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Analysis

# Participatory multi-criteria decision analysis in valuing peatland ecosystem services—Trade-offs related to peat extraction vs. pristine peatlands in Southern Finland

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ABSTRACT

The use of peatlands and the multiple but mutually exclusive ecosystem services they provide is a highly debated issue worldwide. We used a participatory multi-criteria decision analysis (MCDA) to address multiple value dimensions and trade-offs related to peatland ecosystem services in Southern Finland. We evaluated five peatland policy scenarios against provisioning, regulating and cultural ecosystem services as well as socio-economic factors, and engaged key stakeholders in framing the assessment and assigning criteria weights. The MCDA process showed that while peat extraction can basically be reconciled with preserving the most important biodiversity values in Finland, the conflict between peat extraction and carbon stock as well as water quality impacts and the related amenity values is irreconcilable. The role of the participatory MCDA process in promoting learning and reflection was smaller than expected but it did facilitate learning about the flows of peatland ecosystem services. The role of the participants was important not only in making value judgements but also in contributing to the impact assessment, thereby supporting the calls for transdisciplinarity in ecosystem service assessments.

## 1. Introduction

The use of peatlands and the multiple but mutually exclusive ecosystem services they provide is a highly debated issue in Finland. Peatlands have a globally important role in storing carbon (Joosten et al., 2016), and undrained peatlands are expected to have a role in water purification and in certain cases delaying runoff (flood prevention) (de Groot et al., 2006; TEEB, 2010). They also host a wealth of biodiversity and provide a range of cultural ecosystem services, such as recreational opportunities and amenity values. In Southern Finland, around 70% of peatlands have been converted for agricultural and forestry uses or fuel peat extraction and therefore the ecological and social value of the remaining areas have increased (Alanen and Aapala, 2015). At the same time, peat is a domestic fuel that covers around 5% of Finnish energy production (Leinonen, 2010). It has a particular significance in rural areas where peat extraction contributes to the local economy and provides employment opportunities. There is also a growing demand for horticultural peat that is extracted simultaneously with energy peat (Leinonen, 2010). Debates have manifested themselves in conflicts over a particular peatland at the local level (Albrecht and Ratamäki, 2016) as well as in controversies surrounding peatland policies, recently over a national peatland protection program (Alanen and Aapala, 2015).

In this study we used participatory multi-criteria decision analysis (MCDA) to address the trade-offs related to peatland ecosystem services in Southern Finland. MCDA is a general term for methods to support complex decision-making situations with multiple and often conflicting objectives that stakeholder groups and decision-makers value differently (Belton and Stewart, 2002). In environmental management, MCDA methods are increasingly used to structure participatory integrated assessment and valuation processes, which combine information about decision alternatives and their consequences with information about stakeholder and/or decision-maker values and preferences (Kiker et al., 2005; Voinov et al., 2016). MCDA methods have been regarded as particularly helpful in ecosystem service valuation because they can combine qualitative data on provisioning and regulating services with qualitative data on less tangible cultural services (Chan et al., 2012). They also facilitate transparent analysis of the pros and cons of decision-making alternatives with respect to ecosystem services (Spangenberg and Settele, 2010; Geneletti, 2013; Keune and

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Dendoncker, 2014; Saarikoski et al., 2016). MCDA is also expected to support deliberative multi-stakeholder processes in which participants can learn about the consequences of alternative courses of action and reflect on, and possibly revise, their preferences through interaction with other people (Garmendia and Stagl, 2010; Raymond et al., 2014; Kenter et al., 2015). A structured, step-wise MCDA process allows participants to discuss the key framing assumptions, scrutinize the knowledge base and formulate an informed judgment during the weighting stage (Stirling, 2006; Saarikoski et al., 2016). Valuation theorists have also proposed that while monetary valuation is suited for eliciting individual or consumer values, participatory MCDA can assist in the articulation of social values, including self and other-regarding values, ethical judgements and relational values through which people attribute meaning and importance to ecosystem services (Vatn, 2009; Kenter et al., 2015; Pascual et al., 2017).

However, the promise of analytical-deliberative methods such as MCDA does not always emerge in real-world policy-making with conflicting political agendas and interests (Smith, 2003; Straton et al., 2011). The collaborative learning assumption has received some empirical support (see e.g. Stagl, 2006; Antunes et al., 2011; Mavrommati et al., 2017; Lopes and Videira, 2018) but more research is needed on the role of MCDA in building shared understanding of the flows and value of ecosystem services in contested policy problems (Vatn, 2009; Langemeyer et al., 2016; Saarikoski et al., 2016; Pascual et al., 2017). The aim of this study is to analyze the participatory MCDA process from value articulation and collaborative learning perspective. We will ask whether the process assisted explication of key value differences, including social values and ethical considerations, and whether it helped the participants of this study to learn and reflect on facts and values related to peatland ecosystem services and to build shared understanding of their importance.

We first introduce the case study context in Section 2 and present the methodological approach in Section 3. In Section 4, we document the study area and scenarios (Section 4.1) and the assessment criteria (Section 4.2). After that we present estimates of the performance of the scenarios with respect to each criterion (Section 4.3), the criteria weights (Section 4.4), and finally the overall evaluation of the alternatives from different perspectives (Section 4.5). In Section 5, we discuss the key trade-offs and value positions revealed by the analysis (Section 5.1) and evaluate the role of the MCDA process in contributing to learning about values (Section 5.2) and facts (Section 5.3) related to peatland ecosystem services. The key findings are summarized in Section 6.

## 2. The context: peatland policy-making in Finland

Peatlands are an important feature of the Finnish landscape as peatlands amount to one third (9 million hectares) of the land surface in Finland (Alanen and Aapala, 2015). Two thirds of this area is drained for forestry and agriculture and around one percentage of the area is currently used for peat extraction (Ministry of Agriculture and Forestry, 2011). Over 30,000 ha of peat extraction areas have gone out of use (Ministry of Agriculture and Forestry, 2011). Around 13% of the peatlands are protected under national legislation, either as state-owned or privately-owned protected areas (Alanen and Aapala, 2015). Most of the protected peatlands are also part of the European-wide Natura 2000-network. These are mainly located in Northern Finland and cover mostly bare open peatlands. Due to the intensive conversion of peatlands for forestry and other uses, half of Finnish peatland habitats are endangered, particularly the eutrophic peatland habitats in Southern Finland, and a growing number of peatland species are becoming endangered (Alanen and Aapala, 2015).

Two major national level policy processes have addressed the conflicting uses of peatlands. A multi-stakeholder task force was established by the Ministry of Forestry and Agriculture in 2009 to prepare a national peatland strategy, which aimed to reconcile peatland-based energy production as well as forestry and agricultural activities with peatland protection and other environmental goals (Ministry of Agriculture and Forestry, 2011). The strategy was given political authority by the Government Decision-in-Principle on the Sustainable and Responsible use of Mires and Peatlands in 2012 (Government of Finland, 2012). The peatland strategy and consequent government decision recognized the need to identify the most ecologically valuable sites to be excluded from conversion into peat extraction sites as well as from forestry and agricultural use.

