ is used in different ways in this paper: ‘Measurable values’ quantify the amount of collected fruits, harvested hay or the annual timber growth. In the philosophical sense of Emanuel Kant, ‘value’ represents the degree of importance; it stands for all what we respect, what is dear to us, e.g. nature (Grunewald & Bastian 2015b). The term can be understood as an ‘umbrella concept’, comprising several incommensurable kinds of values (Spangenberg & Settele 2016). The ‘biotope value’ (Section 3.2) characterizes the importance of an ecosystem to nature conservation. In terms of ES, quite different types of values are relevant, depending on valuation task and context (Gómez-Baggethun et al. 2016). Of particular importance are economic values (esp. use values and exchange values), preferably expressed in monetary terms, e.g. the prices of sold timber or mushrooms, or equivalent costs for storing carbon, avoiding flood damages, or for managing ecosystems (Section 4). This also includes the willingness to pay for a specific quality of landscape elements (Section 4.2.3.2), whereas stated preferences to capture cultural values (also in Section 4.2.3.2) do not rely necessarily on monetization.

In many cases specific basic data, originating from more comprehensive local studies or from past valuation projects in comparable landscapes (i.e. other parts of the Ore Mountains or neighboring Central German Uplands), were available for assessment by using the benefit transfer method (Plummer 2009), but only regarding the supply side. Local results, were applied by calculating representative average values per hectare and multiplying them with the area of the relevant biotopes.

The assessment methods (and results – see Section 4) are shown in an exemplary manner as follows (Sections 3.3.2–3.3.4).

3.3.2. Provisioning services
3.3.2.1. Provisioning service biomass/fodder from mountain meadows. The calculation based on the market-price method includes possible hay yields on the basis of representative mountain meadows’ vegetation analyses (Hundt 1964) taking into account the need for extensive use in favor of species-rich plant communities. Additionally, the balance between income through hay sales and production costs is altered by subsidies paid by the government(s) and the European Union to compensate for income losses due to nature conservation requirements.

3.3.2.2 Wild fruits (berries and mushrooms). Wild fruits and medicinal plants as well as game and fish are not cultivated or bred; they are taken from nature. Total yields and the amount of collected fruits per household were assessed using the market-price method (data availability was restricted to the Czech side) (Ministerstvo zemědělství 2013).

3.3.2.3. Timber and firewood. Two indicators were calculated:

(1) Annual potential growth of trees in view of species composition of several forest biotope types (if applicable) and harvest from (near-) natural forests taking into consideration that a
considerable part of wood should remain unlogged for nature conservation reasons.

(2) Present volume of wood and potential future growth of firewood on clearance cairns. For the first cut, a manual harvest, and later, a regular mechanized firewood harvesting was assumed. In both cases, the timber resp. wood volume is estimated as physical volume. On this basis, the income was calculated by deducting the maintenance costs.

The market prices of wood tend to be similar in the whole region because of export opportunities. Even though there are generally lower costs of forestry operations in the Czech Republic than in Germany (because of lower personnel costs), the Czech part of the Ore Mountains is steep to very steep (unlike the German part), which means difficult access and relatively high harvest costs. Consequently, our assumption is that the costs of wood production are approximately similar on both sides of the border. Unfortunately we did not get the costs of operation from the Czech side, since this is considered a business secret.

3.3.3. Regulating services

3.3.3.1. Carbon sequestration. The ES consists of annual carbon sequestration and total carbon storage of raised bogs (incl. positive effects of a possible revitalization of degraded bogs), near-natural forests, clearance cairns with trees and bushes, and mountain meadows. Intact peat bogs grow about 0.8 mm per year, which correlates to a carbon accumulation rate of 0.5 t/ha/a. On average, though, peat growth is far less because drainage and desiccation deteriorated them to a point where most of them do not grow actively anymore (UKNEA 2011). By lowering the bog water level, oxygen infiltrates the peat substance, which oxidizes and emits the previously stored carbon as CO₂. In raised bogs this mineralization leads to CO₂ emissions of approximately 15 t/ha annually (Drösler 2009). Nitrogen is also released as nitrous oxide (N₂O). In turn, the rehydration of peat bogs reduces greenhouse gas emissions. Restored, rehydrated peat bogs can once again become the climate-neutral places they once were. Active raised bogs can store up to 10–12 t CO₂ per hectare annually (Siuda 2011).

