GIS and land cover-based assessment of ecosystem services in the North Karelia Biosphere Reserve, Finland

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Conservation and sustainable use of biodiversity, ecosystems and their services are key principles behind the establishment of "Biosphere Reserves". Mapping of ecosystem services is one of the activities that is expected to increase the knowledge of sustainable land use planning. The Biosphere Reserves, established by the UNESCO Man and Biosphere Programme, aims to find the balance between nature conservation, use of natural resources, recreation and other culture-related activities. For this purpose, the ecosystem services approach is a promising tool for examining the relationships between people and nature in practice. This study applies the ecosystem services approach and examines which ecosystem services are perceived to be relevant in the North Karelia Biosphere Reserve in Eastern Finland. The results of a *matrix method*, with expert-based approach, showed that particularly old-growth forests and undrained open and forested mires have a broader potential to provide different ecosystem services. Water and urban areas are considered important for cultural services. However, these areas cover only a relatively small area altogether. The results of the ecosystem services assessment were compared to areas of high biodiversity, as defined by local biodiversity experts. The areas with high capacity for ecosystem services provision (from now on "high ecosystem services areas") were found in areas with high biodiversity. In most cases, these areas are already under protection. The results also showed that ambiguity is an issue with the use of the ecosystem services concept in both stakeholder and expert evaluations.

Keywords: ecosystem services, land cover mapping, expert-based assessment, matrix method, biosphere reserves, trade-offs

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Introduction

Ecosystem services (ES) are a key concept for investigating human-nature relationships with regard to sustainable natural resource use. ES are benefits of nature to human well-being (MA 2005). Assessments and spatially explicit mapping for ES are approaches that support land use decision-making and environmental planning (Cowling *et al*. 2008; McKenzie *et al*. 2011; Maes *et al*. 2012) by supplying information on ES distribution across space (Burkhard *et al*. 2013). ES mapping and assessment are also expected to help stop biodiversity loss and degradation of ecosystems (EC 2011; European Parliament 2012). Biodiversity means the variability of living organisms, and includes diversity of genes, species, and ecosystems (CBD 2019). Fundamentally, biodiversity is considered to be one of the prerequisites for the delivery of ES (Hooper *et al*. 2005; MA 2005; Isbell *et al*. 2011; Brockerhoff *et al*. 2017). By identifying where ES are provided, it is possible to steer land use decisions towards a more ecologically, socially and economically sustainable direction (Cowling *et al*. 2008; Bennett *et al*. 2009). Maps representing synergies and trade-offs among ES services can be compared to the targets and goals of land use planning and policy (Maes *et al*. 2012) and can therefore support decision-makings as an important powerful tool (Troy & Wilson 2006). That means results should be sound and relevant for their potential users such as regional planners and decision-makers (e.g. Cowling *et al*. 2008; Albert *et al*. 2014), and attention must be paid on how maps are presented to avoid misinterpretations (Hauck *et al*. 2013a).

The UNESCO Biosphere Reserves were established to protect ecosystems and to support the ecologically and socially sustainable use of natural resources (UNESCO 2002). Conservation of ecosystems, species and genetic resources, sharing of environmental knowledge and development of their sustainable use are the main goals of the Biosphere Reserves (UNESCO 2000). The overlapping goals of sustainable co-existence between human and nature create an opportunity to test the applicability of the ES approach in biosphere reserves (Costanza *et al*. 1997; Bridgewater 2002). In the case study presented here, the ES approach was applied in the North Karelia Biosphere Reserve (NKBR) in Eastern Finland.

The UNESCO's Man and Biosphere Programme (MaB) (UNESCO 2002) specifically emphasizes ecological and social sustainability. Hence, the concept of multifunctionality is considered beneficial in investigating the potential nature-related human activity in a biosphere reserve. The concept emphasizes the mixed use of landscapes instead of a single use, for instance agricultural use only (OECD 2001; de Groot 2006; O'Farrell *et al*. 2010). The concept of multifunctionality can be applied to questions related to land uses that are dependent on nature to different degrees (Huang *et al*. 2015) and is therefore useful in urban planning (Hansen & Pauleit, 2014; Di Marino & Lapintie 2017). According to Mann and Wustemann (2008), the concept of multifunctionality allows to emphasize the economic production (e.g. in intensive agriculture or forest plantations) which could lead to unsustainable use of natural resources. Thus, constant management and supervision are required to monitor the impacts of economic activities on ecosystems. Therefore, unravelling the relations between land cover and ES, their trade-offs, supply and demand is an essential task. When focusing on the aspect of economic production, multifunctionality assessments may overlook important contributions to ecosystem functionality and human well-being. Moreover, multifunctionality does not take into consideration the trade-offs between different ES (Hansen & Pauleit 2014). By applying the ES approach, the aspects of biodiversity and the role of ecosystems in supporting the supply of ES, that is maintaining their ecosystem integrity, can also be considered (Burkhard *et al*. 2012a; Kandziora *et al*. 2013). That complements the idea of multifunctionality in planning processes (Brandt *et al*. 2014).

In this article, we identify which ES have a high provisioning potential in the North Karelian Biosphere Reserve by using the "ES matrix" approach (Burkhard *et al*. 2009, 2012b, 2014). The aim is to measure the potentials of different land cover types to supply ES based on expert knowledge and to display the results on maps. The same maps are used to analyse how different land cover classes are suitable for multiple uses. The ES maps are then compared to areas that are considered rich in biodiversity by the experts. Finally, we discuss how land use affects the availability and use of the different land cover types and the ES they can provide.

Compilation of Ecosystem services assessment sources and methods

Study area

The North Karelian Biosphere Reserve (NKBR, 3,500 km^2) in Eastern Finland belongs to the southern and middle boreal vegetation zones. The landscape is characterized by a variety of habitats including vast pine and spruce forests, mires, bogs and several water bodies (Fig. 1) (UNESCO 2007; North Karelia Regional Council 2013). One third of the area of North Karelia is covered by mires (Turunen *et al*. 2002). The area is home to a wide range of wildlife, including rare and endangered species, such as wolves and wolverines (endangered), bears and lynxes (nearly threatened species), as well as a variety of fish and bird species (The Ramsar Convention on Wetlands 2004; North Karelia ELY Centre 2013). Key habitats and species in the region are protected through NATURA 2000 programme sites (630 km^2 in the study area), nature parks, and strictly managed nature reserves. State-owned protection areas cover approximately 270 km^2 and 76 km^2 are privately owned. Additionally, some mires are protected as Ramsar sites that have been established to preserve important wetlands and to protect waterfowl (Hokkanen 1995; The Ramsar Convention on Wetlands 2004).