As a follow-up, a multi-stakeholder task force was established by the Ministry of the Environment in 2012 to prepare a Supplementary Program for Peatland Protection. As the name indicates, the aim was to find areas with high biodiversity values that could supplement the existing network of protected peatlands. The most important disagreements concerned the appropriate ways to implement the programme on private lands. At the outset, the aim of the task force, established by the Minister of the Environment from the Green Party, was to prepare a statutory nature protection program to supplement the existing network of peatlands protected under the current nature protection legislation. However, the Green Party left the government in 2014 and the new Minister of the Environment from the National Coalition Party put the Peatland Protection Program on hold to wait for the results from a landowner survey. The land owners, including the Central Union of Agricultural Producers and Forest Owners, had argued that state enforced protection would violate land owners' rights to self-determination and insisted that the program should be implemented on a voluntary basis. In 2015, the task force resumed, with a new assignment to make a proposal for nationally valuable peatlands that complemented the existing protected area network and to search for voluntary measures for their protection. The original aim to prepare a statutory protection program was renounced and replaced with a new program, called as the Proposal for Supplementing Peatland Protection (Alanen and Aapala, 2015). In 2018, the valuable peatland sites that were located on state-owned land, altogether 36,000 ha (Alanen and Aapala, 2015), were all protected. On privately owned land (80,000 ha), the protection proceeds on a voluntary basis and within the limits of the state compensation budget.

## 3. Materials and methods

### 3.1. Multi-criteria decision analysis methods

MCDA methods are used to evaluate the performance of alternative courses of action with respect to criteria that capture the key dimensions of the decision-making problem, and to consider the relative importance of these evaluation criteria in the particular decision-making context (Belton and Stewart, 2002). The following phases are typically carried out in a MCDA processes: a) identifying and structuring the problem including criteria and alternatives; b) estimating the performances of the alternatives with respect to each criterion (scoring); c) eliciting stakeholders' preferences (weighting); d) evaluating the overall performance of the alternatives with a mathematical model; and e) analyzing the sensitivity of the results to changes in the model parameters (Belton and Stewart, 2002). These phases are presented in Fig. 1.

Stakeholders and/or decision-makers are usually asked to provide the subjective weights used in the MCDA process. In participatory MCDA processes, they are increasingly involved also in defining the key framing assumptions and scoring of the alternatives (Stirling, 2006). Due to this interactive nature, the number of stakeholder representatives involved in participatory MCDA processes is usually around 10 to 20, sometimes fewer (see e.g. Proctor and Drechsler, 2006; Straton et al., 2011; Mustajoki et al., 2011). The aim is to capture all relevant perspectives on the problem under study, not to be statistically representative of the population (Aldred and Jacobs, 2000; Marttunen and Hämäläinen, 2008).

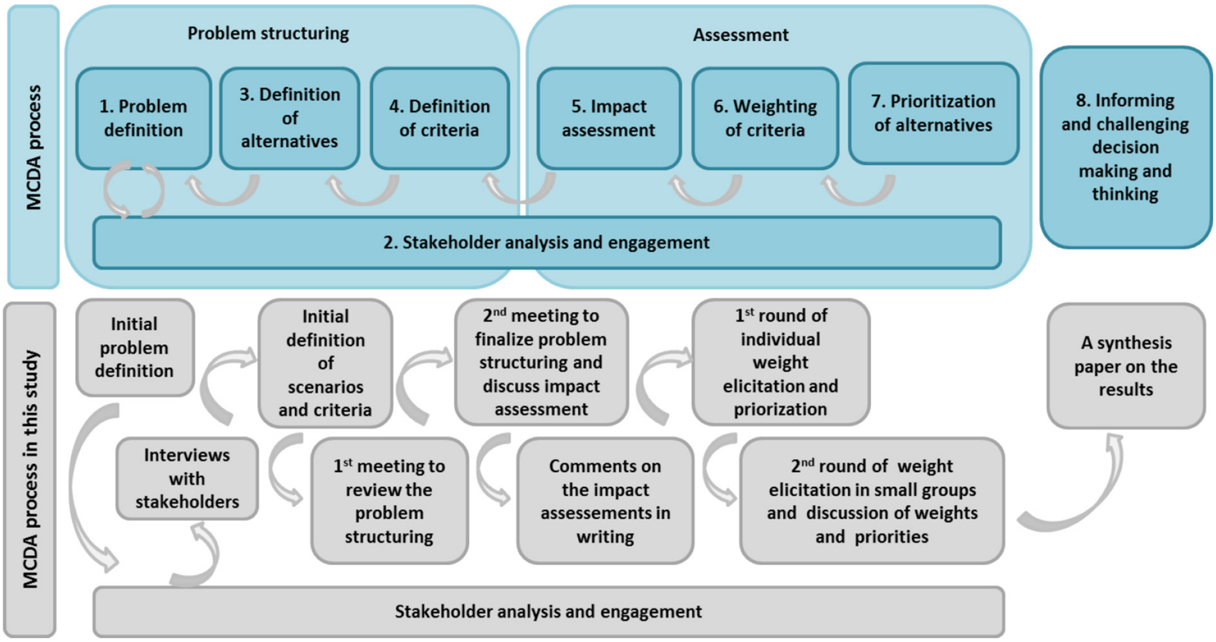


**Fig. 1.** The general steps in the MCDA process, following Belton and Stewart (2002) and Langemeyer et al. (2016), and the MCDA process in this study. The arrows in the upper picture indicate the iterative nature of the process; they are not included in the lower picture for the sake of clarity.

A large number of MCDA methods have been developed to sort, rank or evaluate decision alternatives. They all at least roughly follow the general steps presented in Fig. 1 but have different principles and procedures for eliciting and structuring information and involve different algorithms for combining it (Keisler and Linkov, 2014). In this study, we used a multi-attribute value tree analysis (MAVT), which is a relatively simple and transparent method and is hence suited to working with stakeholders (de Montis et al., 2005). According to a recent review by Langemeyer et al. (2016), value function methods such as MAVT are the most commonly used MCDA methods in ecosystem service assessments. Rank-based methods, which use an ordinal scale instead of a cardinal scale, require less cognitive effort from the participants than MAVT but they also lose some information about the relative importance of the criteria. Neither the rank-based nor the MAVT method can deal with non-compensatory attributes (e.g. spiritual values), which people are not willing to exchange for other types of attributes. Outranking methods such as the NAIADE-approach (Munda, 2004) allows adjustments to be made for the level of compensability of certain criteria but the tool lacks the possibility to use weights explicitly (Munda, 2008) and hence does not support a transparent analysis. A detailed analysis of the pros and cons of various MCDA methods in different appraisal contexts has been carried out by de Montis et al. (2005).

In MAVT, the preferences of the stakeholders are modelled with numerical weights reflecting the relative importance of the criteria. The alternatives are evaluated in terms of each lowest level criterion (i.e. attribute) using empirical studies, literature reviews or expert evaluation. Under certain assumptions (Keeney and Raiffa, 1993), an additive model can be used to obtain the overall values for each alternative by multiplying the attribute-wise performance scores with corresponding attribute weights and then summing them up. Mathematically, the overall value v(x) of alternative x is

$$v(x) = \sum_{i=1}^{n} w_i v_i(x_i)$$

where $n$ is the number of attributes, $w_i \in [0, 1]$ is the weight of attribute $i$ (so that the sum of the weights $w_i$ is 1), $x_i$ is the consequence of alternative $x$ with respect to attribute $i$, and $v_i(x_i)$ express its value on a 0–1 scale. The weight given to each attribute should reflect how important the stakeholder considers the change in this attribute from its lowest to highest consequence value compared to corresponding changes in the other attributes.

### 3.2. The MCDA process in this study

The MCDA process in this study is illustrated in Fig. 1 parallel to the basic steps in MCDA. This was a part of a multi-method valuation research project in which we used the choice experiment (CE) method, deliberative valuation workshops (citizen juries), and MCDA for peatland ecosystem service valuation. The research project started with the CE study, which necessitated scenarios that link to recent policy initiatives (Artell et al., 2017), in this case the Proposal for Supplementing Peatland Protection (Alanen and Aapala, 2015). However, the initial problem definition with a focus on biodiversity protection was extended in the MCDA process following the feedback from the participants (see Section 4.1).