A representative study for comparable near-natural spruce forests in the Harz Mountains, provided by Jacob et al. (2013), found that 1 ha of that forest stores on average 420 t C in the trees, deadwood, litter, and soil-humus. The storage of carbon in species-rich mountain meadows in soil as well as in the plants has been determined after Kettunen et al. (2009) to be 243.2 t C/ha. This value was used for the study area. The storage of peat bogs can be roughly estimated by CARBSTOR (http://www.carbstor.de/) with 2302 t C/ha. Investments to avoid or eliminate CO₂ emissions (by new technology or land-use changes) cause different (replacement) costs, which can vary strongly, e.g. between 8 €/t (EU Emission Trading Scheme – ETS 2012) and 80 €/t, recommended by the German Federal Environment Agency (UBA 2012).

3.3.3.2. Water regulation (flood protection). The contribution of near-natural forests to potential water retention was assessed in comparison with other land-use types of the study area by assuming an extreme flood event, namely a 100-year flood. Different simulations of a rain discharge AKWA-M model (Schmidt et al. 2008) were compared to the costs of a planned dam project to prevent an equivalent flood. According to the substitute cost method the underlying assumption is that the ES of the near-natural forest has a value at least as the cost of the substitute (water reservoir) (cp. Leschine et al. 1997).

3.3.4. Cultural services

3.3.4.1. Landscape aesthetics, recreation. Questionnaire-based empirical studies were carried out on the appreciation of near-natural and natural ecosystems, landscape elements, landscape qualities, and ES (on-site interviews at heavily frequented sites, among them typical ecosystems/nature reserves; use of choice experiment method and contingent valuation method). Interviewees were tourists, as well as residents of the Eastern Ore Mountains.

The on-site surveys were conducted at two locations of the Eastern Ore Mountains at the Czech side of the border (Komáří Vížka and Lesná) at two points in time in summer 2013 and at two locations at the German side of the border (Georgenfeld raised bog and Galgenteiche ponds) at two points in time during summer 2014. The questionnaire was pretested within two rounds of pilot on-site pre-surveys (together 55 respondents) to test the data collection strategy and the length of questionnaire (duration of the interview should be not more than 15 min). To eliminate sample bias in data collection (i.e. interviews) as interviewees were chosen all (adult) Czech visitors of the two Czech sites during the survey days and all (adult) German visitors of the German locations. That means that every visitor from Czech Republic (respectively Germany) who passed the chosen sites was asked to answer. Foreign visitors were not included in the on-site survey. More than 330 surveys were collected with the level of rejection being about 15%.

The survey focused on analyzing the value of cultural services of mountain meadows, clearance cairns, and natural streams. Interviewees were asked on willingness to pay for not overgrown clearance cairns, for
(semi)natural streams and for not-managed or fallow meadows. The survey was based on the stated preferences method (e.g., Bateman et al. 2002), especially on choice experiment method (Vojáček & Pecáková 2010; Kenter et al. 2011) and the contingent valuation method. For more detailed methodological information on the questionnaire-based empirical studies and about results of this research see Vojáček and Louda (Forthcoming 2015).

4. Results

4.1. Biotope mapping

The biotope mapping identified 8510 ha of valuable target biotopes (Figure 9). The data had been provided by the Czech and Germany authorities exclusively for the study. Of these, 2750 ha are mountain meadows; specifically there are 710 ha of contiguous mountain meadows on the German and 640 ha on the Czech side. Furthermore, biotope mosaics make up an additional 1400 ha of mountain meadows of varying qualities. Raised peat bogs make up 1550 ha of the study area, of which just 50 ha of contiguous peat bogs remain on the German side, while 350 ha can be found on the Czech side. Mosaics (with shares of raised bogs) make up for the remaining 1150 ha. After having been drained in the past, only a small part of the peat bogs are still actively growing. The study area’s most common biotope type is near-natural forest with an area of 4210 ha in total, of which 520 ha of contiguous near-natural forest are located in Germany and 1290 ha in the Czech Republic. The remaining 2400 ha of near-natural forests are included in forest mosaics characterized by different human influences. Even though near-natural forests are the most common biotope type, they are only a small part of the whole forested land within the study area. Among the linear biotopes, 330 km of near-natural streams and at least 194 km of clearance Cairns were mapped.