The NKBR is comprised of the municipalities of Ilomantsi and Lieksa. The area has approximately 17,000 inhabitants. The main sources of income are agriculture and forestry management which are also the major drivers of biodiversity and habitat loss and environmental degradation (UNESCO 2007; North Karelia Biosphere Reserve 2013). The main drivers of land cover and land use change are mire drainage and forest management for timber production (Jantunen & Saarinen 2002; Uotila & Kouki 2005). Recreational activities, such as hunting, mire exploration, hiking, skiing, camping, fishing, berry and mushroom picking are actively carried out by the inhabitants, but not all these activities are allowed in areas that are under strict protection (UNESCO 2007; North Karelia Biosphere Reserve 2013). In Finland, the Everyman's rights allow selected recreational activities also in protected and privately owned areas by the law (Ministry of the Environment 2013). Due to the uniqueness of the ecosystems and diversity, this region was included in the UNESCO MaB Programme, thereby creating the North Karelia Biosphere Reserve in 1992 (UNESCO 2007).

High Biodiversity areas dataset

High Biodiversity areas in the NKBR have been delineated as part of the SuoEKO project that was conducted in 2010 to identify and value ecosystem services in mires and peatlands. The project was funded by the Finnish Ministry of Agriculture and Forestry. A stakeholder workshop was carried to bring together stakeholders and scientists to identify the most important ES in NKBR. The areas of high biodiversity were defined by the experts in the workshop and as a result, a map of important BD areas was compiled for further analysis in this study (Fig. 2).

Compilation of land cover datasets

The land cover dataset was compiled from multiple sources of GIS-based datasets in order to use a more detailed land cover map as a basis for the final analyses (Fig. 3). *CORINE Land cover* 2006 (CLC2006) (EEA 2007) 25 m x 25 m pixel raster dataset was used as level one data with categories of 1) *artificial surfaces/urban areas*, 2) *agricultural areas*, 3) *forests and semi-natural areas*, 4) *wetlands* and 5)

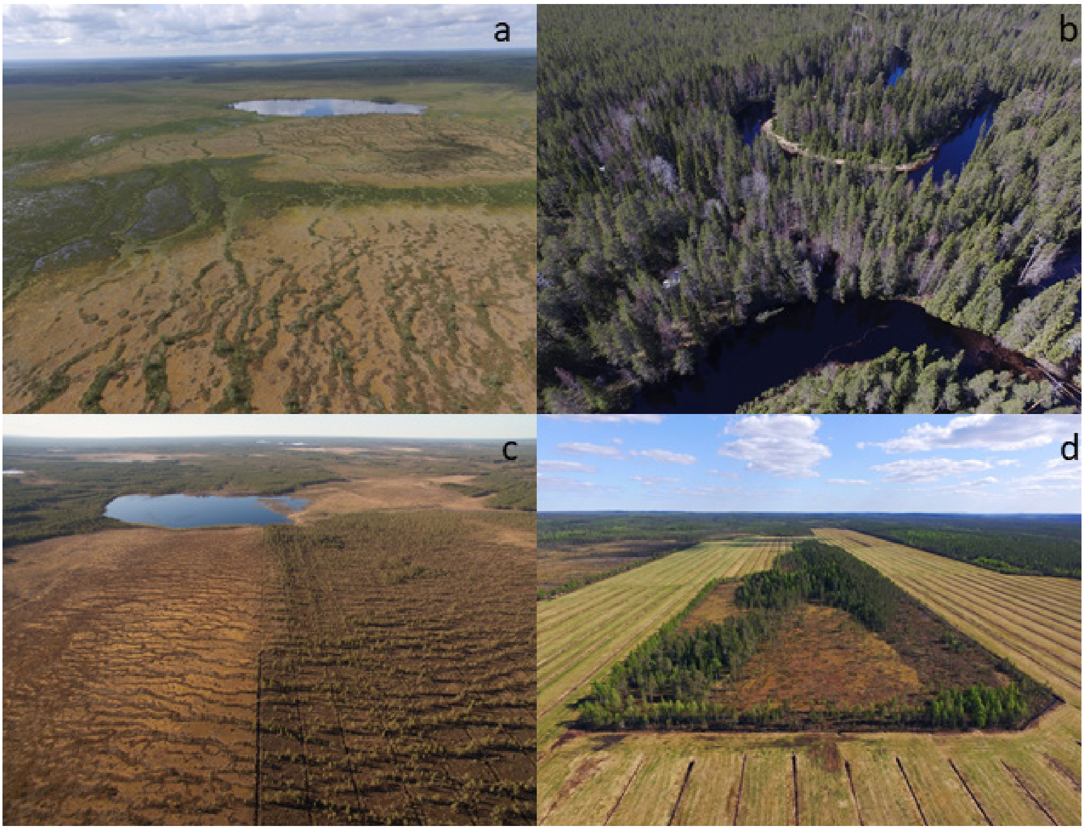

Fig. 1. Landscape of NKBR. a) Natural state open aapa mire of Ilajansuo, b) Ylä-Koitajoki river valley with old growth forest, c) Partly drained Rahesuo aapamire, growth of forest in drained area is rather weak, d) Tohlinsuo aapamire which was drained and prepared for peat mining, but the main use is crop cultivation to feed animals. (Drone photographs: Pasi Korpelainen 2018)

water bodies. A peatland (mire) mask data was obtained from the Finnish Environment Institute (SYKE) from 2009 with a pixel size of 25 m x 25 m with the categories: 1) *undrained peatland*, 2) *drained peatland* and 3) *peat extraction sites*. For forests, *tree stand age* was derived from an open access Multi-source National Forest Inventory (MS-NFI) Raster Maps of 2011 with a pixel size of 25 m x 25 m provided by Natural Resources Institute Finland (LUKE). Forest age classes were divided into four main age categories: 1) *forest age younger than 20 years (< 20)*, 2) *between 21 and 80 years (21–80)*, 3) *between 81 and 120 years (81–120)*, and 4) *older than 120 years (> 120)*.

