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Discussions

A decision analysis framework for stakeholder involvement and learning in groundwater management

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Abstract

Multi-criteria decision analysis (MCDA) methods are increasingly used to facilitate both rigorous analysis and stakeholder involvement in natural and water resource planning. Decision making in that context is often complex and multi-faceted with numerous trade-offs between social, environmental and economic impacts. However, practical applications of decision-support methods are often too technically oriented and hard to use, understand or interpret for all participants. The learning of participants in these processes is seldom examined, even though successful deliberation depends on learning. This paper analyzes the potential of an interactive MCDA framework, the decision analysis interview (DAI) approach, for facilitating stakeholder involvement and learning in groundwater management. It evaluates the results of an MCDA process in assessing land-use management alternatives in a Finnish esker aquifer area where conflicting land uses affect the groundwater body and dependent ecosystems. In the assessment process, emphasis was placed on the interactive role of the MCDA tool in facilitating stakeholder participation and learning. The results confirmed that the structured decision analysis framework can foster learning and collaboration in a process where disputes and diverse interests are represented. Computer-aided interviews helped the participants to see how their preferences affected the desirability and ranking of alternatives. During the process, the participants' knowledge and preferences evolved as they assess their initial knowledge with the help of fresh scientific information. The decision analysis process led to the opening of a dialogue, showing the overall picture of the problem context, and the critical issues for the further process.

1 Introduction

Groundwater resources are facing increasing pressure from land use and water abstraction. There is evidence of dramatic changes in aquifer water resources (Wada et al., 2010). However, public awareness of groundwater resources, groundwater dependent ecosystems (GDEs) and problems related to the pollution and decline of groundwater levels is still surprisingly poor (Kløve et al., 2011a,b).

Due to the high degree of complexity and uncertainty in groundwater management, a combination of thorough analysis and informed deliberation is clearly useful and important for policy formulation. Generally, the need for interdisciplinary and participatory processes combining scientific and local knowledge in environmental research and planning is widely acknowledged in environmental, natural resource and water governance (e.g. Renn, 2006; Silva et al., 2010; Pahl-Wostl et al., 2010).

Multi-criteria decision analysis (MCDA) has increasingly been used as a methodology for fusing available scientific and technical information with stakeholder knowledge and values to support decisions in many fields including natural resources and environment management (Belton and Stewart, 2002). There is a wide range of MCDA applications covering different fields of natural resource management and environmental planning (for references and earlier reviews see, e.g. Keefer et al., 2004; Kiker et al., 2005; Hajkowicz and Collins, 2007; Kangas et al., 2008; Huang et al., 2011). MCDA is increasingly used to support stakeholder participation in environmental and natural resource planning, and experiences from many participatory MCDA applications have been positive (e.g. Pykäläinen et al., 1999; Qureshi and Harrison, 2001; Regan et al., 2007; Hajkowicz and Collins, 2007; Munda, 2008; Marttunen and Hämäläinen, 2008). There is also a fairly rich body of literature related to the use of multi-criteria analysis (MCA) or MCDA in participatory water resource management projects (Brown et al., 2001; Hostmann et al., 2005a,b; Messner et al., 2006; Hajkowicz and Collins, 2007; Salgado et al., 2009; Calizaya et al., 2010; Silva et al., 2010; Straton et al., 2011). A structured multi-stakeholder decision-making (SDM) approach was developed and extensively used in water-use planning in British Columbia (Gregory and Failing, 2002; Failing et al., 2007; Gregory et al., 2012). Multi-criteria methods have often been applied to the analysis of groundwater management, mostly in the form of multi-objective optimization (e.g. Willis and Liu, 1984; Yazicigil, 1990; Duckstein et al., 1994; Yang et al., 2001; Almasri and Kaluarachchi, 2005). However, with a few

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exceptions (e.g. McPhee and Yeh, 2004), decision analysis has been restricted to the assessment of trade-offs among the selected objectives and to the determination of nondominated solutions (Pareto set), and the approaches have not been interactive or participatory (as they have omitted the explicit inference of the stakeholders' preferences).

The use of MCDA in a participatory way is a challenging task requiring careful design and expertise related to the methodology and process (Sparrevik et al., 2011). Many problems have been identified, including the need for transparent and easily applied methods for engaging stakeholders and for developing a robust decision model that accounts for the time and resource constraints experienced by practitioners attempting real-life MCDA applications (Huang et al., 2011). It is said that successful deliberation as part of the decision analysis approach depends on learning, "which in turn depends on the ability of those leading the process to create an environment that fosters dialogue, questioning, and self-reflection" (Gregory et al., 2012, p. 246). This behavioral and learning viewpoint is important when applying any decision analysis framework. The process should be planned in a way that all of the participants can fully understand the reasoning and results. However, practical applications of decision-support methods are often too technically oriented and hard to use, understand or interpret (Kangas et al., 2008). The learning aspect has been mentioned in many papers on MCDA (e.g. Kangas et al., 2001) but not systematically studied in practice.

This paper analyzes the potential of interactive MCDA – especially the decision analysis interview (DAI) approach (Marttunen and Hämäläinen, 2008) – for facilitating stakeholder involvement and learning in groundwater management. It evaluates the results of an MCDA process conducted for the Rokua esker aquifer in Northern Finland. The disturbance of the system's water dynamics by human activity is leading to the loss of ecosystem goods and services, affecting recreation and other associated activities in the area. The MCDA started a process, in association with stakeholder groups, to find out ecologically sustainable, economically feasible and socially acceptable options for

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sustainable land-use management of the esker area and to evaluate these alternatives systematically and transparently.