The stakeholder analysis was based on the principles of the influence-interest matrix method, which distinguishes between key players (high interest, high impact), subjects (high interest, low impact), context setters (high impact, low interest) and the crowd (low interest, low impact) (Reed et al., 2009). We invited ten stakeholder representatives from the key players (relevant ministries and peat industry representatives) and subject groups (land owners, recreational users, and environmentalists) and aimed to achieve a balanced representation of stakeholders who either supported or opposed additional peatland protection. However, one environmental non-governmental organization (ENGO) declined the invitation due to their stated lack of time and personnel. The nine policy actors engaged in the process represented the central ministries (Ministry of the Environment, Ministry of Agriculture and Forestry, Ministry of Trade and Industry), peat industry, land owner organizations, ENGOs and recreational organizations. As the focus was on national level peatland policy, we did not include any local or regional level stakeholders, especially as ordinary citizens were engaged via three parallel citizen juries in the same research project. The implications of this omission are discussed in Section 5.1. The engagement of the policy actors was steered by the research team as the MCDA process had no formal links to governmental peatland policy initiatives. However, as the Proposal for Supplementing Peatland

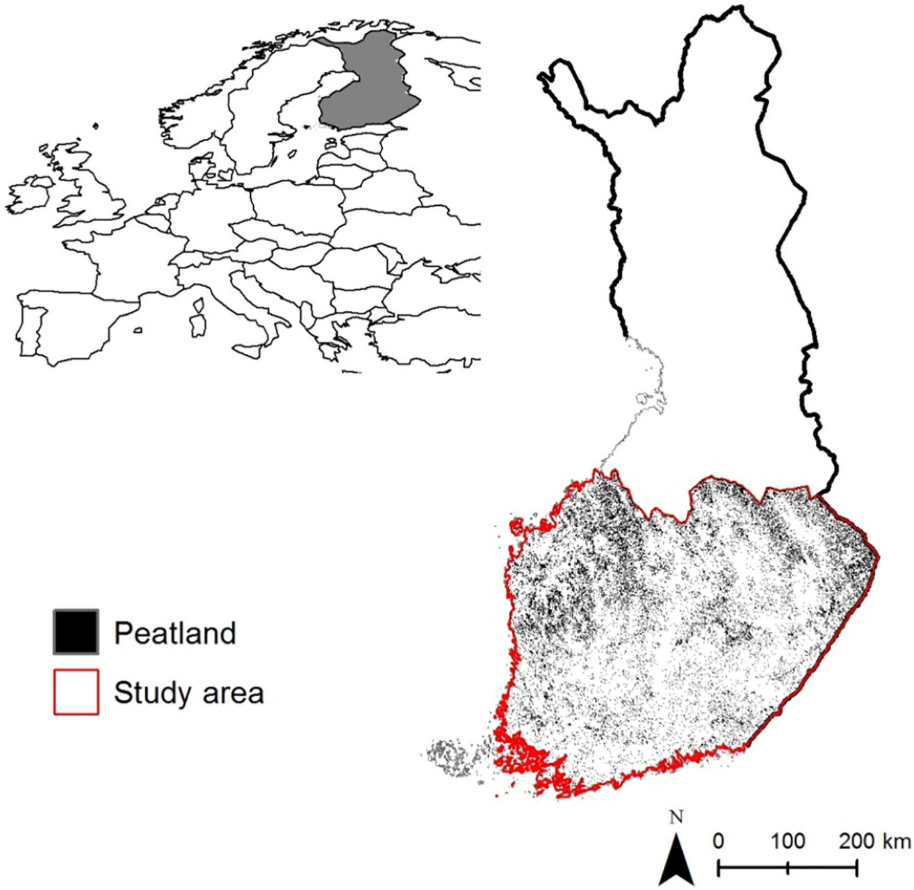


**Fig. 2.** The study area, marked in red, indicating peatlands in the study area. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Protection had just been released, the MCDA process provided one forum to continue the discussion among the stakeholders.

The MCDA process was designed as a joint problem-solving process to assist in a structured, step-wise dialogue on peatland policy alternatives and their impacts on ecosystem services and to examine the value arguments related to their importance. The stakeholder representatives were first interviewed individually to obtain an overall picture of their views and perceptions on the use and protection of peatlands (see also Primmer et al., 2018). This information was used as a starting point to prepare initial peatland scenarios and their evaluation criteria, which were discussed in the first half-day meeting with the stakeholders in September 2016. The participants produced an initial list of ecosystem services, which were mapped into CICES (2013) categories. They also requested some alterations to the scenarios (see Section 4.1).

The second half-day meeting took place in December 2016. The researchers presented the revised scenarios and criteria, which were approved by the participants. At this point, it was jointly agreed to drop some ecosystem services, such as water purification, which were not relevant in this case (see Section 4.2). The researchers also presented an initial assessment of the scenarios against the criteria, and the participants provided feedback on them. After the meeting, the research team revised the evaluations and compiled them into a background report, which was sent to the participants for written comments in February 2017. Several participants provided valuable input for the impact assessments especially at this point (see Section 5.3).

Individual decision analysis interviews (Marttunen and Hämäläinen, 2008) were carried out in spring 2017 to elicit weights that the participants would assign to the evaluation criteria. We used a computer program on a laptop (Mustajoki and Hämäläinen, 2000), which showed the results immediately, and allowed the participants to adjust the weights if the output of the analysis did not match their preferences. A sensitivity analysis was carried out to assist in this process. We also asked the participants to provide justifications for the weights that they provided and documented these (Table 4).

The initial plan was to hold a third meeting with the stakeholders to discuss the results and justifications for criteria weights. However, the results from the first round of interviews showed that we needed to add socio-economic criteria to the value tree (see Section 4.2). Consequently, we needed to carry out a new round of decision analysis interviews with the participants. This turned out to be useful because several participants stated that they fully understood the weighting procedure only during the second round of interviews (see Section 5.1). However, due to the additional interviews, we had to give up the original meeting schedule and could not find a time for a half-day meeting that would have suited all the participants before the research project ended. Therefore, we organized four separate small-group meetings with the participants, with 2–3 stakeholders with different interests and concerns in each meeting to combine the second round of interviews and discussion of the results. We first presented the results from the first round of interviews, including a summary of the justifications, and asked the participants to assign new weights for the adjusted value tree (including the socio-economic criteria) individually using separate laptops following the same procedure as before. We then projected the new set of weights on a screen and asked the participants to share the reasoning behind them. Finally, we had a brief discussion on the (possible) areas of agreement that were identified in the course of the meeting. The tone of these small-group meetings was less adversarial than the large-group meetings, but we did not ask the participants to reach a group decision on the weights (see e.g. Proctor and Drechsler,

2006) as it was clear that the participants were not comfortable with it. However, it would have been helpful to have a meeting with all the participants at the end of the process to facilitate group deliberation on the results. Research on deliberative valuation in citizen jury context has suggested that people need some time between valuation sessions to reflect on their values and preferences (Kenyon, 2007). Instead of a joint discussion, a summary of the results was circulated to the participants for written comments and published as a professional journal article (Saarikoski et al., 2019). We will discuss the implications of the shortcomings of the process in Section 5.2.

## 4. Results

### 4.1. The study area and scenarios

The study area is Southern Finland (Fig. 2) where peatlands cover around 25% of the land surface (Natural Resources Institute Finland, 2019). Aapamires (minerotrohic fens) are typical to the northern part of the study area and raised bogs elsewhere. The use of peatlands in the study area has been very extensive and of the original 3 million hectares of peatlands, over 80% have been utilized for forestry, agriculture, peat extraction or other uses. The intensive use of the peatlands reflects the fact that around 87% of the population in Finland lives in the study area.