The datasets had overlapping pixels. They were used to generate new classes and some of them were merged with already existing classes. For example, the data from LUKE included stand age of trees in forests within urban areas, which overlapped with the Corine's artificial surfaces/urban areas. In this case, the urban pixels were maintained as in CLC2006 data. Figure 2 shows the procedure: the original values were maintained with level 1 (L1) land cover classes. From the L2 dataset, the peat extraction sites were used as they were in the original dataset. The undrained and drained peatlands with no overlapping pixels were reclassified as: *'undrained open mires'* and *'drained open mires'*. However, the undrained and drained mires with overlapping pixels with a L3 level were reclassified as: *'undrained forested mires'* and *'drained forested mires'*. The original classification was maintained for the remaining areas of L3, that is the original stand age classes of forests. Nevertheless, some areas remained unclassified with no information from any of the datasets. According to the experts who were consulted, most of these unclassified areas were identified as *riparian zones*. These riparian

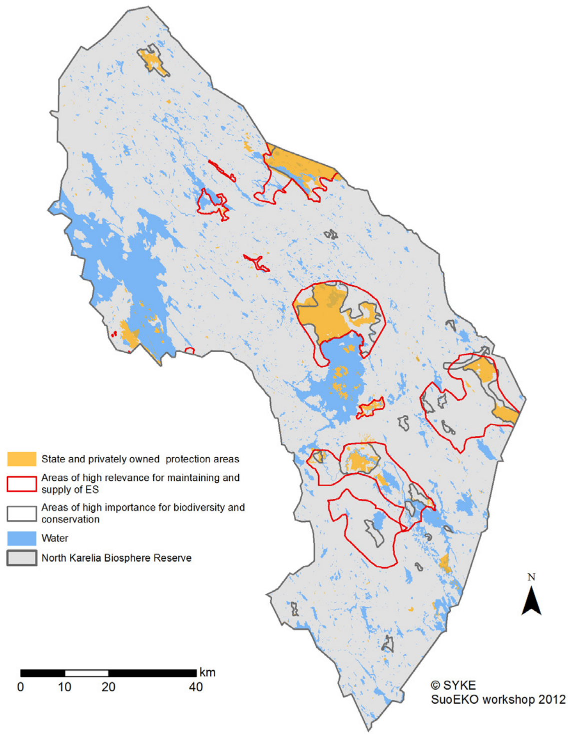

Fig. 2. Map of the North Karelia Biosphere with the outlined areas of high importance for biodiversity and conservation (gray line) and of high relevance to maintain and supply ES (red line) from the SuoEKO workshop. Private and public protection areas are shown in orange.

areas are considered important due to their high biodiversity, flood control function, maintenance of biological connections, and other services (Clerici & Vogt 2013). In total, 13 classes were composed for the final map.

Matrix method

The "ES matrix" approach was applied to evaluate potential ES supply in the NKBR. The potential ES supply denotes the capacity of the social-ecological system to provide ES (ES supply) where the ecological basis for their provisioning is affected by ecosystem properties and their condition (Syrbe *et al*. 2017). The method is based on linking geospatial units such as land cover classes with ES supply (or demand) and has been used in several ES mapping studies (Burkhard *et al*. 2009; Vihervaara *et al*. 2010, 2012; Burkhard *et al*. 2012b; Sohel *et al*. 2015). The method is considered as Tier 1 level method to link scores of ES potentials with land cover units defined by the methodological framework by MAES (Mapping and Assessment of Ecosystem Services) EU working group (Vihervaara *et al*. 2018).

In this study, the matrix was presented to specialists who were asked to evaluate the potential of different land cover types to supply ES. The matrix consisted of 34 ES in three main categories (provisioning ES, cultural ES and ecosystem integrity and regulating ES; the ES list and categories follow the lists used in the SuoEKO project) (Table 1) on the x-axis and 13 land cover classes on the y-axis, with a total of 442 fields to be assessed. The ES matrix was sent to seven experts with long-standing experience in nature conservation and environmental management of the biosphere reserve and the ES concept. They represent the fields of biology, ecology and geography. The ES potentials of the different land cover types represented in the matrix were scored with values between 0 and 5 (with 5 = very high potential for ES supply of the respective ES; 4 = high potential; 3 = medium potential; 2 = relevant potential; 1 = low relevant potential; and 0 = no relevant potential). The collected data was coded to Microsoft Access© and an arithmetic mean for all included ES was calculated. The means were rounded to the nearest integer shown in the results. However, the original mean values were used to maintain the original ranking. The resulting table was loaded into a GIS and combined with the detailed land cover data from the NKBR and maps for all three ES categories, but since the category maps aggregate data, we decided to make individual maps from six independent ES to demonstrate the effect of aggregation.

Ecosystem services distribution in North Karelia Biosphere Reserve

The land cover map

The compilation of multiple GIS datasets resulted in a detailed land cover map (Fig. 4). The final land cover map has 13 classes with detailed information on of forest age and the status of mire drainage. This map was used as the basis for subsequent analyses. The land cover map showed the highest areas for forests between the age 20–80 years, drained forested mires and water areas (Table 2).