The main objective of this paper is to evaluate the usefulness of the MCDA process in sustainable land-use and groundwater management in the Rokua case. The questions to be answered include: Did the process facilitate stakeholder involvement and learning among the participants? What was the benefit of the interactive MCDA process for the land-use planning in the area? Was the process successful in enhancing the conditions for learning (meaningful participation and dialogue among participating stakeholders) and in fostering learning (especially a common understanding of the problem)?

2 The case study: land use in the Rokua esker area in Finland

The Rokua esker aquifer is one of the largest groundwater bodies in Finland with an area of 139 km^2, of which 92 km^2 is groundwater recharge area (Fig. 1). Aquifer thickness varies from 30 to 100 m and consists of sand and local deposits of gravel. The esker is protected under the European Union's Natura 2000 network and contains a national park. The Rokua esker aquifer is an example of unique dune formations caused by the wind and fluvial and coastal currents as well as deep depressions and kettle lakes formed by the preferential melting of ice. Among the area's key ecosystems are the crystal clear, oligotrophic, groundwater-dependent kettle lakes. Recently, Rokua was also introduced as a member of the UNESCO Geoparks Network. It is a popular recreation area and holiday resort with hotels and second homes. The economic impact of the annual 120 000 tourists (mainly hikers and cross-country skiers) on the local economy is significant (Jurvakainen, 2007).

As in most inland eskers in Finland, the Rokua groundwater system is unconfined in the recharge zone. It discharges into peatlands, where peat confines the groundwater. These peatlands have been used for forestry, peat extraction and, on a smaller scale, agriculture. In the past, Finnish water management did not consider drainage in the groundwater discharge zone as a threat to the esker aquifer. Drainage for forestry was

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supported by government subsidies and conducted on a large scale from the 1950s to 1980s. Possible environmental impacts of this practice were studied and noticed only later (e.g. Kløve et al., 2011a). Currently, drainage of pristine peatlands is rare, but poorly functioning drainage systems are enhanced by drainage improvements (i.e. the reopening of filled ditches).

At Rokua, groundwater-dependent lake levels were observed to decline after a drought period in the 1980s, and the same decline was also repeated after later dry seasons. The need for research in the Rokua area was catalyzed by a dry period in the 2000s, when the water level of the Rokua lakes and groundwater were, as in the 1980s, again substantially declining. At this point, several factors were indicated as the reason for the decline, including forestry ditches and the nearby peat harvesting area. Intensive hydrogeological studies of the Rokua groundwater system started in 2008. Thus far, the studies have shown that the groundwater level and the dependent lake levels are closely related to annual changes in precipitation and evapotranspiration. After a dry period, the groundwater levels declined for several years, whereas high precipitation periods again gradually raised the water levels. However, studies have also suggested a slower, longer-term decline in the Rokua water levels. This decline could not be explained by climate conditions, as effective precipitation (precipitation – evapotranspiration) has increased during the 30 yr reference period from 1980 to 2010.

According to a study by Rossi et al. (2012) and the first tentative groundwater flow model, the anticlinal Rokua esker groundwater discharge zone conditions were dependent on land use. Therefore, drainage (either for forestry, peat extraction or agriculture) of peatland is likely to be one of the reasons for the long-term decline of the Rokua groundwater level. As the study results are still uncertain concerning how much the discharge zone conditions actually affect the esker groundwater level, precautionary principles should be applied in the Rokua area until more exact scientific evidence is available.

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The EU Groundwater Directive states that the quantitative and qualitative deterioration of groundwater should be prevented. However, public awareness of the problems relating to the decline in groundwater level is in many cases poor among the EU member states (Kløve et al., 2011a,b). The same problem concerns the Rokua esker area, as public knowledge of groundwater is limited. In Rokua, groundwater is the connecting factor between the surface waters, i.e. the esker lakes and the streams and ditches within the peatland discharge area. Accusations among various stakeholders concerning the reasons for the water level decline during the 2000s have increased tensions between the different stakeholder groups in the area. To open the discussion between the stakeholders on the role of different land uses and their impacts on the Rokua water levels, up-to-date knowledge on groundwater should be distributed. For this reason, the decision analysis tool used in this study was also simultaneously used as a learning tool.

3 Methodology

3.1 The role of MCDA in stakeholder participation and learning

Increased attention has been paid to the importance of learning in supporting collaborative environmental and natural resource management (e.g. Pahl-Wostl et al., 2010). However, there are multiple, contradictory and confusing definitions of learning. For example, social learning is becoming a normative goal in natural resource management, even though as a concept it has a number of definitions and it is often confused with the conditions necessary to facilitate social learning, such as stakeholder participation. Furthermore, the difference between individual and social learning is rarely made (Reed et al., 2010). According to Armitage et al. (2007), "ongoing efforts to link learning and collaboration will require further specificity and clarity in terms of the different definitions and meanings ascribed to learning".

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Despite a rapidly growing body of literature on learning, especially social learning, there is limited empirical evidence on the role or effectiveness of learning in participatory planning and decision making. In research, the effects of individual variables on learning are seldom evaluated, and it is seldom tested which techniques can best lead to learning. The evidence on the effectiveness of learning is explored and reported on the basis of hindsight, personal experiences or uses of empirical data extrapolated from activities meant to evaluate other processes or concepts (e.g. participation) (Rodela et al., 2012; Reed et al., 2010)

A collaborative process can facilitate a learning process in which all involved parties, including project managers, scientists and experts, learn from each other. It is reported that in many cases stakeholder or public participation does not foster learning (e.g. participation is not useful in clarifying the issue) nor lead to better decisions (Booth and Halseth, 2011). However, structured decision-making approaches have been found to help the participants to learn about the options and trade-offs as well as their own and the other participants' values and interests (Gregory et al., 2012).

In this paper, our intention is to analyze whether there is any improved understanding of the groundwater issue in the Rokua area among the participants after the MCDA process, and if there is, how the applied approach, particularly the meaningful participation and open dialogue among the participants, enhanced the conditions for learning.