The time horizon was until 2050 which is a relevant period from the perspective of the United Nations' Paris Climate Agreement (United Nations, 2015). The scenarios were spatially explicit, and they were constructed using CORINE Land Cover data. From the 'open and sparsely forested peatlands' class we identified all contiguous open peatlands over 10 ha (altogether 255,000 ha), and classified the unprotected peatlands (altogether 141,000 ha) into drained (56,000 ha) and pristine (85,000 ha) peatlands using databases from the Finnish Environment Institute. A minimum of 10 ha was used as a lower size limit because most commercial peat extraction sites are not smaller than this. Furthermore, such pristine peatlands in Southern Finland are valuable from both a habitat and species protection perspective. The most valuable peatlands over 10 ha identified in the Proposal for Supplementing Peatland Protection in the study area amount to 15,000 ha.

We initially constructed four scenarios, or policy alternatives, with different levels of peat extraction (Table 1). We used the term scenario to refer to the long-term (35 years) policy alternatives; the scenarios were not alternative futures as described in the scenario analysis literature (e.g. Reed et al., 2013). Scenario 4 represented business as usual (BAU) with the current amount of peat extraction. Scenario 3 assumed that the Proposal for Supplementing Peatland Protection (PSPP) would be fully implemented. The volume of peat extraction was the same as in scenario 4 (BAU), but all ecologically most valuable sites identified in the PSPP were protected. In scenario 4, the extraction sites were randomly placed across the peatlands using an ArcGis sampling design tool NOAA/Biogeography Branch), and also included also PSPP sites. In scenario 5, the level of peat extraction increased 30% and in scenario 2 the level decreased by 30%. At the latter level, it was possible to preserve all pristine peatlands over 10 ha and use only those areas that are already drained. This is because large areas of peatland were drained in the earlier years for forestry and agriculture but never used for such purposes.

The aim was to construct scenarios that echoed the calls from different stakeholders and enable them to identify with at least one scenario (see Garmendia and Gamboa, 2012). However, the original starting point was the debate surrounding the PPP and hence the focus was on biodiversity protection vs. peat extraction. In the first stakeholder meeting an environmental non-governmental organization (ENGO) representative requested a scenario in which peat extraction would be phased out completely by 2030. Therefore, we constructed scenario 1, in which no new peat mining areas would be established after 2020 and the use of energy peat would end by 2030.

**Table 1**
The scenarios and the peat extraction targets, volumes and level of conservation in them.

| Scenario | Peat extraction target | Volume of peat extraction, ha/a | Need for new extraction areas by 2050, ha | Level of conservation | Pristine peatlands, including existing protected area network, in year 2050, ha |
|---|---|---|---|---|---|
| S1: Conservation+ | Extraction will end by 2030 | 34,000 until year 2030, 0 from year 2030 | 7000 | All pristine peatlands will be protected | 200,000 |
| S2: Conservation | Extraction will decrease by 30% | 34,000 | 56,000 | All pristine peatlands will be protected | 200,000 |
| S3: Proposal for Supplementing Peatland Protection (PSPP) | Extraction will continue at the current level | 47,000 | 80,000 | All PSPP sites will be protected | 164,000 |
| S4: Business as usual (BAU) | Extraction will continue at the current level | 47,000 | 80,000 | 60% of PSPP sites will be protected | 164,000 |
| S5: Intensified peat extraction | Extraction will increase by 30% | 64,000 | 104,000 | 47% of PSPP sites will be protected | 153,000 |

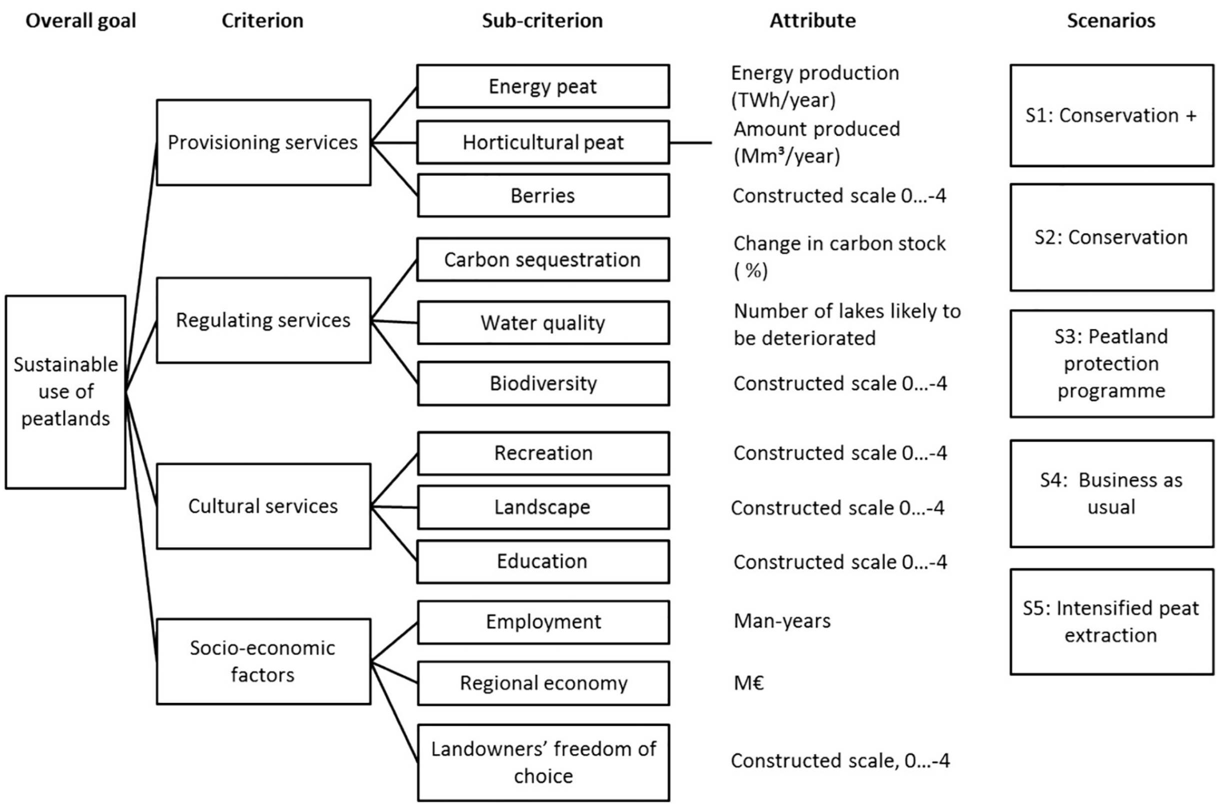


**Fig. 3.** The value tree with the scenarios, criteria and their attributes (units of measurement).

The participants representing peat extraction also provided valuable input for the scenario building phase. They pointed out that unlike the research team had assumed, peat is extracted not only from open peatlands but also from their sparsely forested fringe areas; an omission of this fact had caused a 25% mistake in the calculations of the amount of remaining pristine peatlands in each scenario. This figure served as a starting point for the estimates of cultural services as well as berry picking and biodiversity, and hence they had to be revised accordingly.

### 4.2. Definition of the criteria

The criteria according to which the scenarios were evaluated were initially ecosystem services provided by the peatland social-ecological systems. These included provisioning services (energy peat, horticultural peat and berries), regulating services (carbon stock, water quality, biodiversity) and cultural services (recreation, landscape and education) (Fig. 3). The CICES (2013) common international classification system for ecosystem services was used as a starting point to ensure that all relevant ecosystem services were considered. The initial set of ecosystem services were supplemented with socio-economic criteria that were emphasized by the stakeholder representatives in the first round of interactive decision-analysis interviews (see Section 5.3). These included the regional economy and employment as well as landowners' freedom to make decisions concerning their holdings.