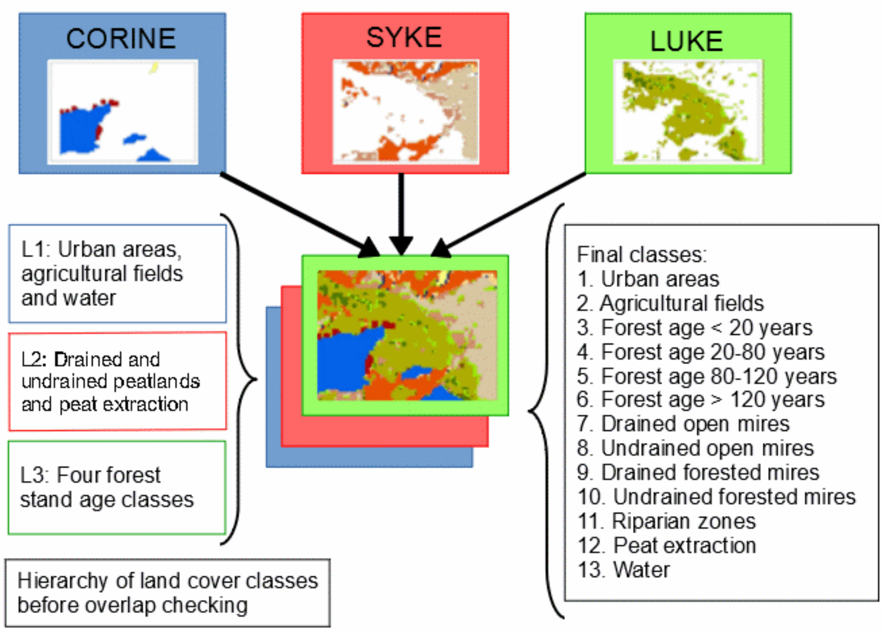

Fig. 3. Data compilation of the land cover data. Multiple GIS datasets were combined and altogether 13 land cover classes were generated.

Table 1. The list of ecosystem services used in the SuoEko Workshop (Aapala et al. 2013).

Ecosystem integrity and regulating ecosystem services	**Provisioning ecosystem services**
Maintenance of biodiversity	Berries (cloudberry, cranberry, blueberry)
Pollination services	Game (birds, moose, bear)
Disease and pest control	Mushrooms
Carbon sequestration	Raw material for arts and crafts
Carbon storage of peat	Natural dyes
Carbon storage of trees	Horticultural peat (peat growing mix)
Water purification	Bedding peat (peat litter)
Maintenance of groundwater supply	Firewood (household use)
Local climate regulation	Energy wood (industrial use)
Flood protection	Energy peat
Cultural ecosystem services	Bioenergy (other than wood)
	Saw-timber trees and pulpwood
Nature travel and tourism	Textile fibres
Outdoor activities and recreation	Functional products (with health benefits)
Teaching, science, education	Cosmetics
Cultural and spiritual values	Natural drug ingredients
Aesthetic and scenic values	Grain
	Genetic resources

The ecosystem services matrix

Table 3 shows the ES matrix with the average values of ES supply potentials based on the expert evaluation. The values are highlighted with a colour scheme where dark green indicates higher values. Higher values were found particularly for the ecosystem integrity and regulating services as well as for the cultural services. The highest values for ecosystem integrity and regulating services were concentrated in old growth forests (stand age older than 81 years) and in undrained open and forested mires. The same land cover classes had a high potential for cultural ES. Water and urban areas were also identified as important areas. For both ecosystem integrity and regulating services and cultural services, riparian zones showed significant ES potential values. Forested areas with a stand age older than 21 years and undrained open and forested mires presented high potentials for a few provisioning services which is the case also with agricultural fields and undrained mires.

A ranking based on the expert evaluation is presented in Table 3. All the cultural services as well as many of the ecosystem integrity and regulating services have a high ranking. Only two provisioning services, game and berries, also have a high ranking. Most of the provisioning services and only two

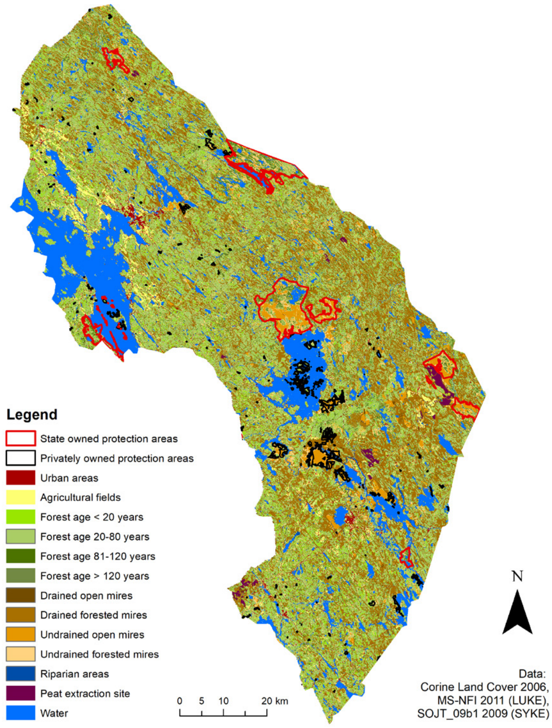

Fig. 4. Detailed land cover map of the North Karelia Biosphere Reserve.

regulating services and ecosystem integrity components ('carbon storage of trees' and 'long-term carbon storage of peat') were ranked low. These services show significantly lower average values compared to the other ES from the same category. This is due to a lower share of the land cover classes in the area. Nevertheless, the average values are higher than the average values of the provisioning services found in larger areas.

Using the data from Table 3, a summary with the average values of the expert-based ES assessment was conducted using the average values for each land cover class. The ES maps were created to visualize the distribution of ES in the three main ES categories in the North Karelia Biosphere Reserve (Fig. 5). Again, the results were rounded to the nearest integer to keep the original ranking system from 0 to 5. In the maps, the areas with high or very high ES potential were visualized. Many of the ES maps have overlaps in the protected areas. Undrained mires also show high values. In the map of cultural services, the ES are found in protected areas, undrained mires and water areas. A dark green belt-like area, approximately in the middle of the map going southeast, shows high potentials for ES. A large share of the area is protected and its importance for biodiversity and outdoor activities and recreation is illustrated on an individual ES map in Figure 6. The NKBR shows generally low potentials for provisioning services. The ecosystem integrity and regulating services have overall medium to high potentials across the whole area. Urban areas and peat extraction sites have a low relevant potential for ecosystem integrity and regulating services (Fig. 5).

Maps for top six individual ES are presented in Figure 6. Maps from ES within the same categories show similar patterns, for example 'maintenance of biodiversity' (top-left) and 'genetic resources' (bottom-left); 'aesthetic and scenic values' (top-middle) and 'outdoor activities and recreation (top-right). In general, the protected areas show high values in all maps, but the dark green areas (high –

Table 2. Distribution of land cover types in the study area according to the compiled map.