3.2 Interactive MDCA in the Rokua case

The aim of the MCDA process was to support stakeholder participation and increase the overall understanding of the problem for all parties. The focus is on MCDA as an actor system (used in an interactive participatory process), not as an expert system (Kain and Söderberg, 2008). In the beginning of the MCDA process in Rokua, the groundwater management issue seemed to be an "unstructured problem" (see Turnhout et al., 2008 about the problem definition) with no consensus concerning either the goals or the means and with great scientific uncertainty. In this kind of context, decision making requires a high level of participation by actors holding conflicting perspectives and

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interests. Policy development becomes a learning process, a dialogue where actors develop and reflect upon conflicting perspectives (Turnhout et al., 2008).

The MCDA method applied in the Rokua case is based on the multi-attribute value theory (MAVT) (Keeney and Raiffa, 1976), and it takes advantage of the decision analysis interview (DAI) approach (Marttunen and Hämäläinen, 2008; Marttunen, 2011) based on personal interviews using a multi-criteria model. At the core of the DAI framework is MCDA-based interactive and individual analysis. In the DAI approach, the entire process of MCDA is realized in close co-operation with the key stakeholders. In the interviews, the decision analyst uses MCDA software and poses questions to the interviewee, ensuring that the interviewee's views are taking account as closely as possible.

In MAVT, a decision problem is formulated with multiple attributes, and these attributes are used in the evaluation of the alternatives. MAVT has been proven to be a systematic and transparent way to model problems with multiple criteria and alternatives when working with stakeholders (see, e.g. Mustajoki et al., 2011). In the interviewing process, the stakeholders or decision-makers are asked to give numerical preference statements which are used to calculate the attribute weights describing the trade-offs between the attributes in the additive value function model. In eliciting the weights of the criteria, the interviewees are encouraged to profoundly consider their own values and the trade-offs. This "learning by analyzing" technique is one of the main advantages of the DAI approach (Marttunen and Hämäläinen, 2008).

The DAI approach has been observed to help the participants in assigning consistent and unbiased weights. In an interactive interview, the analyst can notice possible inconsistencies, misunderstandings and biases in the interviewee's answers (Marttunen and Hämäläinen, 2008). For example, in watercourse planning, the MCDA models have inspired learning and understanding in a different manner than traditional meetings. The interactive use of the models has supported the systematic analysis of the stakeholders' preferences and helped to analyze how the preferences have affected the ranking

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of the alternatives (Marttunen and Suomalainen, 2005; Marttunen and Hämäläinen, 2008).

3.3 Application

The decision analysis process was led by an expert group consisting of researchers from the University of Oulu. The expert group organized altogether four different meetings or workshops with the stakeholders (see Table 1) where the MCDA work was processed. Figure 2 describes the main phases of the decision analysis process.

3.3.1 Stakeholder analysis and forming of the value tree

In the first stakeholder meeting, the initial list of stakeholders and the definition of the decision context in the Rokua esker area and groundwater management were presented to the various interest group representatives. As a result of that meeting, a list of stakeholders (see Table 1) to be involved was finalized, and a first draft of the value tree including the stakeholders' objectives concerning groundwater management and land use in the Rokua esker area was formed (see Fig. 3). The next step was to finalize the value tree. In the second stakeholder meeting, the objectives (reflecting "what matters" to those whose views should be considered in a given decision context) on the basis of the initial proposal for the value tree were discussed. In the same meeting, the attributes for the measurement of each objective were set up (Table 2).

The meeting mainly focused on the discussion of the objectives and their measurement. For example, there was discussion about how to measure the change in tourism if the water levels in the kettle lakes continue to decrease. It was generally accepted that changes in the number of tourists visiting the area due to water level variations cannot be evaluated convincingly, since many other issues (e.g. the overall standard of tourism services) influence the attractiveness of the area in the future. The ecosystem services of the kettle lakes that provide recreational and aesthetic benefits for visitors are one of the area's attractions, but they do not form the only and decisive factor for

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the whole tourism sector. Indirect economic benefits of tourism and forestry for the local and regional economy were also discussed. It was decided not to focus on these benefits in the assessment due to the considerable level of uncertainty concerning how much water level changes may affect these factors.

3.3.2 Development of alternatives and impact assessment

The possible land-use management options were considered while structuring the value tree. The set of alternatives was first formed by the expert group and revised in the second stakeholder meeting. The alternatives developed reflect the key objectives, interests and issues of conflict:

Alternative A: business-as-usual

Forestry practices continue as usual; reopening of drainage ditches in the groundwater area is not prohibited but is under case-by-case consideration by the regulators.

Alternative B: expansion of the groundwater protected area

Three- to five-square-kilometer expansion of the Rokua groundwater protected area into the surrounding peatlands where groundwater is confined under peat (exfiltration risk areas, Fig. 4). Forestry practices will be limited or forbidden in these areas. The environmental administration's control over the area will be strengthened.

Alternative C: active restoration (technical solutions) of peatlands

Restoration of critical groundwater exfiltration areas either by damming or filling the drainage ditches. The alternative focuses on adaptive management efforts to locate the most critical areas of groundwater exfiltration instead of protecting larger land areas.

Locations and areas for groundwater area expansion (Alternative B) and restoration targets (Alternative C) were estimated by using the groundwater exfiltration risk

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prediction method developed for Rokua by Eskelinen (2011). The method estimated the most likely locations of groundwater exfiltration from the slope of the esker, distance from the recharge zone, distance from springs, baseflow of the discharge area watersheds and peat thickness (Fig. 4).