4.2. Ecosystem services

4.2.1. Provisioning services

4.2.1.1. Fodder/biomass from mountain meadows.

The yield of the 2750 ha mountain meadows located within the study area could be up to 17,000 t hay annually through extensive meadow usage taking nature conservation requirements into consideration (using a mixed calculation, approximately 6.33 t/ha yield from the occurring meadow types). On the German side the yield could be up to approximately 4500 t generating possible revenues of about 450,000 € (10 €/100 kg as in 2013, cf. the market review for hay prices on http://www.proplanta.de/Markt-und-Preis/News/Heupreise). Management costs amount to about 300,000 €, which leaves a possible profit of 150,000 €. However, this calculation only adds up when the uneconomical management of marginal meadows that are difficult to use due to uneven surface structure or steep slopes are compensated by subsidies. These subsidies may cover maintenance costs. Surfaces that are easier to cultivate are more profitable. For the 12,500 t hay from Czech side, no comparable market price reviews are known.

Figure 9. Map of selected characteristic biotope types in the Eastern Ore Mountains study area.
### 4.2.1.2. Wild fruits.

On average, every household in the Czech Republic picks 5.8 kg mushrooms per year. The projection for the whole country amounts to approximately 21.9 million kg per year, which correlates to a value of 71.9 million € (Ministerstvo zemědělství 2013, Table 2), without considering the costs of acquisition. Unfortunately, specific numbers for the Eastern Ore Mountains are unknown.

#### 4.2.1.3. Timber and firewood.

A total of 21,300 ha forest exist within the study area (58%), of which 4210 ha are near-natural forest. On the German side, the tree species composition is on records and, therefore, an annual stock of wood growth of 3350 m³ can be assumed. Projected on the whole study area, this would mean a growth rate of 27,520 m³ (24,170 m³ on the Czech side). However, not every trunk is or should be taken from the forest.

The forest enterprise of the nature protection association (NGO) Landesverein Sächsischer Heimatschutz (http://www.saechsischer-heimatschutz.de), which is located in the eastern part of the study area, emphasizes strongly on conservation measures. Their sustainable allowable cut is 4.5 m³/ha annually, which generates a surplus revenue (only from timber, without other benefits like water retention or carbon sequestration) of 5 €/ha (Walczak & Wilhelm in Bastian 2013). Extending this calculation to the 4120 ha of near-natural forest existing within the study area, an allowable total cut of 18,963 m³/year and a surplus revenue of 21,000 € is feasible, which includes 2326 m³ or 2585 € on the German and 16,637 m³ or 18,485 € on the Czech side (assuming identical prices in both countries).

Even though there are generally lower costs of forestry operations in the Czech Republic than in Saxony (because of lower personnel costs), we assume that the costs of timber production are similar on both sides of the border, because the Czech part of the Ore Mountains is steep to very steep (unlike the German part), which means difficult access and relatively high management costs. Besides, we could not get data on costs of production from the Czech side, since this is considered a business secret.

The increasing demand for firewood also makes the harvest and maintenance of shrubs and trees on clearance cairns more attractive, in contrast to the past decades when such activities have been scarce. The initial resumption of clearance cairns’ pruning back takes years. The clearance cairns within the study area would accumulate 3.446 bulks cubic meters firewood for the first 4 years assuming a harvestable clearance cairn stripe width of 2 × 3.5 m (Bittner 2013). After that, 620 bulk cubic meters timber could be harvested each year by cutting the renewable coppice. Assuming a firewood price of 20 €/bulk cubic meter the possible income of the first 4 years is 68,920 € and 14,860 € annually for the following years. Our inquiries revealed that the assumption of average prices of 20 € for both countries is justified.

#### 4.2.2. Regulating services

##### 4.2.2.1. Carbon sequestration.

Assuming that 1 ha of near-natural forest stores totally around 420 t C (Jacob et al. 2013, see Section 3.3.3.1), the study area’s 42 km² near-natural forests store 1.8 million t C, i.e. 0.2 million t on the German and 1.6 million t on the Czech side. Based on these numbers, the calculated natural storage equals to 541 million € (if we assume 80 €/t) or only 54.1 million € (if 8 €/t).

Assuming that the destruction of species-rich meadows can cause a release of about 243.2 t C/ha (Kettunen et al. 2009, see Section 3.3.3.1), damaging mountain meadows may cost up to 7,140,352 €/ha (80 €/t).

The peat bogs’ storage can be roughly estimated with 2302 t C/ha giving a total of 3.6 t C for the study area’s peat bogs.