	Land cover class	%
1	Forest age 20–80 years	36.76
2	Drained forested mires	21.31
4	Water	13.72
3	Forest age < 20 years	8.64
5	Forest age 81–120 years	4.92
6	Undrained forested mires	4.06
7	Undrained open mires	3.25
8	Agricultural fields	2.05
9	Urban areas	1.94
10	Drained open mires	1.66
11	Forest age > 120 years	0.83
12	Riparian areas	0.45
13	Peat extraction areas	0.41
	Total	**100**

very high potential) vary between ES categories. The map of game contradicts the map of provisioning services which demonstrates the issues related to the aggregation of ES into categories.

To assess the expert values composition, a standard deviation from the average values per category was calculated for all land cover types (Fig. 7). The cultural services show the highest disparity when compared with the other categories, that is a bigger range of values was given by the experts when evaluating the land cover maps. The provisioning services have a smaller value for the standard deviation. The results show more concurrence between the experts in regard to the low potential provisioning services. The bigger disparity with cultural services indicates a subjectivity on how cultural services relate to different land cover classes, which emphasises the necessity of understanding the cultural characteristics of an area. More details on the expert responses are presented in Figure 8.

Discussion

Ecosystem services in the Biosphere Reserve

The resulting land cover map in regard to ecosystem services showed the largest areas for forests (20–80 years) (36.76%), drained forested mires (21.31%), water courses (13.72%) and young forests (< 20 years) (8.64%) in the NKBR. However, the results of the ES assessment indicate higher values for other land cover classes. Forests (>120 years) and undrained open mires had high potentials for multiple ecosystem services in all categories, forest (81–120 years) in provisioning and regulating categories, undrained forested mires for regulating services and waters for cultural services. These land cover types are also commonly found in protected areas. The human impact is evident in younger forests and drained forested mires; they had only a moderate potential for a variety of provisioning ES besides high values for wood products and collectables. The land use steers the trade-offs between services. For example, with forests (20–80 years), the high potentials were shown for berries, saw timber and pulpwood, firewood, mushrooms and outdoor activities and recreation. When using forests for saw timber and pulpwood, there are less opportunities to simultaneously use those same forests for collectable products (e.g. Peura *et al*. 2016) and outdoor use (e.g. Tyrväinen *et al*. 2017). However, both collectable products and outdoor use can be combined with timber production when

Table 3. Ecosystem services matrix filled with the average values of the expert-based assessment (n = 7). The numbers were rounded to nearest integer. The values follow the scheme: No potential = 0, Low relevant potential = 1, Relevant potential = 2, Medium potential = 3, High potential = 4, Very high potential = 5.

	Ecosystem integrity and regulating services											**Provisioning services**																	**Cultural services**					
	Maintenance of biodiversity	Genetic resources	Disease and pest control	Water purification	Flood protection	Pollination services	Carbon sequestration	Maintenance of groundwater supply	Local climate regulation	Carbon storage of trees	Long-term carbon storage of peat	Game (birds, moose, bear)	Berries (cloudberry, cranberry,	Raw material for arts and crafts	Functional products (with health	Saw-timber trees and pulpwood	Firewood (household use)	Natural drug ingredients	Mushrooms	Natural dyes	Energy wood (industrial use)	Cosmetics	Energy peat	Peat growing mix	Peat litter	Grain	Textile fibres	Bioenergy (other than wood)	Outdoor activities and recreation	Aesthetic and scenic values	Art (painting, literature, photography)	Teaching, science, education	Nature travel and tourism	Cultural and spiritual values
Urban	2	2	2	1	1	2	1	0	2	2	0	0	1	1	1	1	1	1	1	1	0	1	0	0	0	1	1	1	3	3	4	3	2	3
Agricultural fields	2	3	3	1	1	3	2	1	2	1	1	2	1	2	3	1	1	3	0	2	1	2	0	1	1	5	3	4	1	3	3	2	2	2
Forest age < 20 years	2	2	3	2	2	2	2	2	2	2	0	3	3	2	2	1	2	1	2	2	2	1	0	0	0	1	1	0	2	1	1	2	1	1
Forest age 21–80 years	3	3	3	2	2	3	4	2	2	2	0	4	4	3	3	4	4	2	3	2	4	2	0	0	0	1	1	0	3	2	2	3	3	2
Forest age 81–120 years	4	4	4	4	3	4	4	3	3	4	0	4	5	4	3	5	5	3	5	3	4	2	0	0	0	1	1	0	5	4	4	3	4	3
Forest age > 120 years	5	5	4	4	3	4	4	4	4	5	1	4	5	4	4	4	4	3	5	3	3	2	0	0	0	1	1	0	5	5	4	4	5	4
Drained open mires	2	2	2	2	2	2	1	2	2	1	2	2	3	2	1	1	1	1	1	1	1	1	3	3	3	1	1	2	2	1	1	2	1	1
Drained forested mires	3	2	2	2	2	2	2	2	2	3	2	3	2	2	1	3	3	2	2	1	2	1	3	2	2	1	1	1	2	1	1	2	1	1
Undrained open mires	5	4	3	5	5	3	4	4	3	1	5	4	5	2	3	1	0	3	2	2	0	2	3	4	3	0	1	1	4	5	4	4	4	4
Undrained forested mires	5	4	3	5	5	4	4	4	3	3	4	4	4	2	3	2	2	3	2	2	2	2	3	3	3	1	1	1	4	4	4	4	4	3
Riparian zones	5	4	3	4	4	3	2	3	2	1	1	3	2	2	1	1	1	1	1	2	1	1	0	1	1	1	1	1	3	4	4	3	3	3
Peat extraction areas	0	0	1	0	1	1	0	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	4	2	3	1	2	2	1	1	1	2	1	0
Water	4	4	2	2	3	1	2	4	4	1	1	3	0	1	2	0	0	1	0	0	0	1	0	0	0	0	0	1	5	5	5	4	5	5
Sum	42	39	35	34	34	34	32	32	32	27	18	37	35	28	28	25	25	25	24	22	21	19	16	16	16	15	15	14	40	39	38	38	36	32
Ranking	1	3	9	11	11	11	14	14	14	20	28	7	9	18	18	21	21	21	24	25	26	27	29	29	29	32	32	34	2	3	5	5	8	14