The impact assessment of the selected alternatives was conducted by the expert group after the second stakeholder meeting. The hydrological, ecological and socioeconomic impacts of the proposed alternatives during a 30 yr period are presented in Table 2. The impact assessment is based on the conducted studies and the preliminary results of ongoing research in the area. As the assessment is partially based on preliminary results and the time span of the assessment is 30 yr, the uncertainty of the impact assessment is considered to be high. For this reason, some of the impacts are studied using less precise, qualitative measures. These qualitative measures indicate if the alternative has a negative impact (–), if there is no change from the current situation (0), or if there is a positive (+) or highly positive impact (++). For example, active restoration is assessed to have a highly positive impact on the springs surrounding Rokua. A more exact evaluation of the impacts to the attributes is presented in the Supplement.

3.3.3 Decision analysis interviews

Stakeholder preferences were taken into account in the MCDA model by means of decision analysis interviews. In the third stakeholder meeting and learning workshop with the interviewees, the results of the impact assessment were presented and the process of the decision analysis was described. A questionnaire for the interview and an information package were handed out to the interviewees with information about the case, the approach and the interviewing. The package also included the description of the applied value tree, the grounds for the alternatives, criteria and measurement value estimates.

The interviews, conducted by two researchers in September 2011, involved 19 representatives of the stakeholder groups (see Table 1). In one case, three interviewees

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(representing the same stakeholder group and organization) wanted to give mutual criteria weights, so finally 17 different weighting profiles and evaluations were gathered in order to infer the preferences of the main stakeholder groups. We used local scales (as attribute measurement values on a 0–1 value scale), as thus the end points are truly realistic values. Thus, for each criterion, the lowest attribute value among our alternative set was mapped to 0 and the highest value to 1, while the other attribute values were mapped linearly to this scale (Belton and Stewart, 2002).

We selected the SWING method for eliciting the weights for the criteria (von Winterfeldt and Edwards, 1986). The SWING procedure was chosen in order to ensure that the participants account for the decision context by identifying the most important attribute first, and then the relative importance of the other attributes was compared to it. It is crucial that when eliciting weights for the highest level attributes, the participant is fully aware of the meaning of the attributes.

The interviews lasted from one and a half to four and a half hours. In the first half of the interview, we laid out the general principles of the DAI approach, the case and the applied model in order to make sure that the interviewee had understood all of the details relating to the interview process. After this, the interviewee's preferences were fed into the model using the software Web-HIPRE (Mustajoki and Hämäläinen, 2000). The final phase of the interview consisted of analyzing the results and explaining the reasons behind them to the interviewee.

3.4 Data for the evaluation

The data for the evaluation comprises mainly the results of the decision analysis interviews and the feedback survey for the participating stakeholders. The feedback questionnaire was introduced in the fourth stakeholder meeting, where the results of the MCDA process and interviews were presented and discussed. The participants were asked, for example, to evaluate the suitability of the applied MCDA approach for meeting the different objectives and the success of the implementation of MCDA in Rokua in supporting learning (see Fig. 8).

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4 Results and evaluation

4.1 Results of the decision analysis interviews

4.1.1 Importance of objectives

The interviewees were asked to consider the range of impacts of the alternatives and the importance of the objectives/issues considered. As the results show (Fig. 5), there is agreement among stakeholders that the water level of the lakes and the aquifer (more than 30 % share of the total weight – median value) is the most important criterion in the context of the Rokua case study. Most of the interviewees considered this criterion as the basic unit when measuring the success of land-use management.

The ecological status of lakes and springs receives a more than 20 % share of the total weight (median value, Fig. 5), but there is much more disagreement (range between min/max and 75th percentile) about how important this criterion is and about the impact that the proposed alternatives might cause. The recreational value of second homes was considered as an important objective, but the impacts (measured by change of monetary value per second house) were rated low by the participating stakeholders. Therefore, the overall importance of this criterion (median value of weights) is set as being smaller than that of the water level, ecological status and tourism attractiveness.

Tourism attractiveness was seen as a significant issue for the Rokua area and its surrounding municipalities. However, some interviewees estimated that the marketing and development of new tourism services is more decisive for the attractiveness of the area than the state of the water bodies or lake water levels. The importance of forestry to the local economy was generally recognized among the interviewees, but the impact of the alternatives on forestry income was considered peripheral. Here the forestry representatives disagreed, emphasizing (more than others) the indirect incomes and monetary flows to the regional and national economy. Peat production was considered to be the least important criterion. There are two reasons for that: first, risk analysis and hydrological studies showed that the role of peat production in the water-level

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decline in the Rokua esker area was minimal. Second, during the MCDA process, the representative from the peat harvesting company announced that peat harvesting in the area would end by 2018.

4.1.2 Desirability of alternatives

The results (Fig. 6) indicate that all stakeholder groups are willing to accept that some measures should be promoted in the esker area in order to improve the hydrological and ecological conditions in the area. The ranking of the alternatives shows that the alternative of active restoration (Alternative C) is the preferred one among all interviewees. However, the difference in the preferences of alternatives is not substantial among the stakeholders stressing the significance of forestry (left side of Fig. 6) as compared to the stakeholders mainly emphasizing the ecological and hydrological issues (right side of Fig. 6), who clearly prefer alternative B over A, and C over B.

4.1.3 Different stakeholders' viewpoints

The analysis revealed that different views about the impacts of the different alternatives and the importance of the criteria can be found. Three different viewpoints of stakeholders were elicited from the analysis: forestry, administrative and local economy.

The forestry viewpoint focuses its concern on the adverse economic impacts on forestry (Fig. 7). This can be noticed from the high value given to the BAU alternative, where negative impacts on forest income can be avoided. The proponents of this viewpoint also emphasize the indirect impacts of forestry on the local, regional and even national economy.