In the first meeting, the participants also brought up flood prevention and water purification as important peatland ecosystem services. However, the assessment process showed that the peatlands included in the scenarios were not located near critical areas vulnerable to flooding, and the surface area was not significant for flood protection. Similarly, the role of peatlands in water purification was smaller than expected. Certain types of peatlands (minerotropic ones) do play a role in filtering phosphorous and nitrogen from waters running through them but the impact of this natural water purification on the quality of nearby water bodies is relatively small, especially compared to the nutrient emissions from peat extraction sites (Tahvanainen, 2011). The impacts on ground water were also excluded because peat extraction sites near ground water reservoirs are not permitted according to the Finnish environmental protection law.

### 4.3. Evaluation of the impacts

The impact matrix in this study is presented in Table 2. The estimate of peat extraction for energy is based on annual statistics on the volume of peat extraction ($m^3$) and the amount of peat energy (TWh) produced (Metsätilastollinen vuosikirja, 2014). The economic and employment impacts estimates are based on Piirainen et al. (2013). The estimate of horticultural peat extraction is based on Leinonen (2010) and berry picking on Roininen and Mokkila (2017). The total change in the carbon stock in 2017–2050 was estimated on the basis of carbon emissions from pristine and drained peatlands as well as the carbon content of the peat extracted in different scenarios, drawing on Kirkinen et al. (2007) and Pohjala (2014). The baseline is the current amount of carbon stored in peatlands in the study area (Minkkinen, 1999). The effect of peat extraction on water quality was estimated using specific loading coefficients per area unit (Kortelainen et al., 2006) and an estimate of the present loading, the latter was calculated with the VEMALA-model (Huttunen et al., 2016). The biodiversity impact assessment is presented in Table 3. The impacts on cultural ecosystem services were evaluated on a constructed scale from 0 (no impact) to −4 (a major negative impact), drawing on the area of pristine peatland in each scenario, relevant literature (Ojala et al., 2013) and a GIS-based accessibility analysis, which estimated the number of people living within a 5 km radius of the nearest peatland. The best option is 0 (no changes) because the supply of services such as recreation is dependent on the area of pristine peatlands, and the peat formation process (paludification) is extremely slow; no new peatland will be formed within the time frame of this study. Hence the area of peatlands available for recreation cannot increase, only remain the same.

**Table 2**
The impact matrix which presents the performance of the scenarios with respect to each criterion.

| The criteria and attributes | S1 | S2 | S3 | S4 | S5 |
|---|---|---|---|---|---|
| Energy produced with peat, TWh/year | 8[a]/0[b] | 8 | 11 | 11 | 15 |
| Horticultural peat, $Mm^3$/year | 0.7[a]/0[b] | 0,7 | 1 | 1 | 1.3 |
| Berries, constructed scale 0…-4 | 0 | 0 | −1 | −1 | −2 |
| Change in carbon stock of peatlands in Southern Finland in 2017–2050, % | −2 | −6 | −9 | −9 | −12 |
| Water quality, the number of lakes in which the water quality is likely to be deteriorated | 0 | 9 | 70 | 70 | 110 |
| Biodiversity, constructed scale 0…-4 | 0 | 0 | −1 | −2 | −4 |
| Recreation, constructed scale 0…-4 | 0 | 0 | −1 | −1 | −2 |
| Landscape, constructed scale 0…-4 | 0 | 0 | −1 | −1 | −2 |
| Environmental education, constructed scale 0…-4 | 0 | 0 | −1 | −1 | −2 |
| Increment value from peat extraction, incl. multiplicative effects from intermediate products, M€/year | 100[a] 0[b] | 100 | 140 | 140 | 190 |
| Employment in peat extraction, man-years, incl. multiplicative effects from intermediate products | 1500[a] 0[b] | 1500 | 2100 | 2100 | 2900 |
| Landowners' freedom of choice, constructed scale 0…-4 | −3 | −3 | −2 | 0 | 0 |

Scale: 0 = no changes (or very minor changes) −3 = large negative impacts.
−1 = small negative impacts −4 = very large negative impacts.
−2 = quite large negative impacts.
[a] Until year 2030.
[b] From 2030 on.

### 4.4. Weighting of criteria

The criteria weights, i.e. the relative importance of the range of variation in each criterion, were elicited via two rounds of interactive decision analysis interviews (Marttunen and Hämäläinen, 2008) with the stakeholder representatives in spring 2017. We used a swing method (von Winterfeldt and Edwards, 1986), in which the interviewees were asked which swing, i.e. change from the worst value to the best value for each criterion, would provide the greatest increase in overall value; this criterion was then awarded the highest point (100). This process was repeated for the remaining set of criteria, the importance of which was compared to the most important one. The final weights were obtained by normalizing the sum of the given points to 1. An overview of the criteria weights in the first (without the socioeconomic criteria) and second round (with the socioeconomic criteria) for each interviewee are presented in Fig. 4 and the interviewees' justifications for low and high criteria weights are summarized in Table 4.

### 4.5. Ranking of the scenarios

In order to obtain an overall evaluation of each alternative, we used a value function method which combines an assessment of the performance of alternatives with information about the criteria weights (Belton and Stewart, 2002). The criteria-wise performance scores were calculated by using the impact matrix (Table 2) and local scales: The alternative which did best on a particular criterion was assigned a score of 100 and the one which did the least well was assigned a score of 0.

**Table 3**
Biodiversity impacts in different scenarios on a scale of 0 (no changes) … -4 (very large negative impacts).

| Scenario | Mire habitat and mire complex types | Mire species | Score |
|---|---|---|---|
| S1 and S2 | The full implementation of the Proposal for Supplementing Peatland Protection (PSPP) improves the representativeness of the current protected area (PA) network for habitats and species of raised bogs and southern aapamires. The decline of threatened mire habitats and complex types slows down. The area of undrained raised bogs and aapamires does not decrease due to peat extraction. Mire habitat types typical to the central parts of raised bogs (*Sphagnum fuscum* bogs and ridge-hollow pine bogs) do not decline. No significant effect on habitat types typical for the margin parts of raised bogs and aapamires. | Localities of threatened mire species in undrained raised bogs and aapamires do not disappear due to peat extraction. The decline of threatened species typical to these mire complex types slows down. | 0 |
| S3 | The full implementation of the PSPP improves the representativeness of the current protected area (PA) network for habitats and species of raised bogs and southern aapamires. The area of undrained raised bogs and aapamires outside the PSPP and PA network decreases by 42% due to peat extraction. Decline of threatened mire habitat and complex types continues. Mire habitat types typical to the central parts of raised bogs (*Sphagnum fuscum* bogs and ridge-hollow pine bogs) may become threatened. The decline of already threatened habitat types in both raised bogs and aapamires may increase. | Some of the localities of threatened mire species in undrained raised bogs and aapamires may disappear due to peat extraction. | −1 |
| S4 | The area of raised bogs in the PSPP decreases approximately 40% and that of aapamires 50%. In addition the area of other undrained peatlands outside the PA network decreases by approximately 43% due to peat extraction. In total, the area of all undrained peatlands outside the PA network decreases by 42%. The decline of raised bogs and aapamires continues. Mire habitat types typical to the central parts of raised bogs (*Sphagnum fuscum* bogs and ridge-hollow pine bogs) may become threatened. The decline of already threatened habitat types of both raised bogs and aapamires may increase. | Clearly more localities of threatened mire species in undrained raised bogs and aapamires may disappear due to peat extraction than in scenario S3. | −2 |
| S5 | 64% of the area of undrained raised bogs and aapamires disappear, including 53% of the area of the PSPP sites. The decline of raised bogs and aapamires accelerates. The decline of habitat types typical to the central parts of raised bogs and aapamires accelerates. The decline of habitat types typical of the margin parts of raised bogs and aapamires may continue. | A lot of the localities of threatened mire species in undrained raised bogs and aapamires disappear due to peat extraction. The decline of threatened species typical to these mire complex types accelerates. | −4 |