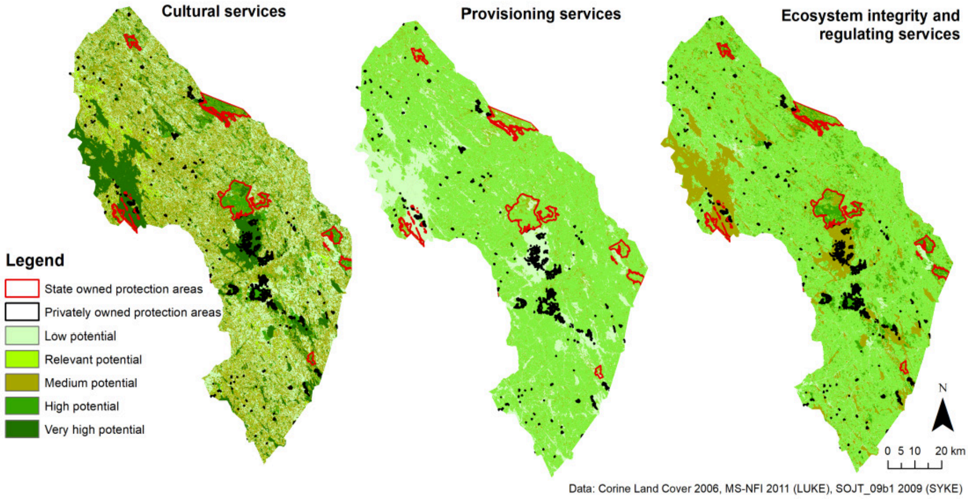

Fig. 5. Maps of the ES potentials grouped in the ES categories in the North Karelia Biosphere Reserve: cultural services, provisioning services and ecosystem integrity and regulating services. The average data from the expert evaluations for each ES category were taken and final values were rounded to the nearest integer.

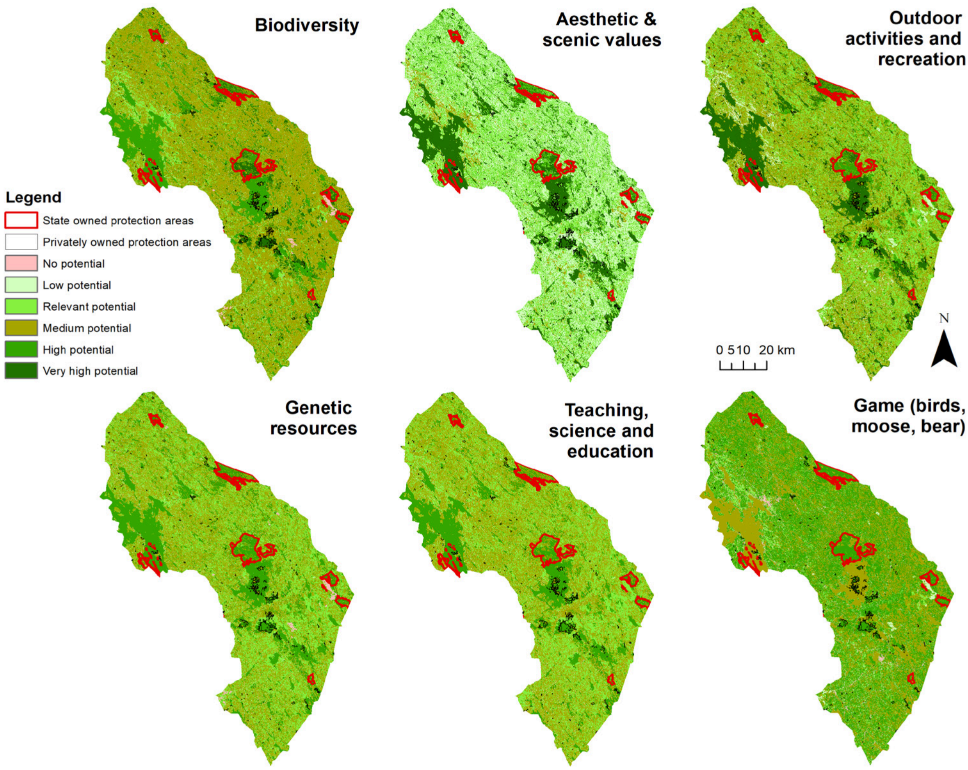

Fig. 6. Maps of the six ES with the highest ranking (according to Table 3): maintenance of biodiversity, aesthetic and scenic values, outdoor activities and recreation; genetic resources, teaching, science and education, and game (birds, moose, bear). Data: Corine Land Cover 2006, MS-NFI 2011 (LUKE), SOJT_09b1 2009 (SYKE).

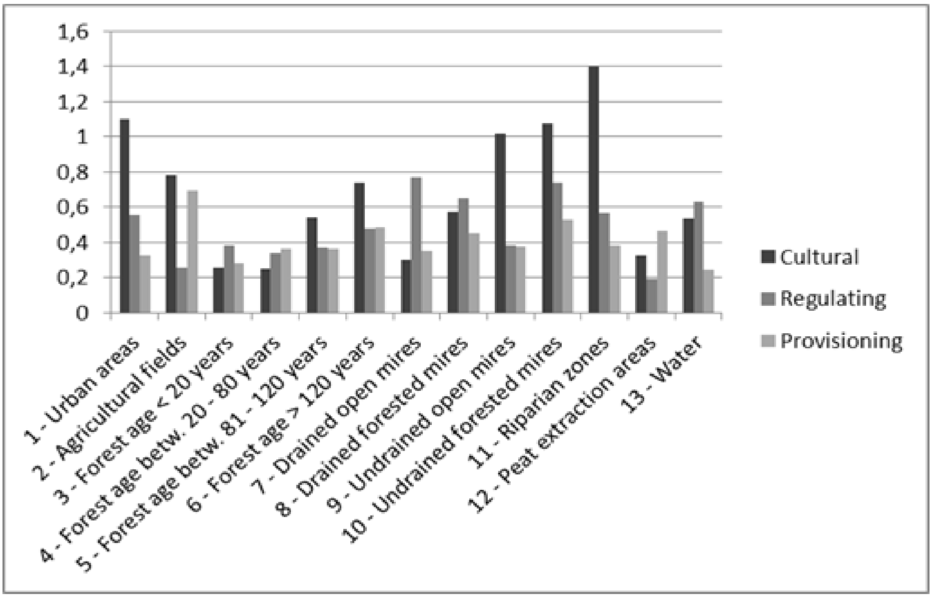

Fig. 7. Standard deviations from the average of the ES classes in relation to the area of the different land cover types.