Both the local economy viewpoint (Fig. 7) and the administrative viewpoint (Fig. 7) emphasize more ecological and hydrological objectives. According to the local economy viewpoint, the water levels and the ecological status of the water bodies should be kept in a good condition, since tourism is the most important source of local income, jobs and tax revenues. Also, the attractiveness of the area (weighted as the

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most important criteria) depends on the ecosystem services provided by the specific types of local esker ecosystems.

The administrative perspective (Fig. 7) places more emphasis on the ecological and hydrological criteria than the other two points of view. The overall value of alternative B is greater among the representatives of this group compared to the other groups. The administrators believe that the positive impacts on the groundwater level and the ecological status of the lakes and springs can also be achieved by expanding the boundaries of the groundwater protected area.

4.2 Evaluation of the approach by the stakeholders

At the final workshop, the members of the participating stakeholder groups were asked to evaluate both the suitability of the applied approach for this case and the practical implementation of the process including their understanding of the process and the results. The mean mark for the overall evaluation of the success of the applied approach was 8.3 (on a scale from 4 to 10). The approach was considered the most suitable for the identification of the key issues of the problem, for increasing the understanding of the views of the different stakeholder groups and for the collection of information (Fig. 8). In the meeting discussions, the stakeholders appreciated the method's capability for collecting information from different sources while at the same time showing the different views of the importance of the different land-use practices and the overall objectives of the stakeholders. There was agreement that this was the most significant benefit of the MCDA method.

All participating stakeholders considered the MCDA process necessary as a starting point and as a basis for further negotiation about the land use in the area. Most of the stakeholder representatives think that the applied MCDA process is highly useful for Rokua's land-use planning (Fig. 8). In their feedback evaluations most of the respondents considered personal learning to have occurred during the process. For the analysts, it is obvious that the participating stakeholders learnt about Rokua's groundwater system itself, about how land-use and climate change might affect the system,

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and about the different stakeholders' preferences. Computer-aided interviews helped the participants to see how their preferences affected the desirability and ranking of the alternatives. Yet, the participants considered weighting as a challenging task.

The MCDA process having ended, learning success is now evident, and many results (facts, issues, viewpoints) brought out during the process will be usable in decision making in the Rokua area. Nevertheless, important gaps are present as, for example, the hydrological modeling is still at a preliminary stage.

5 Findings and conclusion

The MCDA process in the Rokua case was successful in finding a way towards sustainable land use in the esker aquifer area. First, it has opened the discussion about possible land-use management options in a conflicting situation with a considerable amount of distrust between the different stakeholders. Stakeholder meetings, as well as structured and transparent methods of analysis, have enabled the discussion and consideration of other points of view, and especially reflection on the participants' own preferences in this context. We have observed that the participants' understanding and preferences evolved during the process as they assessed their previous knowledge about new scientific and socioeconomic information and reflected on their preferences in the context of new knowledge and specific options. When the participants had an opportunity to see visually their attribute weights and the effects of these on the desirability of the alternatives, this interactive and iterative way improved the participants' trust towards the method and promoted the transparency of the whole process – this has also been observed with earlier DAI studies (Marttunen and Hämäläinen, 2008). At the beginning of the process, the stakeholders' comments and arguments in defense of their prior point of view and the interests of their stakeholder group were observed to be more rigid compared to later stakeholder meetings.

Second, the analysis has revealed that the stakeholders actually agree on many crucial issues. The most important issue is that some active measures should be realized

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in the esker area in order to hinder further decline of the groundwater levels. The analysis was effective in opening a dialogue and negotiations. However, the stakeholders still disagree with each other about the measures and the effects of the alternatives. A critical issue for the social acceptance of the management option in the Rokua case is what measures (restoration efforts and/or expansion of groundwater area) are conducted and where, and what will be the compensation tools (monetary, land exchange or something else) for the forest owners who will lose part of their income if forest area owned by them is protected and/or restored.

Third, the MCDA process has informed decision-makers about the possible alternatives in land-use management in the Rokua esker area. The MCDA work can be seen as a first step in the process of building up a sustainable land-use plan. It has opened the way towards a new process, showing an overall picture of the problem and decision contexts as well as the different views of the stakeholders (agreements and disagreements), and has identified the critical issues (e.g. new research needed) in furthering the process. The next step in the Rokua case will be to continue the adaptive co-management approach (Armitage et al., 2009) by forming a collaborative management group including all major stakeholders, officials and researchers. This group will act as a coordinator and advisor for all land-use management issues (e.g. research, restoration, new regulation) in the Rokua area. In the last meeting of the MCDA process, it was agreed that this group will be established.

In conclusion, this study demonstrates the usefulness of the structured decision-aiding approach in supporting a collaborative process and learning in groundwater management. The applied decision analysis framework enhanced the participants' capabilities for collaboration and individual learning. The decision analysis method with interviews is confirmed to be an effective learning process for the participants. It is found that the decision analysis method assists the participants in making informed judgments, which in turn can lead to identifying the most effective, acceptable and sustainable solutions.

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Supplementary material related to this article is available online at: http://www.hydrol-earth-syst-sci-discuss.net/10/8747/2013/hessd-10-8747-2013-supplement.pdf.

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Table 1. List of stakeholder groups and representatives in the decision analysis interviews.

Stakeholder	Representation	Number of interviewees
Forestry	Forest Centre (state organisation)	2
	Forestry association	1
	Forest owner	3
Regional administration	Groundwater management	3
	Conservation of habitats	2
Nature park administration	Forest park services	1
Municipalities	Chief engineers	2
Tourism	Hotel manager	1
Local NGO	Rokua association	1
Second house owners	Association of owners	1
Development organization	Humanpolis/Geopark	1
Peat production	Turveruukki company	1

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Table 2. Objectives, attributes and impact matrix of different alternatives.