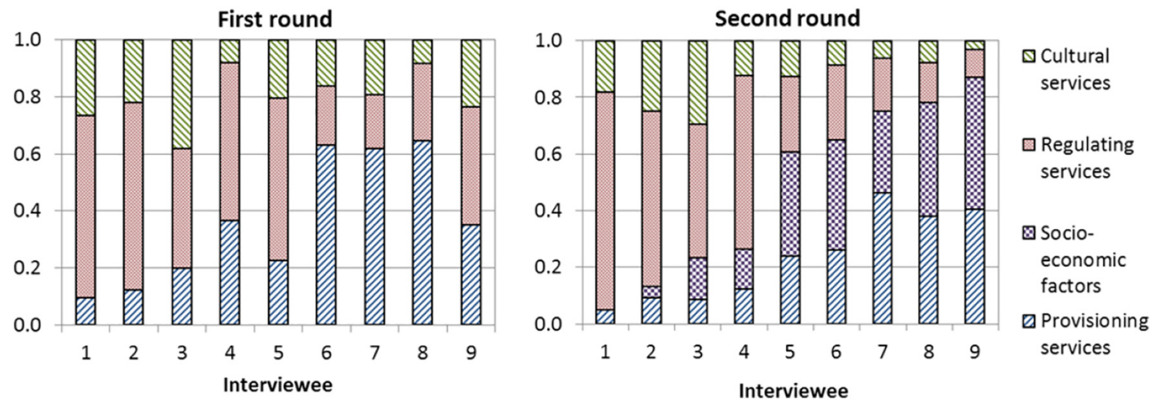


**Fig. 4.** The weights that each interviewee assigned to cultural, regulating and provisioning services during the first (left) and the second round (right) of the interactive decision analysis interviews. Socio-economic factors were included in the value tree used in the second round.

**Table 4**
The justifications by the interviewees for high and low criteria weights.

| Criteria | Justification for a high weight | Justification for a low weight |
|---|---|---|
| Energy peat | It is a domestic and secure source of energy, which can replace fossil fuels and be used as a supporting fuel in power plants using forest-based bioenergy. | We need to give up the fossil economy and invest in new energy technologies to combat climate change, which is the biggest global challenge of our times. |
| Horticultural peat | There is a growing market for these peat products in green construction and gardening. | Horticultural peat extraction is not economically viable in Finland without energy peat extraction; the former leads to the latter. |
| Berries | Berry picking is an outdoor activity which maintains physical and mental health. | Most of the berry-yields remain under-utilized even at the moment. |
| Climate regulation | Peatlands don't play a major role in climate regulation. | Peatlands are a globally important carbon sink. |
| Biodiversity | Extinction of endangered peatland species is irreversible and hence depletes the nature heritage of future generations. | Biodiversity can be revived by restoring old peat extraction sites. |
| Water quality | The good status of water bodies is important for drinking water and recreational activities such as fishing and swimming. | Peat mining areas use the best available technology and cause very few emissions compared to forestry and agriculture |
| Cultural ecosystem services | Peatlands are aesthetically pleasing and part of the Finnish national landscape. They are important for local inhabitants as well as for people with recreational houses near pristine peatlands. | The scenarios have a relatively low impact on recreational activities, landscape and education. |
| Regional economy and employment | These are important factors for human well-being. | New jobs and economic activities in rural areas could be generated in the forest bioenergy sector replacing peat mining activities. The estimates focus only on peat extraction and do not take into account the increasing economic role of nature-based tourism. |
| Land owner's freedom of choice | The protection of private ownership is a constitutional right. | No-one has the right to destroy biodiversity and landscapes that are common property to be passed on to future generations. |

We assumed that the value functions were linear, that is, an increase of one unit in the measurement value of the criterion would give the same additional value on all parts of the scale. The results were calculated by using an additive model which multiplies the criteria-wise performance scores with corresponding criteria weights and sums them up (Belton and Stewart, 2002).

The overall evaluation of the scenarios for each interviewee in the second round is presented in Fig. 5. The nine interviews resulted in an equal number of preference models, which were grouped into four clusters according to the preference order of the alternatives (Fig. 6). In this figure, we have presented four overall rankings of the scenarios given by four interviewees who are representative of their cluster. We were not interested in average rankings but in the range of variation as well as the arguments and value statements behind the criteria weights (Table 4).

The interviewees who were identified as belonging to Group 1 gave a lot of weight to regulating services and some weight to cultural services, and hardly any weight to peat extraction and the related socio-economic factors. Consequently, for this group, the scenarios were better the less peat extraction they included. Group 2 has a fairly similar preference structure compared to Group 1 but they gave a little more weight to peat extraction, especially horticultural peat, and the related employment and regional economy impacts, and hence this group favored scenarios 1 and 2 equally. Group 3 emphasized provisioning services and the related socio-economic factors but gave quite a high weight also to regulating and cultural services. Therefore they preferred the middle scenarios. Group 4 placed a lot of emphasis on peat extraction and the related socio-economic factors and therefore they preferred the scenarios with the highest level of peat extraction.