forests are carefully managed. The purpose of the intensive mire drainage between 1950 and 1990 was to produce dry peatland for timber production. In many cases, the benefit of draining has been low for increased forest growth (Paavilainen & Päivänen 1995). In drained forests the trade-off is mainly between timber production and ecosystem integrity and regulating services (maintenance of biodiversity, genetic resources, water purification, flood protection, long-term carbon storage) as well as all cultural services. In commercially unproductive peatlands, there is no objection to restore these peatlands to secure ES that have been lost after drainage (Tolvanen *et al*. 2013). Water areas have high potential for all cultural ES. Studies have shown that the quality of water has a high impact on other services, such as outdoor activities (fishing, swimming), aesthetic and scenic values and drinking water (Keeler *et al*. 2012). Land use activities, such as forestry (e.g. Ahtiainen & Huttunen 1999; Piirainen *et al*. 2007), agriculture (e.g. Granlund *et al*. 2005) and peatland drainage (e.g. Skaggs *et al*. 1994; Ekholm & Mitikka 2006) have negative impacts on water quality.

The main sources of livelihood, agriculture and forestry management must be taken into careful consideration. Land use is dependent on the specific land cover as well as on the functionality of ecosystems, and therefore the research community must investigate which functionalities can co-exist in practice (Manning *et al*. 2018). Trade-off analyses of ES bundles have been considered to estimate the multifunctionality of ES more effectively (Raudsepp-Hearne *et al*. 2010). A variety of methods have been developed to find the balance between land use objectives and ecosystem provisioning (e.g. Nelson *et al*. 2009; Bradford & D'Amato 2012; Holmberg *et al*. 2015). Scenario analyses may further be used as a mediator in discussions and problem-solving with the aim to find a consensus for land use options of socio-environmental systems (Seppelt *et al*. 2013).

According to the expert assessment, the ES maps showed high potentials in protected areas for all ES categories. Our findings show that areas under biodiversity protection are also valuable for ES delivery. The comparison of ES maps and the biodiversity rich areas was feasible underlined by several studies investigating the positive linkage of ES provision and biodiversity in some instances (Balvanera *et al*. 2006; Egoh *et al*. 2009; Schneiders *et al*. 2012; Brandt *et al*. 2014). Especially old-growth forests are known to be hot spot areas for maintaining biodiversity as well as ecosystem processes and functioning (Juutinen 2008; FAO 2012).

Comparison of the role of various classes of biodiversity (taxonomic, functional, ecosystems) for ES provisioning is challenging, and should be tailored to meet the purpose, for example functional diversity in relation to the selected regulating services. The linkage has been found to vary between services (Harrison *et al*. 2014) which is a reason to conduct joint evaluations of both biodiversity and ES to guarantee that both are taken into account (Chan *et al*. 2012; Turner *et al*. 2007). Ecosystem integrity and regulating services are especially supported by high biodiversity which supports also