Objective	Attribute(s)	Business-as-usual	GW-area expansion	Active restoration
Normal level of groundwater and dependent lakes	Change of average Rokua water level in 30 yr (groundwater and lakes)	−1 m	−1–0 m	+1 m
Good ecological status of lakes and springs	Chemical state of lakes Chemical/ecological state of springs	0 0	0/+ 0/+	+ ++
Good recreation value of second homes	Recreation value change of second homes at kettle lakes in 30 yr	−150 000–−230 000 €	0–−230 000 €	0
Attractive tourist resort	Change in attractiveness of Rokua for tourists in 30 yr	–	0	+
Profitable forestry	Forestry income loss in 30 yr compared to current state	0	−50 000–−250 000 €	−500 000–−2 500 000 €
Minimal loss for peat production	Income loss for peat production or losses caused by restoration of peat harvesting area	0	0/–	–

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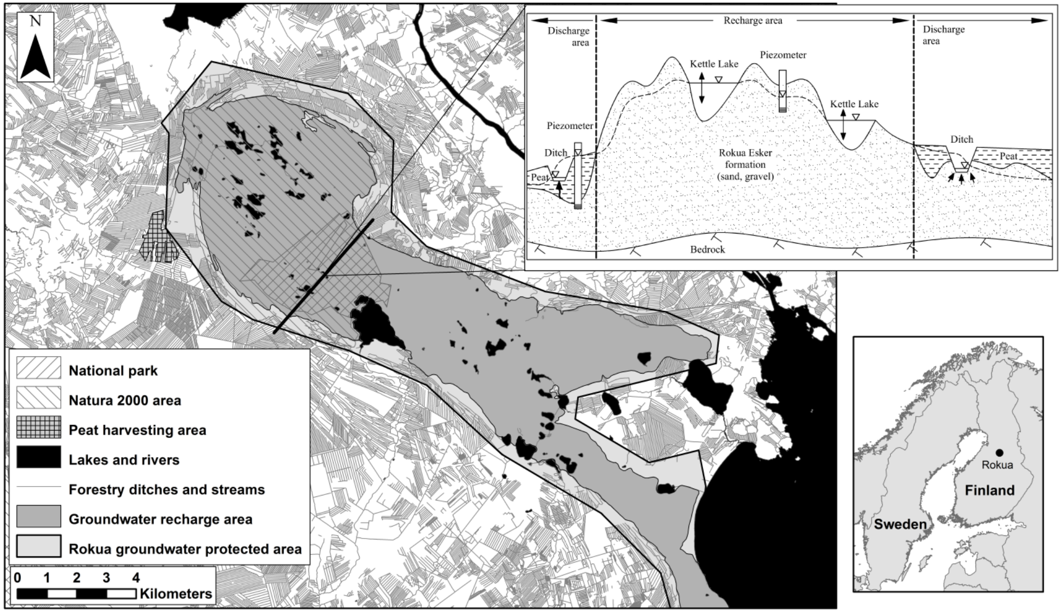

Fig. 1. The Rokua esker area and a cross-section sketch of the esker with recharge and discharge areas.

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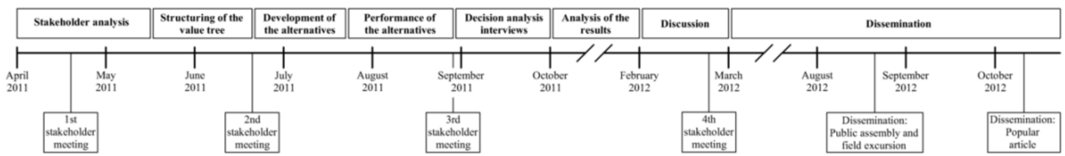

Fig. 2. Decision analysis process in the Rokua case.

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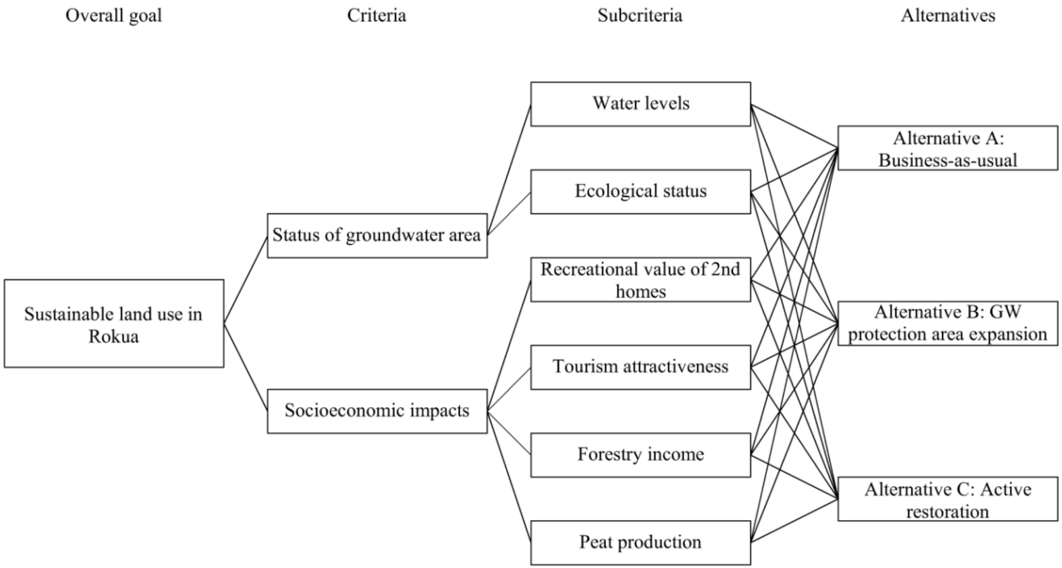

Fig. 3. Value tree for the multi-criteria decision analysis of Rokua.