##### 4.2.2.2. Water regulation (flood prevention).

In 2010, the global financial damage caused by flooding events amounted to about 36 billion €. In 2002, floods in Germany alone caused damage amounting to 9–15 billion €; a large part of it was caused by the Elbe river, which is also fed by streams of the study area. In 2002, the Czech district Teplice encountered flood damages of 1.73 million € to its municipal property and damages of 1.04 million € to the district’s private property. The village Petrovice in the Ústí nad Labem district alone encountered infrastructure and municipal damages to the amount of 870,000 € (Povodi Ohře 2002).

The damage potential has increased significantly in recent decades due to the enhanced development of flood-prone locations. Landscapes with natural ecosystems, such as forests, bogs or wetlands, delay rainwater runoff and, thereby, lessen flood waves and flood damage. On average, 1 km² of forest reduces the flood peak discharge by approximately 0.44 m³/s during a 100-year flood (own calculation basing on Münch et al. 2007).
The construction cost of a planned flood retention basin with a capacity of 1 million m$^3$ near the small town of Glashütte in the Eastern Ore Mountains is estimated at 2.5 million €. The study area’s 42 km$^2$ near-natural forests are able to retain 0.5 million m$^3$ water over a period of 8 h (typical 50% peak of a 100-year flood). In order to achieve this storage function by a technical investment, such as the Glashütte basin with twice the capacity, one would have to invest about 1.25 million €. In this way, the forests, just by existing, avoid these costs. The total area of (near-)natural forests in the study area is able to save half of the costs of the Glashütte flood retention basin. For further information on the water management discussion and the preference of specific measures in the Czech Republic see Slavíková and Jílková (2011).

4.2.3. Cultural services

4.2.3.1. Ethical values. Ethical values include mankind’s responsibility for nature and the preservation of species’ and ecosystem diversity. For the Eastern Ore Mountains this is especially true for the regionally almost extinct black grouse (Tetrao tetrix). The Czech part of the study area houses the largest Central European black grouse population outside the Alps. Therefore, the protection and preservation of its habitat is not only of interest at a regional but also at the European level (Bastian et al. 2010).

4.2.3.2. Aesthetic values. The questionnaire-based survey among visitors (tourists) showed that interviewees clearly preferred near-natural streams, mountain meadows, and mixed forests over other landscape elements. Coniferous forest plantations did not perform as well in comparison to near-natural forests. The majority of tourists had chosen the Eastern Ore Mountains as a destination in order to experience nature (85%), to rest and relax (70%), or to be physically active (40%). Negative changes to the landscape, such as a decrease of biodiversity or an increase in wind farms, would lead to changes in visitation and recreation patterns going as far as considering a complete avoidance of the area if these changes occurred. Concerning ES, most people considered recreational values and provisioning services (drinking water and air) as well as habitats for animals and plants as most important (Figure 10, Bastian et al. 2015, Vojáček & Louda 2015).

Czech and German visitors of the Eastern Ore Mountains showed very similar preferences regarding biotope conditions in the surveys. Nevertheless, some differences in preferences between Czechs and Germans could be identified. People from Germany preferred overgrown (wooded) clearance cairns but also meadows with grazing cattle, while visitors from Czech Republic preferred both clearance cairns without woods and fallow grassland without cattle (Vojáček & Louda 2015).

5. Communicating ecosystem services

In order to achieve broad acceptance for nature conservation, ES have to be presented and communicated in a comprehensible way (TEEB 2010; Grunewald & Bastian 2015b). Different knowledge levels as well as needs of stakeholders consisting of decision-makers, affected groups, and the general public, present a challenge. The use of innovative technologies and new media, which can be adapted to meet different requirements, is a promising way to improve communication and presentation of ES.

Since the 1990s, digital media has become more and more important for educational purposes. While critical discussions were led in Germany in the early 2000s whether the internet should be integrated in schools or not, a life without new media is unthinkable for most people today.
The diversity of information easily accessible via mobile devices, such as smartphones, has many significant advantages. In the case of environmental education frequently observed positive effects on motivation and the willingness to learn were reported. Furthermore, the facilitation of independence, personal responsibility, capacity for teamwork, and social skills are good prerequisites for communicating value-oriented subjects (Molitor 2014).

Especially modern geo-information technology can be used in manifold ways for tourism and environmental education. Examples are museum and city guides, mobile navigation and hiking trail planning tools, such as gpsies.com or komoot.de, as well as nature classification tools like iKosmos or the Merlin birding app. games, e.g. geocaching, are also a popular way to use modern technologies.