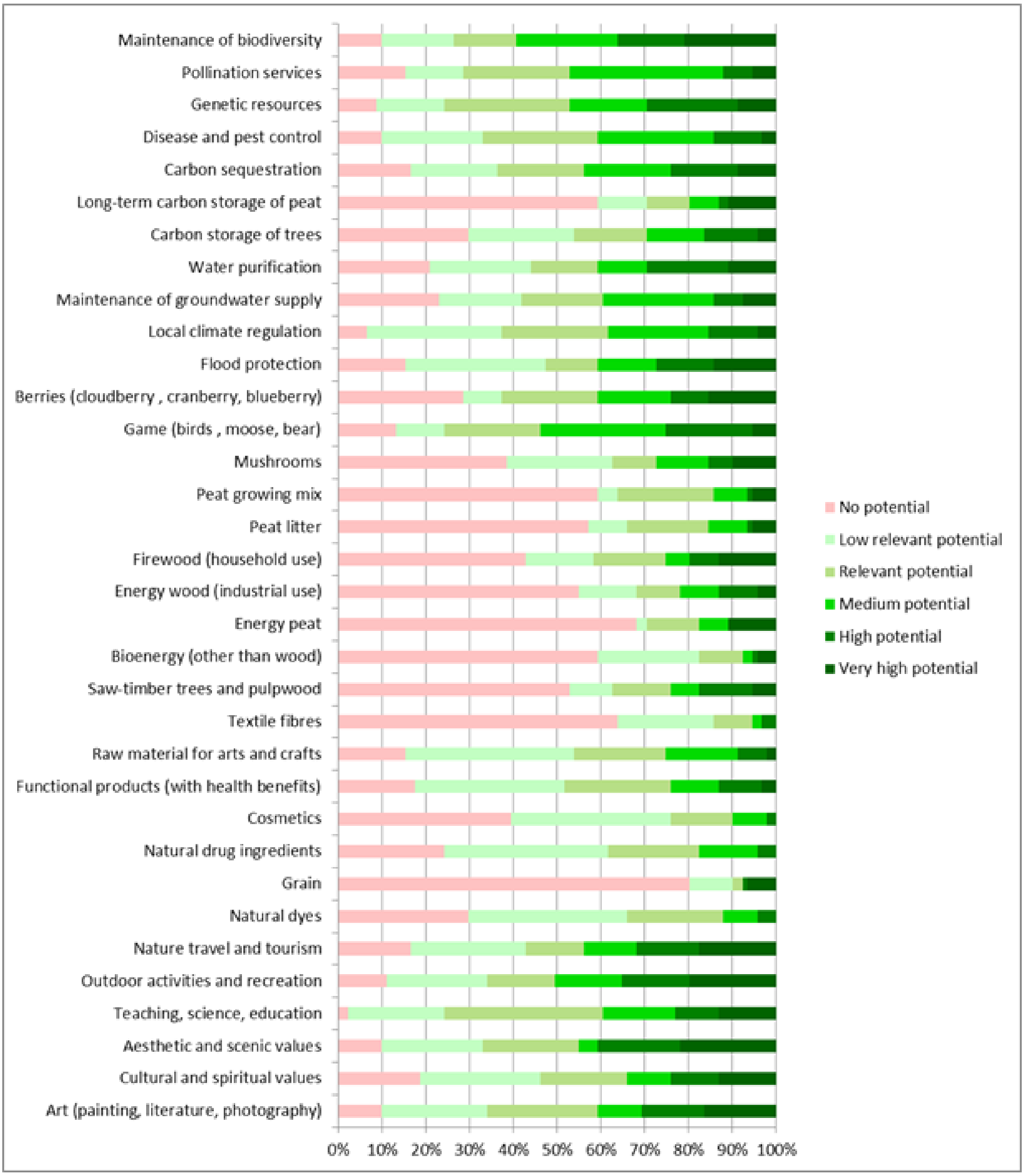

Fig. 8. Composition of ES classified according to their supply potentials, based on the experts' evaluation. The expert scores for each ES were counted without considering the land-cover.

ecosystem functioning. Protected areas also secure habitats for animals. Nature conservation may overlook the social perspective which is why the ES approach was expected to overcome this gap (Reyers *et al*. 2010a, 2010b). From the perspective of multifunctionality, the protection status restricts intensive utilisation of natural resources, that is some of the ES.

Uncertainties of the assessment

Various issues are related to the use of land cover data in ES assessments, especially, when derived from different sources. However, classification uncertainty and misclassification are also among key concerns with respect to differences in spatial scales (Hou *et al*. 2013). In our study, the uncertainties are related to land cover data as well. In general, issues with data can be related to the availability of the suitable data, scale or interpretation of the data (Hou *et al*. 2013). The datasets that were used in this study have been generated from satellite images (CLC 2006), aerial images (mire data), or modelling based on multiple sources (MS-NFI). Their interpretation to land cover datasets already creates basis for the first set or errors on maps.

This experiment also revealed issues and uncertainties that are related to expert-based analyses. Hou, Burkhard and Müller (2013) refer here explicitly to preference uncertainty, where expert's with different knowledge and experience level are to evaluate the same issue, and natural supply uncertainty dealing with ecological complexity and knowledge gaps (Hou *et al*. 2013). The number of seven respondents was quite low in our study, whereas ideally a panel should have a minimum of 10–15 experts (Campagne *et al*. 2017). This is reflected in the disparities between the expert responses in our study. The credentials of experts influence how they understand a question which can also impact the results (Jacobs *et al*. 2015). In this study, there were different understandings of the definitions for ES categories (cultural services in particular) and some specific ES as well (cf. Fig. 8). Services that might also belong to the cultural services but listed under provisioning services are “berries” and “game”. Both serve in the study area especially also recreational purposes in terms of berry picking and hunting. Additionally, it is to mention that the ecosystem service “peat” for energy was used, which is disputed as for its use peatland ecosystems need to be exploited. It is known that imprecise definitions are a critical issue in such assessments (Scolozzi *et al*. 2012; Mononen *et al*. 2016, 2017). The use of average values simplifies the results significantly. Therefore, careful interpretation of the reasons for a high variation is essential. The use of expert-based analysis, such as the matrix method, can help create a good overview of a topic that includes complicated information (Jacobs *et al*. 2015). Such methods allow the involvement of further stakeholder knowledge for evaluation. It is crucial to involve a wide range of different stakeholders in ES assessments to identify all potential ES synergies especially when they are used as a basis for decision-making (Hauck *et al*. 2013b). The cooperation between different stakeholders has been emphasized to operationalize the ES concept in decision-making (Chan *et al*. 2012; Daily & Matson 2008).

Restrictions of the ES approach

Initially, decision-makers reacted slowly to integrate ES into decision-making (Chan *et al*. 2006; Daily *et al*. 2009) mainly due to conceptual, methodological and valuation challenges of ES (De Groot *et al*. 2010), but recently the situation has improved (e.g. IPBES 2019). A series of conceptual and practical limitations have also prevented the integration of ES into conservation programmes (e.g. Hauck *et al*. 2013b). A key aspect is the limited understanding of the ecological underpinnings of ES (Kremen 2005; Luck *et al*. 2009) and the role of biodiversity as a part of the biophysical system responsible for ES supply. Trade-offs between different ES, mismatches between political and ecological scales, and difficulties regarding ES quantification and valuation (Turner & Daily 2008; Luck *et al*. 2009) also hamper ES assessments, planning and management.

Our study put an emphasis on local ES in biologically valuable areas and showed how they reflected ES that are related to economic activities and different land uses. The inclusion of a wider range of experts and multiple stakeholder groups could improve the integration of multiple objectives of an area. That way the assessment of multifunctionality would also be implemented in the analysis in a more consistent manner. The success of ES assessments is dependent on reliable methodologies and information that support decision-making in a credible way. Attempts to supply this information to scientists and to decision-makers have recently taken major steps forward (Santos-Martin *et al*. 2018; http://www.esmeralda-project.eu/). This progress helps overcome the restrictions that hinder the integration of ES in sustainable policy making.

Conclusions

The land cover and expert-based assessment of ecosystem services in the North Karelian Biosphere Reserve is a useful method to detect areas with ES of different potential levels. The areas with high ES potentials can mainly be found in the protected areas within the Biosphere Reserve, emphasizing the importance of conservation to maintain biodiversity, or ecological functioning and the higher range of different ES. Further research with up-to-date information on land cover and a variety of stakeholder groups should be conducted to gain more thorough information on the area and would help to make ecologically and socially sustainable multifunctional plans for the North Karelian Biosphere Reserve.

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