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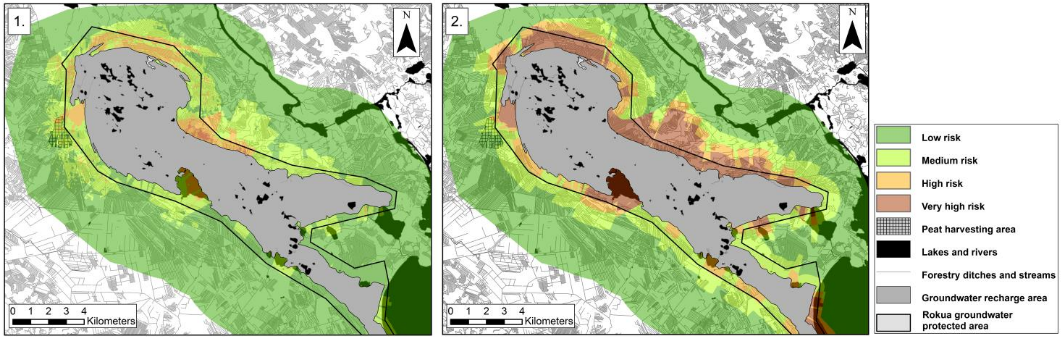

Fig. 4. Groundwater exfiltration risk analysis maps for Rokua with different data sets. In Map 1, risk analysis was based on terrain slope, distance from the recharge zone and springs, and peat thickness. In Map 2, peat thickness was not considered.

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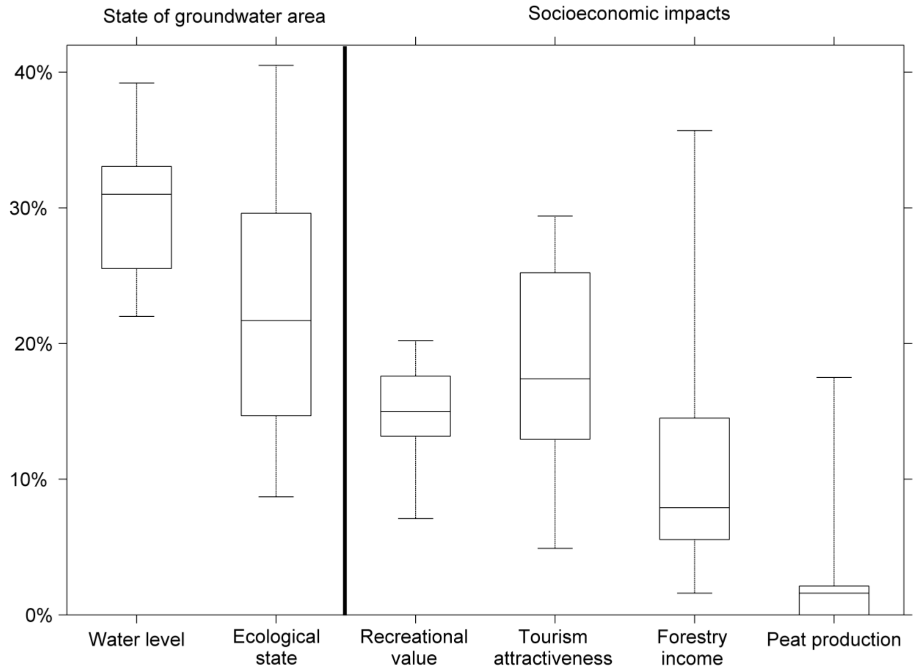

Fig. 5. Importance weights of the criteria in the Rokua groundwater case given by the interviewed stakeholders (min, median, 75th percentile, max).

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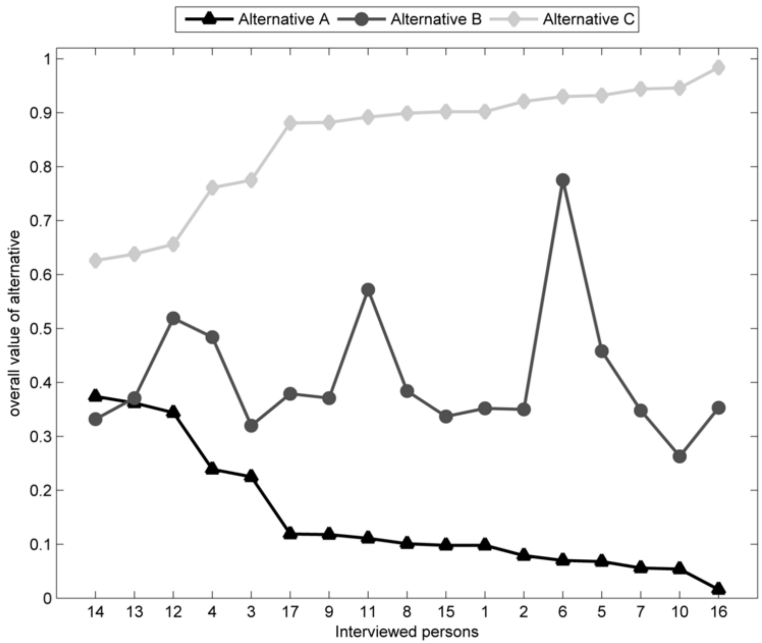

Fig. 6. Overall values of the alternatives for each interviewed stakeholder.