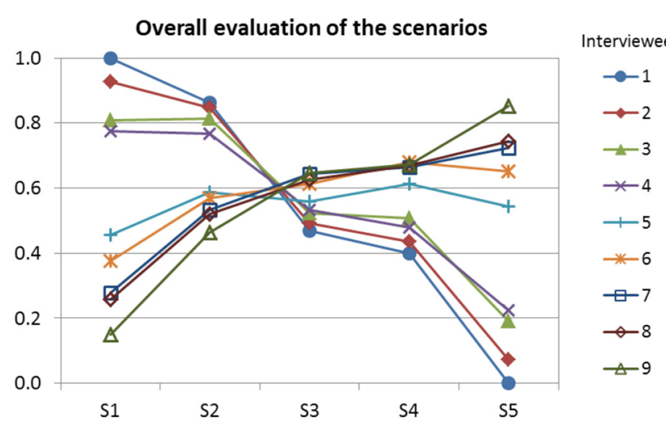


**Fig. 5.** Overall scores and the preference order of the scenarios for each interviewee.

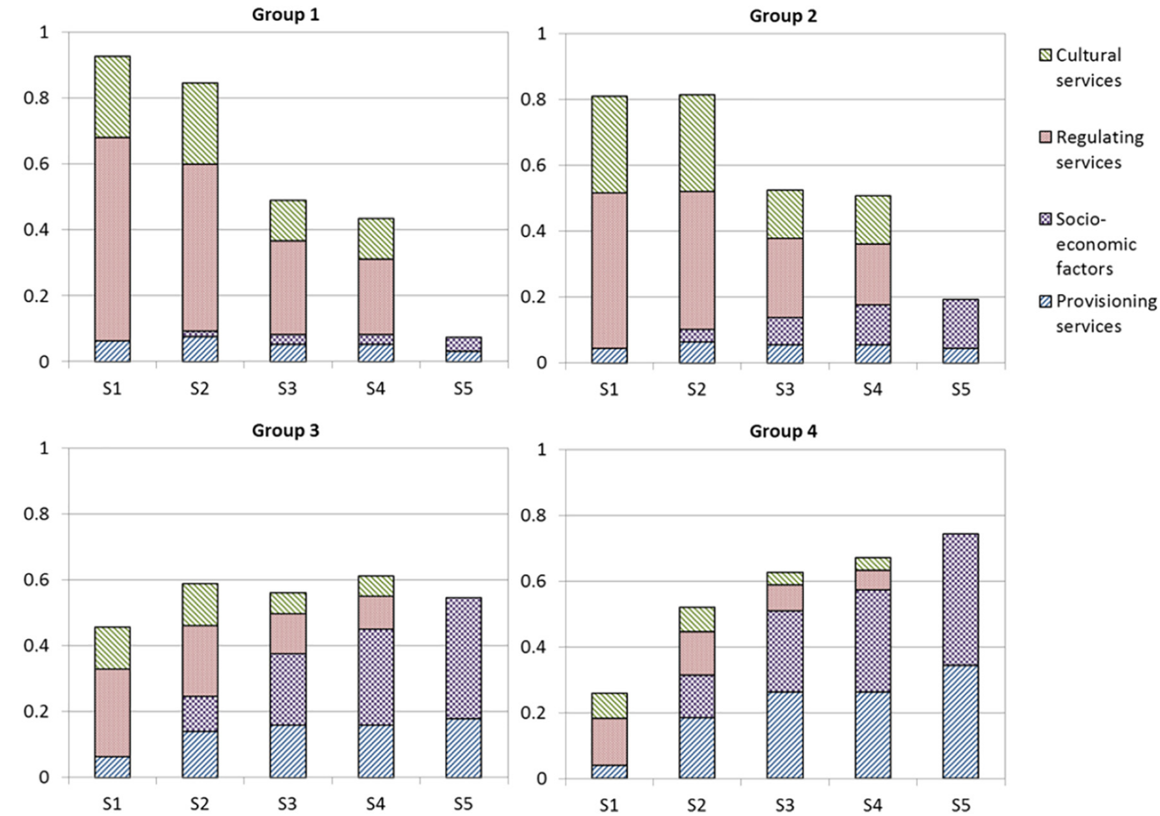


**Fig. 6.** A ranking of the scenarios by four different interviewees, whose rankings are typical examples of a group of interviewees with a similar preference structure.

## 5. Discussion

### 5.1. The trade-offs and value positions in the peatland debate

The analysis suggests that it is basically possible to accommodate the current level of energy and horticultural peat extraction with the protection of all pristine peatland sites over 10 ha by directing all new peat extraction sites to peatlands that are already drained and hence have already lost their ecological values. This would help to reconcile peat extraction and the protection of biodiversity as well as related amenity and recreational benefits from undrained peatlands. However, the conflict between peat extraction and preserving the long-term carbon store is irreconcilable. Peat is essentially a fossil resource whose utilization increases net carbon emissions. No significant carbon storage to replace the lost carbon content will take place in peatlands within the time frame of the Paris climate convention target year of 2050. The water quality impacts could be, in principle, be minimized by using the best available techniques, but zero emission peat extraction is not currently available and hence also the trade-off between water quality and peat extraction and the related amenity values cannot be erased.

The analysis demonstrates that the value positions are highly polarized as some interviewees gave nearly all the weight to regulating services and hardly any weight to peat provisioning services while others emphasized mainly peat provisioning services and the related socio-economic factors. As a consequence, the interviewees advocated diametrically opposite strategies, either to give up peat extraction altogether (scenario 1), or to increase it considerably (scenario 5). However, some participants adopted a more balanced approach and endorsed the middle positions, which allowed a mix of peat extraction and peatland protection. All participants evoked shared social values in support of their criteria weightings. The participants who stressed regulating services pointed out their vital importance to humans whose well-being is ultimately dependent on climate stability and planetary life-support systems. The participants who emphasized provisioning services also justified their position with arguments of human well-being but focused on the welfare effects of employment and economic security. The participants also used ethical arguments and referred to transcendental values (Kenter et al., 2015) in either defending the existence and bequest value of biodiversity, or the constitutional rights of landowner to make decisions concerning their holdings.

Somewhat surprisingly, none of the stakeholders gave much weight to cultural ecosystem services. Even the representative of an outdoor recreational organization gave more weight to regulating services than cultural services, arguing that s/he wanted to adopt a global perspective and emphasized climate change and biodiversity loss rather than local amenity values. However, the recreational aspect was strongly included in the water quality criterion (swimming, fishing, canoeing, etc.), which received a lot of weight from most interviewees. Another reason for the relatively low weight of cultural services was that the scenario analysis carried out at the level of Southern Finland diluted" the impacts on particular peatland areas and encouraged the participants to consider the recreational and landscape values in terms of percentages and average travel distances to pristine peatlands, keeping in mind the existing network of protected areas and recreational sites. Had the analysis named and described the specific peatlands to be drained and mined in each scenario, it is likely that some interviewees would have given cultural services a much higher weight, especially if the peat extraction plans had been strongly opposed by local residents (see Albrecht and Ratamäki, 2016). Furthermore, the place-specificity of cultural ecosystem services could have received more attention if the process had included regional level land use planners who were more sensitized to local debates. Hence, the low weight of cultural ecosystem services in this study might reflect shortcomings in the representation of interests in the process.

### 5.2. Learning about values

The interests and values that the participants expressed in the interviews in at the outset of the process did not change markedly, if at all, throughout the process, and the weights given in the first and second interviews remained relatively stable (Fig. 4). Several participants gave much less weight to peat provisioning services in the second round of interviews, but this did not reflect a change of preferences, but rather that the first value tree did not include the employment or regional economy impacts of peat extraction. The modified model included these factors which the participants had implicitly valued when giving a high weight to peat extraction during the first round of interviews. There was also some variation in the other criteria weights but according to the interviewees, the primary reason was that they found the weighting process very challenging and struggled with it especially during the first round. An exception was one interviewee whose preferences were markedly different in the first and second round of interviews. Most likely, this interviewee expressed his/hers personal weights during the first individual interview and put forward organizational weights during the second interview in a small-group setting.

We also did not observe any notable convergence of views or discovery of shared values in the meetings as a result of give-and-take of arguments. This observation diverges from the learning hypothesis (e.g. Raymond et al., 2014) and agrees more with Soma and Vatn (2010), who have pointed out that people adhering to certain stakeholder groups are less likely to deliberate and change their opinions during a dialogue. Stakeholder representatives are also constrained by the agenda of their organizations and constituents, which restricts the scope for genuine dialogue and individual learning. MCDA processes which have generated consensus or convergence of the relative values of ecosystem services have usually involved citizens (e.g. Stagl, 2006; Mavrommati et al., 2017) or management practitioners (Proctor and Drechsler, 2006).

According to Raymond et al. (2014), it is substantially more challenging to achieve consensus on the social values provided by ecosystem services across diverse representations of interests and concerns than within a social representation. They maintain that effective facilitation and communication can lead to negotiation and compromise or consensus also across different interest groups (see also Forester, 1999) but this kind of process requires time and serious commitment from the participants. In this case, the organization and length of the process steered by the researchers did not provide adequate time and institutional support for learning and reflection on values and interests. As the literature on collaborative environmental governance indicates, a more extensive process and a stronger motivation—preferably a direct link to the actual decision-making process—would have been needed to engage the participants in a serious effort to uncover some common ground (see e.g. Smith, 2003).

However, in some instances the interactive decision analysis interviews helped the participants to scrutinize their own interests and understand them better. For example, one interviewee initially gave a very low weight to all regulating and cultural services and a high weight to provisioning services but was not happy with the output of the analysis, which indicated the most intensive peat extraction scenario as the most preferable one. When probed for reasons why s/he preferred less intensive peat extraction, s/he referred to the loss of pristine peatlands (around 30% in scenario 5) which s/he considered far too high from a biodiversity perspective. S/he then went back and changed the initial weight on biodiversity, which s/he did not value so much in general but did value in this particular context. This example links to the observation by Belton and Stewart (2002) according to which people tend to essentially express the same ratio of importance for one criterion relative to another, irrespective of the context of the specific decision problem. The interviewees struggled with keeping in mind the range of variation under each criterion and reverted to heuristics when facing the cognitive challenge of weighting.