In the Eastern Ore Mountain region, a couple of mobile apps delivering specific information about nature and geological characteristics as well as planning tools for hiking tours exist, for which information can be retrieved online. New technologies are opening up new opportunities for environmental education, particularly for the establishment of new (nature) trails. Instead of static panels, websites can be implemented, which can be retrieved via smartphones or other mobile devices (Figure 11). The advantages are that information can be changed and updated at any time, it can be tailored target-group specific as well as adjusted to show or not show certain information related to seasons or special occasions.

Three nature trails using solely mobile devices to transmit information were implemented within the project’s study area: one on the German side, one on the Czech side, and one cross-border trail (Figure 12). Each of the trails has a certain number of stops with information on the services that the typical Eastern Ore Mountain ecosystems provide there. This information can be retrieved with smartphones, tablets, or GPS devices. Each stop showcases the additional value that nature provides exemplified by a tangible example at the exact location of the ES.

Figure 11. Smartphone app ‘nature trail’ using augmented reality (photo: N. Kochan).

Figure 12. The three routes of nature trails in the study area Eastern Ore Mountains.
The information was processed for mobile devices (smartphones) to transmit the findings in ways that conventional environmental education tools, such as information panels, are unable to do. This way of presenting the information addresses not only people traditionally interested in nature but also technophiles, such as young people, to whom this offer might be more appealing. Environmental education has the potential to become a valuable – and popular – part of the local tourist infrastructure by using innovative and alternative information services that are increasing in popularity, such as nature trails enhanced by virtual contents or GPS-supported scouting games.

In order to enable access to the virtual trails to as many users as possible the contents were prepared for various systems and platforms:

- Web app (also works offline, presentation with text and pictures)
- Wikitude Augmented reality-Browser (only online but with maps linked to web app)
- Gpx-file (readable by a wide range of devices, offline without pictures)

To inform the public, flyers in German and Czech language were printed and deposited at the Central tourist information office in Altenberg and at several visitor magnets (museums, restaurants). Additionally, signs with QR codes were affixed at some places in the study area to draw attention to the availability of the three digital nature trails, and to provide access to the web app. Information in the internet is available at several websites:

- http://wissenswege.ioer.info, https://www.ioer.de/downloads/
- https://www.ioer.de/esom
- http://esom-project.org/de/?cat=22
- http://esom-project.org/cs/?asides=virtualni-naucne-stezky

Until March 2015, after performing some guided opening excursions, we created a track to trace the access to the web server. On average, 50 users per month (altogether 518 in 2015) have used this service (accesses to the nature trail websites resp. downloads of the smartphone app).

To provide another way to experience values of nature and ES, a scouting game with mobile devices (smartphone) was developed. The participants (players) are moving actively in the field and have to detect and ‘conquer’ specific ES by answering questions like ‘Where (at which location/ecosystem) is the highest carbon sequestration?’ Possible locations for this question can be seen in Figure 13. After viewing the question, the sites have to be visited and assessed and the location/ecosystem with the best supply of the ES concerned has to be found and marked on the mobile device. The game can be played individually or in groups and is available as an online-app. It is connected with the virtual nature trails also developed within this project, thus, providing adequate background information.

College/university education is another way to communicate ES. At the J. E. Purkyně University (UJEP) in Ústí nad Labem, the educational course ‘Ecosystem services of Ore-Mountains and their evaluation’ was established, which combines the ecological and economic perspectives of the ES research. The course includes campus work as well as distant learning using an E-learning program (http://elearning.esom-project.org). The annual, several-day campus courses in Ústí nad Labem with students both from the Ústí University (Czech Republic) and the Anhalt University of Applied Sciences (Bernburg, Germany) are ongoing also after the official end of the project duration. The courses include lessons but also placements and scientific qualification work which contribute to enhance the ES knowledge base concerning the study area.

Figure 13. GPS-based nature experience game app (examples).
6. Discussion

The study addressed various aspects of ES in a trans-boundary setting of the Eastern Ore Mountains. It is the first research work related to this region emphasizing an ES approach. It illustrates both potentials but also limits for the application of this methodology.

International political borders rarely coincide with natural ecological boundaries. Because neighboring countries often share ecosystems and species, they also share ES (e.g. López-Hoffman et al. 2010).