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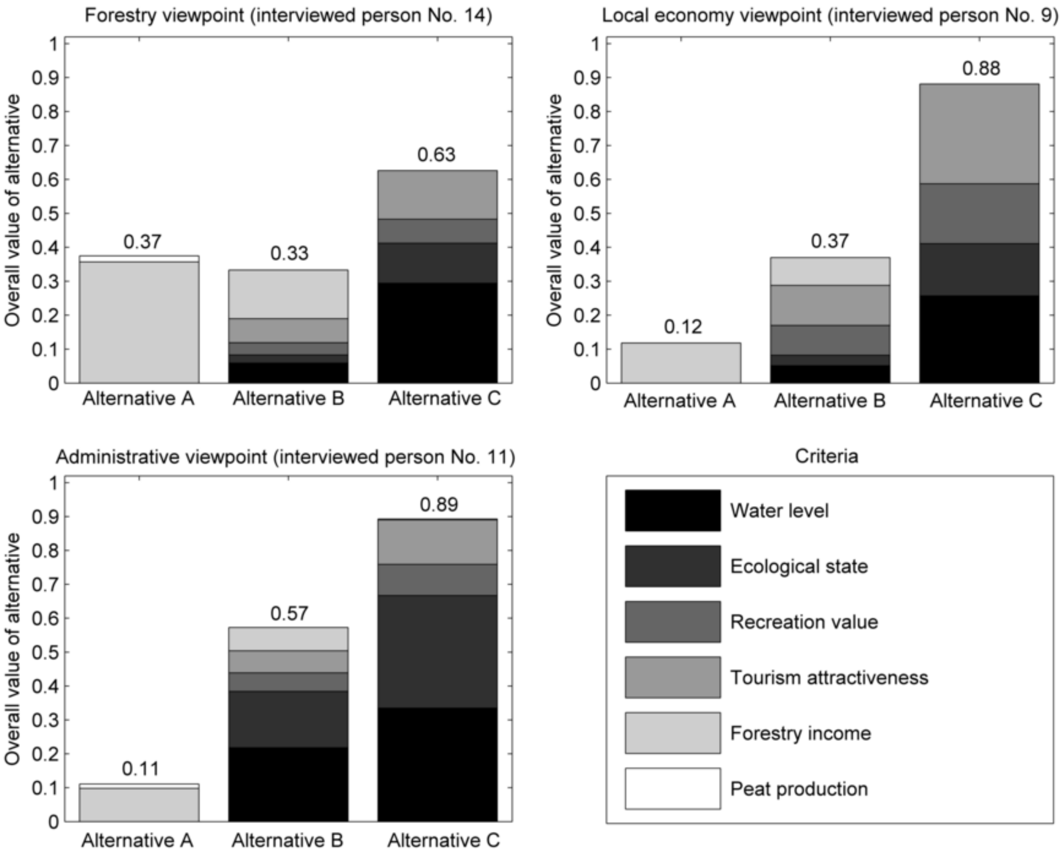

Fig. 7. Overall values of the forestry, local economy and administrative perspectives.

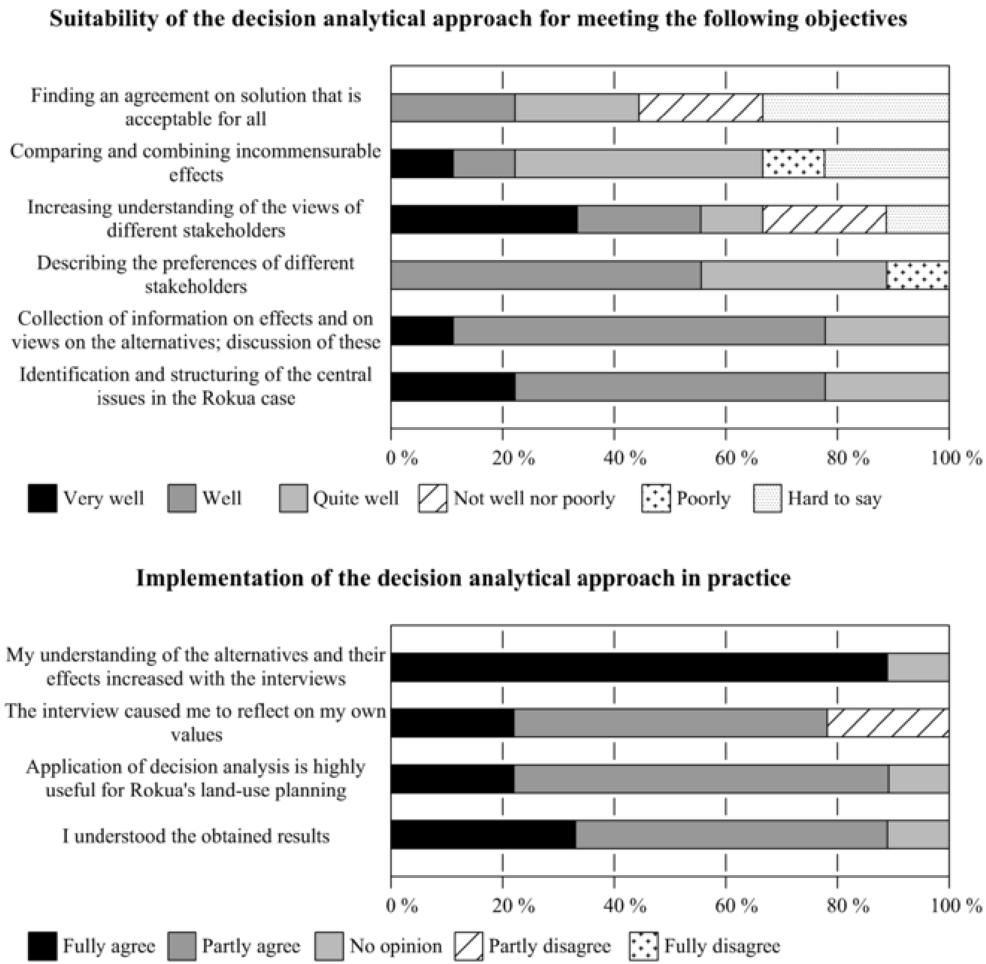

Fig. 8. Results of the feedback questionnaire among the participants of the MCDA process.

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