Also the small-group discussions during the second round of interviews created some common ground. The tone of these meetings was more cooperative than of the large group meetings and therefore it was more conducive to constructive dialogue. For example, some participants who placed a lot of emphasis on employment from energy peat extraction acknowledged the argument that nature-based tourism relying on pristine peatlands has the potential to create jobs in the future. Interestingly, the participants representing the peat industry pointed out that energy peat will gradually be replaced by horticultural peat as well as new peat products such as activated carbon and fiberboard, which are far less material intensive. It seems that the participants were not ready to reflect on their positions concerning peatland protection—a topic of recent intensive debate—but they could have found some shared understanding on innovative uses of peatlands for the future. For collaborative learning purposes, then, it might have been more helpful to focus on desirable futures and new pathways to reach them (see e.g. Reed et al., 2013) instead of anchoring the MCDA to the contested Proposal for Supplementing Peatland Protection.

### 5.3. Learning about facts

The most important learning in the MCDA process took place in relation to structuring the problem and the assessment of the impacts of the scenarios on ecosystem service delivery. As pointed out earlier, the shortcomings of the initial value tree, which followed the ecosystem service framework, become evident in the first round of decision analysis interviews, in which the participants favoring peat extraction scenarios found it difficult to express their preferences via a model where a single service from peat extraction (peat provisioning) was juxtaposed with seven services provided by pristine peatlands.

One could, of course, argue that the analysis following the ecosystem service framework aptly illustrates that one has to assign disproportionately high weight to peat provisioning services to compensate for the multiple regulating and cultural services from pristine peatlands. However, the provisioning service 'energy and horticultural peat' did not sufficiently capture the range of benefits from peat extraction. The participants who gave a lot of weight to the 'peat' criterion implicitly considered jobs and stable economic development in rural areas and they found it helpful that these were explicitly included in the value tree in the second round. Additionally, the actors who did not assign a great deal of value to these factors acknowledged that their inclusion made the assessment more policy-relevant and provided a 'reality-check', as one participant formulated it. For the same reason, all participants agreed on the relevance of the 'landowners' freedom of choice' criterion, which determined the fate of the Supplementary Programme for Peatland Protection. A similar choice is made by Proctor and Drechsler (2006), whose multicriteria evaluation on recreation and tourism activities in a catchment area in Australia covered ecosystem services criteria as well as social criteria (e.g. public access and jobs) and economic criteria (costs and benefits).

Stakeholders are often engaged in an MCDA process to give subjective criteria weights but they can also play an important role in defining the key framing assumptions and providing the factual grounds for the assessment (Stirling, 2006; Failing et al., 2007; Saarikoski et al., 2013). In this case, the ENGO participants contributed significantly to the scenario building exercise by initiating a new scenario (scenario 1), in which peat extraction would be completely phased out by 2030. They also provided citizen observation data which showed that the water quality impacts from peat mining sites could be considerably higher in exceptional circumstances such as overflows due to heavy rain than the ones calculated on the basis of average loading coefficients. The accuracy of this factual claim was later confirmed by freshwater scientists. Another important modification came from a peat industry representative who noted that peat is extracted not only from open peatlands but also from sparsely forested fringe areas of peatlands. This lack of technical knowledge by the research team comprised of ecologists, modelers and social scientists caused an initial error of 2% (which was corrected in the course of the assessment) in the estimates of biodiversity and cultural ecosystem services, which were based on hectares of pristine peatlands in each scenario.

The process also helped to draw attention to some frequently repeated but unfounded assumptions concerning peatland ecosystem services. In the first stakeholder meeting, some participants argued that peat is a (slowly) renewable biofuel and that the net carbon emissions from peat burning are uncertain because pristine peatlands are a source of methane, which is a much stronger greenhouse gas than carbon dioxide released from peat burning. Other participants maintained that peatlands play an important role in flood protection and water purification. These arguments were not used by the interviewees towards the end of the process, which can be interpreted as a sign of factual learning. It does not mean, however, that the participants would have encountered this new knowledge and adopted it only during this assessment process. Instead, it is likely that they (un)intentionally reverted to standard argumentative repertoires at the beginning of the process but could not sustain them in the face of quantitative, research-based evidence which quite unequivocally invalidated them. For instance, it is an undeniable fact that the methane emissions from undrained peatlands are insignificant compared to the store of carbon that is accumulated in peatlands over thousands of years (e.g. Joosten et al., 2016). Furthermore, the greenhouse gas emissions from peat extraction sites are far higher than from pristine peatlands (Kirkinen et al., 2007), a fact that came as a surprise to most interviewees. In a similar way, the evidence is quite conclusive that individual peatlands do not play such a big role in flood protection and water purification as is often expected (see Section 3.3).

Despite some signs of factual learning, the MCDA process did not succeed in creating a shared understanding of all the impacts of peat extraction on ecosystem services. As observed in the decision analysis interviews, some participants gave a low weight to criteria such as water quality and carbon stock and also to the regional economy and employment, not because they considered them as unimportant but because they maintained that the scenarios did not have significant (or any) impacts on these criteria (Table 2). By doing this, they indirectly dismissed the impact assessments, which indicated that water quality in more than 100 lakes would deteriorate in scenario 5. One explanation for this is that people tend to cope with a cognitive dissonance by ignoring or denying information that contradicts their existing beliefs and values (Festinger, 1962).

## 6. Conclusions

The participatory MCDA process was effective in structuring the peatland debate along cognitive and value dimensions. It supported a systematic scrutiny of the key aspects in the peatland debate and brought to light the most important trade-offs, namely the conflict between peat extraction and the carbon stock as well as water quality impacts. It also highlighted the areas of convergence by demonstrating that it is basically possible to accommodate the current level of peat extraction with the protection of all remaining pristine peatland sites. The assessment also assisted an articulation of the interests, values and ethical judgements pertaining to the problem situation. It brought up the clash between two ethical positions, one emphasizing the constitutional rights of land-owners to retain their self-determination, and the other highlighting the rights of current and future generations to enjoy common environmental benefits such as clear water bodies and species richness. Furthermore, it juxtaposed the arguments concerning the local human well-being effects (employment and stable rural development) related to peat extraction with the global human well-being effects related to climate stability and protection of biodiversity.

The process facilitated cognitive learning and the co-creation of knowledge on the flows of peatland ecosystem services. The participants made an important contribution to the impact assessment process by exposing the shortcomings of mathematical water quality models and by providing a practice-based understanding of peat mining procedures as well as the quality of water bodies. These experiences align with arguments about the importance of transdisciplinarity in integrated ecosystem service assessment (McKenzie et al., 2014; Saarikoski et al., 2018) and sustainability assessments in general (Lang et al., 2012).

The role of the MCDA process in promoting social learning and value reflection was smaller than expected. It was helpful in illustrating value differences but not in reconciling them. This is partly because social learning between stakeholders with vested interests is more challenging than sometimes assumed; in this case partially because the design, length and status of the process did not provide adequate support for learning across diverse representations of interests and concerns. In particular, the experiment would have benefitted from additional time to discuss the value arguments and their justifications at the end of the process. Additionally, a training session for the participants on the method, especially the weighting procedure, would have been helpful. Further research is needed on MCDA that combines insights from transdisciplinarity, environmental mediation, participatory scenario development and deliberative valuation in fostering new ideas and shared visions on the sustainable use of ecosystem services.

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