When addressing country-specific differences in ES, language barriers are an issue for cross-border studies. Supply and demand sides have to be distinguished as well. The supply side is mostly driven by biophysical (environmental) conditions, which are quite similar on both sides of the German–Czech border due to the identical or similar landscape of the Ore Mountains. Differences arise also from quantity and spatial pattern of the selected biotope types (e.g. there are much more raised bogs in the Czech than in the German part). Comparable results were achieved wherever the same assessment methods could be applied (e.g. for the ES timber production or carbon sequestration). However, the varying data situation between both countries was a major issue, e.g. regarding the valuable biotopes (incl. NATURA 2000 habitats) and different organizational structures of authorities managing the data. Thus, data for several ES could only be found for one country (e.g. provision of wild fruits) and some of the data available for both countries was not comparable (e.g. definition and mapping of some biotope types).

There are also differences in land management practices in both parts of the study area, due to the different population density, the historical roots of the people (the majority of the population in the Czech part has been living there for maximally 70 years, only), political and economic/financial differences (e.g. the use of incentives for managing valuable biotopes).

Particularly regarding the demand side, the different historical development of societies on both sides of the border must be taken into account. Due to the historic reasons the relationship between people and the landscape is not as strong as on the German side. Different results of the questionnaire-based preference analyses and the choice experiments (Vojáček & Louda 2015) may arise also from these circumstances. The different preferences concerning clearance cairns (overgrown versus unwooded) and mountain grassland (with/without grazing cattle) may be due to differences in management rules, the rarity of some landscape element specifications, and habituation effects. Further research is needed to reveal the real reasons. There are examples for different appreciation of natural features/ES values, depending on the economic situation and cultural traditions, also from other countries/regions, e.g. from the Middle East (Sagie et al. 2013; Orenstein & Groner 2014).

The amount of provisioning services delivered by near-natural or natural ecosystem types in the Ore Mountains (at both sides of the border) is not very high in comparison with regulating or cultural ES. The advantage of such ecosystems is not the maximization of few (mainly provisioning) services, but the supply of bundles of manifold ES. For example, small near-natural streams are poor in fish, water, and energy, but of prime importance for biodiversity, scenic quality and recreation. Yield and revenue of fodder from mountain meadows are mostly poor except in the case of special fodder/hay for animal nutrition. Modern industrial agriculture prefers fodder from arable fields (crops). Also, for energetical purposes the ratio between expense and benefit is not attractive. Nevertheless, due to regulating and cultural ES, and particularly because of their rich biodiversity, mountain meadows should be maintained also in future (Bastian 2013).

Not only in the study area but as a general phenomenon, there are often unrecognized potentials of wild species for manifold purposes (cp. Harrison et al. 2010). This applies, e.g. to medicinal plants growing on mountain meadows. It is not easy to quantify such goods, their values, and benefits or to always make a clear distinction between different services, e.g. between provisioning and cultural services. For example, arnica (Arnica montana) is a very old medicinal plant being widely used in phyotherapy. Due to the strong decline of this composite plant growing on mountain meadows, also in the Eastern Ore Mountains, the provisioning service of the wild plants cannot be exploited any longer. Instead, the cultural values (ethical, aesthetical values, testimony of usage history) gain the upper hand. A typical local example is the endangered European crab apple (Malus sylvestris), Central Europe’s only wild apple species. In order to support the conservation of the European crab apple’s population in the Eastern Ore Mountains, its long-term usage is promoted, e.g. the production of fruit tea, jelly, and fruit spirits, as well as the use of the wood, or the planting in groves, tree nurseries, and on clearance cairns (Proft & Heinz 2011).

The proportions of near-natural forests in the whole study area as well as yields (timber harvest) from these forest types are relatively low. Such forests are more important for other ES, primarily for regulating and cultural ones. Clearance cairns can produce measurable amounts of firewood. The withdrawal of trees is favorable for characteristic light-preferring species valuable from a nature-
conservation point of view, among them many mosses (Bryophyta) and lichens (Lichenes), fire lily (Lilium bulbiferum), Sequier’s Pink (Dianthus seguieri), the common European adder (Vipera berus), and weasel (Mustela) species. Tourism is also benefitting from clearance cairn management, i.e. from better visual axes and the maintenance of landscape diversity.

In contrast to provisioning services, the role of the selected near-natural ecosystem types in terms of regulating services is more significant. Thus, it is important for future increases of carbon sequestration that there are many more potential (degraded) raised bogs in the Eastern Ore Mountains than active ones. The restoration of these bogs would make an important contribution to carbon storage and climate protection. The conservation or restoration of bogs also has a positive effect on biodiversity.

Considering another regulating ES, water retention, it has to be stated that the increasing surface sealing and development of flood-prone areas in the last decades has led to an increase of damage potential. A rich landscape structure with forests, bogs, hedgerows, meadows, and other elements may slow down the discharge of precipitation water and reduce the extent of flood waves and damages. However, model-based simulations of water drainage in small catchments of the study area also show that technical flood protection can be substituted only partly by (near-)natural ecosystems (Münch et al. 2007). On the other hand, some locally effective technical flood protections, such as levees and floodwalls close to the riverbanks, may in turn increase the total flood wave. This aggravates the flood situation by reducing the available space even further and sending the flood wave downstream. Recent floods in the Czech Republic involving the Vltava River Water Dam Cascade have put the effectiveness of water dams for protection against large floods into question. This is important considering the ongoing discussion of pros and cons of dam constructions. In any case, the removal of endangered buildings and the avoidance of construction activities in floodplains should be strived for in order to reduce risks and damages.

Concerning cultural services, the results of the questionnaire-based survey showed that the attractiveness of the Eastern Ore Mountain landscape is very important for tourism. It is seen as the main reason to spend holidays or leisure time there. Our survey conforms to results of similar studies, e.g. Grunewald et al. (2012) in the Western Ore Mountains and Lupp et al. (2013) in the Müritz Region, in which most tourists cited beauty, harmony, and naturalness of the landscape as key travel motivations. Pröbstl et al. (2009) argue that ‘landscape experience’ and ‘nature experience’ are among the most important motivations for tourism in general.

A German-wide representative survey of nature awareness (BMU & BfN 2014) revealed that a vast majority of people attached a high value to nature. Nature equaled quality of life, health, and recreation; 80% of respondents felt closely linked to nature and their home region’s landscape. There was a strong agreement for nature to be used in a sustainable way to preserve plant, animal, and habitat diversity, as well as the beauty and character of landscapes for now but also for future generations. Many people are not familiar with the ES concept, but they are still aware of and appreciate the diverse services nature provides. Tourism, like no other economic sector, is dependent on attractive nature and ecosystems. This is especially true for economically underdeveloped rural areas (Job et al. 2006). Also Czech people show a positive attitude toward natural values as expressed in a study, where 44% of 2000 respondents would prefer to extend wilderness in the Czech Republic, and only 19% were against (the rest was undecided) (Krajhanzl et al. 2015).

We expressively want to underline that monetary valuation is only one of quite many different approaches. Monetization can help policy-makers shed light on the contribution made by various ES, be it directly or indirectly, and, thus, serve as an information function. It can help overcome the systematic bias in decision-making by providing a common scale of valuation between human-made and natural capital, present and future benefits/costs, and various resource types. Economic valuation can also show the impacts of service losses on existing markets and public expenses.

One possible approach for complementing conventional neoclassical valuation methods is calculating the economic value of biodiversity on the basis of restoration costs and restoration time. This way, not only the costs for restoring habitats but also those for managing valuable ecosystems, such as the mowing of mountain meadows, can be conceived as revealed public preferences (Spangenberg & Settele 2010). However, the management costs spent to maintain an ecosystem or a population of wild plants or animals cannot be equated with the value they represent or with the ES value they provide. Some dimensions of human well-being cannot – or should not – be measured in terms of money (TEEB 2010). Many services also simply do not have a market (Mertz et al. 2007; Bayon & Jenkins 2010). Monetary valuation is also hardly feasible for environmental goods and services with a religious or spiritual value or amenity (Spangenberg & Settele 2010). In this regard, Kinzig et al. (2011) emphasize that there are many cases where monetary approaches are simply inappropriate. In cases where it is impossible to use prices as indicators of the scarcity
of ES, other parameters are needed. For example, physical indicators of the state of ecosystems need to be integrated into income and product accounts into decision-making processes.

The many clearance cairns and mountain meadows in the Eastern Ore Mountains are valuable not only for timber but also for hay or several regulating ES. As traditional landscape elements they shape a highly unique historical cultural landscape. Such landscapes are distinguished by the fact that historical structures have not been removed or overshadowed by contemporary, modern methods of land utilization, and where many relics of the past outlived until today (Antrop 2000; Bastian et al. 2013). Traditional landscapes represent a reflection of the complicated historical development, a reflection of the coexistence and/or struggle between man and nature as well as reflection of cultural, social, political, and economic transformations of the society. Such (ethical, aesthetical, educational, scientific, and other) values can hardly or not at all express in monetary terms.

Awareness rising becomes increasingly important to meet the goals and demands of nature conservation. Current trends in tourism focus on nature as a travel destination, on health, and high quality of offers and services. Travelling is more and more used for educational purposes. Especially, nature tourism in the Ore Mountains is in need for development (Landestourismusverband Sachsen 2008). Attractive education programs (e.g. by using digital media) may support sustainable regional development as they enhance the region’s popularity. In addition, tourists can become aware of and sensitized for environmentally friendly behavior in order to reduce ecological pressure caused by tourism. From a scientific point of view, it would be interesting to examine whether information provided by the three digital nature trails in the Eastern Ore Mountains has significant influence on awareness and behavior of the users.

7. Conclusion

The aim of the ES concept is to demonstrate and valuate mankind’s dependency on nature more clearly than has hitherto been the case in order to achieve a higher appreciation for the value of our natural basis of life. The ES concept may complement and support the traditional legal means of nature conservation, such as specific laws, conventions, and related regulations. Economic arguments help support and strengthen conservation efforts. This is very important particularly in the transboundary context of the Ore Mountains, where valuable biotopes, whole biotope complexes and protected areas are crossing borders, and should be regarded as an entity.

Many countries, including Germany and the Czech Republic, already apply certain parts of the ES concept – besides legal and planning instruments – but usually without explicitly using the term ES. There is an ongoing debate whether and how the ES concept can be implemented in practical planning processes and decision-making (von Haaren & Albert 2011; Albert et al. 2012). These ideas translate into economic tools such as financial incentives, labels, reduction of environmentally harmful subsidies, granting of tax reliefs, financial compensations establishment of new markets for sustainably produced goods and services, or targeted state/supranational incentives, e.g. agro-environmental schemes. But education, public relations, and awareness raising for the importance of nature, biodiversity, and ES should play an integral role in the implementation of ES concepts.

The awareness of the value of nature in the study area may be reflected to a certain extent in the willingness to pay for nature conservation on both sides of the border (Bastian et al. 2015; Vojáček & Louda 2015). In rural mountain regions, such as the Eastern Ore Mountains, many ES are crucial for various economic branches and other sectors of society: the provision of products from agriculture and forestry, the regeneration of drinking-water resources, or flood protection. Particularly in the Eastern Ore Mountains, ES analyses and communication are helpful, e.g. for nature conservation and the development of environmentally friendly economic activities in this deprived region. Thus, the highly threatened transboundary population of black grouse in the Eastern Ore Mountains would benefit from transboundary ES approaches.

According to López-Hoffman et al. (2010), the ES concept is suitable to transboundary conservation, because it frames mutual interests between countries, considers a diversity of stakeholders, and provides a means for linking multiple services and tradeoffs. For example, the development of improved management strategies in shared ecosystems is important.

Sagie et al. (2013) highlight the development of improved management strategies in shared ecosystems. Instead of being zones of conflict, shared natural resources (e.g. water) can provide a basis for cooperation and benefit-sharing. Ensuring political commitment that can result in institutional, policy and legal reforms in the countries concerned is the key to sustainable development of transboundary resources (Uitto & Duda 2002). Wolmer (2003) addresses the re-establishment of ecological integrity across ‘artificial’ frontiers and administrative boundaries in Africa. Also ecological networks can benefit from transboundary coordination and management (Leibenthal et al. 2010). Ensuring political commitment that can result in institutional, policy and legal
reforms in the countries concerned is the key to sustainable development of transboundary resources (Uitto & Duda 2002).

Especially in the context of valuable biotopes and nature conservation we must be aware that the applicability of economic valuation methods, in particular monetization, is limited. In addition, it is important to take into account that ES may be valued differently depending on country/culture and contexts.

Some methodological problems aggravate a better implementation of the ES concept, such as the lack of data (compatibility) and methodical and institutional differences between the two countries. Future challenges for transboundary ES studies include improving coordination and compatibility of databases (e.g. biotope cadastres) and methods to be applied, enhancing transparency and accessibility of data collections which may differ between two countries as we experienced in our case study. Such disparities make the work considerably more difficult. Depending on the special tasks, expense and data availability, further ecosystem types ES and scales should be included into investigation. To important tasks belong analysis and comparison of opportunities and constraints for the application of the ES concept in both countries or in (trans)boundary regions. Moreover, transboundary effects of supply and demand turn out to be very interesting questions. Finally, there is a high innovation potential regarding the creation of new or the improvement of existing tools, instruments, and institutions for the application and communication of the ES concept, as we could show on the example of the digital nature trails basing on modern geo-information technology.

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