Available online at www.sciencedirect.com

SCIENCE DIRECT®

Forest Policy and Economics 7 (2005) 603–614

Forest Policy and Economics

www.elsevier.com/locate/forpol

Socioecological landscape planning approach and multicriteria acceptability analysis in multiple-purpose forest management

Jyrki Kangas[a,*], Ron Store[b], Annika Kangas[c]

[a] UPM Forest, P.O.Box 32, FIN-36701 Valkeakoski, Finland

[b] Finnish Forest Research Institute, Kannus Research Station, P.O.Box 44, FIN-69101 Kannus, Finland

[c] University of Helsinki, Department of Forest Resource Management, P.O.Box 27, FIN-00014 University of Helsinki, Finland

Received 29 April 2003; received in revised form 28 November 2003; accepted 10 December 2003

Abstract

In the socioecological landscape planning of natural resource management, sociocultural and ecological decision criteria are integrated with 'traditional' economic considerations in an analytic and systemic way. As the main phases, the approach involves (1) pinpointing the sites of foremost importance from the viewpoint of ecological and sociocultural management objectives; (2) elaborating different so-called ecological and sociocultural networks, the combinations of which determine alternative socioecological networks; (3) producing alternative timber production programmes for areas not included in different socioecological networks (resulting in different alternative management plans for the whole area under planning); (4) evaluating the relative worth of alternative plans with respect to each relevant objective; and, finally, (5) the holistic comparison of alternative management plans by applying multiple criteria decision aid methods. This article first discusses the principles and rationale of the approach. Then an illustrative application of the new planning approach is presented. In the application, recreational and ecological objectives were integrated into forest management planning of a landscape owned by the State. The criteria were measured on ordinal scale, and they were ranked according to their mutual importance. Stochastic multicriteria acceptability analysis with ordinal criteria (SMAA-O) was used in the holistic comparison of alternative landscape-level plans. The socioecological landscape planning approach was found practicable. The Finnish Forest and Park Service, governing the vast majority of State-owned lands in Finland, has already made the decision to apply the approach in strategic natural resource management.

Keywords: Forest planning; GIS; Landscape planning; Multicriteria analysis; Multi-functional forestry; Natural resource management; SMAA methods

1. Introduction

The multi-objective approach can be considered to be a starting point for almost all planning involving the natural resources. In many planning situations, the number of objectives is greater the greater the number of people and interest groups affected by the planning and the more there are final decision-makers. The spectrum of objectives in forest planning and the demands set on planning are generally at their widest in forests owned by public bodies, for example, by the state. There the plans typically apply to large areas,

* Corresponding author. Tel.: +358-202-163863; fax: +358-204-163808.

E-mail address: jyrki.kangas@upm-kymmene.com (J. Kangas).

1389-9341/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.forpol.2003.12.001

and the number of people keen to participate in decision-making related to the management of the common resource is great. In practice, there have been attempts to face up to the challenge of multi-objectivity by means such as participatory and ecosystem management planning.

The ecological aim in ecosystem management planning is to apply broad-in-scope ecological review to find the means of securing the biodiversity of the landscape (Grumbine, 1994; Lackey, 1998; Leitao and Ahern, 2002). Landscape ecological assessments are implemented to determine the ecological potential of the planning area, to produce alternative ecological solutions and to assess the worth of alternative solutions in relation to the preservation of the viability of organisms. In practice, ecosystem management and landscape ecological planning often also include considerations related to objectives other than those of just ecology, such as objectives related to wood production, forest recreation and nature tourism (e.g. Karvonen, 2000; Pirot et al., 2000).

Then the central task of planning at the landscape level becomes that of reconciling the various objectives, forms of use, and multi-functionality of the area under consideration. To take an example from practical forestry; sites of great ecological or scenic value are often taken into account by leaving some forest stands or other sub-areas outside forest treatment aimed at wood production. From the viewpoint of wood production, this creates set-aside areas of different kinds in the forests. Planning is at its most efficient if the choice of these sites is considered simultaneously in regard to all the relevant planning-case-wise objectives (Store and Kangas, 2001). However, a problem of central importance has been how to efficiently integrate sociocultural objectives into multi-functional planning.

The socioecological landscape planning approach provides one solution for alleviating this integration problem. The approach was recently introduced by Kangas and Store (2002). The socioecological planning represents a typical task for the management of multiple-purpose forestry to find a balance between timber production, recreation and nature conservation, and to identify areas of conflict. In the socio-ecological planning, as presented in this paper, the process of multi-functional planning is approached in an analytical, systematic and systemic way so that all the phases of the process together form an integrated whole.

2. General outiline for the socioecological forest planning approach

In the socioecological planning process, a host of different alternative ecological networks consisting of ecologically valuable patches and connections between them are produced. For areas belonging to these ecological networks, only ecologically acceptable treatment options, if any, are allowed. Correspondingly, alternative sociocultural networks are elaborated with various amounts of land area reserved for recreational and other sociocultural purposes. Combinations of these two kinds of networks form the socioecological networks. If there are l ecological networks and n sociocultural networks, the number of alternative socioecological networks is $l \times n$.

In the next phase, when applied in forestry context, each socioecological network is provided with m alternative wood-production programmes involving different treatments for forest stands not set aside from wood production due to their ecological or sociocultural values. Thus, we finally have $l \times n \times m$ alternative management plans each with different ecological, sociocultural, and economic consequences.

These entire landscape level forest plans are then finalised for the evaluation step. For example, additional analyses useful in the evaluation can be produced, such as wildlife habitat assessments utilising spatial models within GIS. The priorities of alternative plans are assessed with respect to their ecological, sociocultural and economic objectives, and finally holistically with respect to all objectives. In the holistic evaluation, Multiple Criteria Decision Aid (MCDA) methods are applied (for a review of MCDA methods, see, e.g. Bouyssou et al., 2000; Belton and Stewart, 2001; Kangas and Kangas, 2002 for their forestry applications). Elaborating sociocultural and ecological networks as well as using MCDA methods in the evaluation of alternative plans can also serve as channels and platforms for public participation.

The final choice among the alternative plans is up to the management objectives and their weightings. There are no universal rules to be applied everywhere when it comes to the criteria and their relative importance. Instead, in the socioecological landscape planning approach, MCDA methods are made use of in evaluating alternative plans holistically with respect to the objectives set for the area.

The choice of the MCDA methods to be applied is up to case-wise characteristics of the planning process, such as what are the objectives, how the decision makers can participate in and support the process, what other stakeholders are involved, and what kind of information is available (Kangas et al., 2001b). For example, some methods are developed for making use of ordinal information, some require cardinal data as input. Furthermore, some are developed to be used by expert planners and some for participatory processes, and so on.

3. An example of the approach

3.1. Background information for the planning process

The first application of the approach in Kainuu, Eastern Finland served as the testing tool while at the same time also producing valuable information for the practical management of the area. The area is 3336 ha in size, owned by the state, and governed by the Finnish Forest and Park Service (FPS). A landscape ecological natural resources plan had already been produced for the area (Näpänkangas et al., 1998), serving as a starting point for the elaboration of alternative ecological networks.

The average soil fertility within the area is rather low and the total volume of standing timber is approximately 410 500 m^3, of which more than 80% is Scotch pine. The volume of deciduous trees is approximately 11 800 m^3, the rest being Norway spruce. The mean annual volume growth is estimated to be approximately 10 200 m^3. The area of old-growth forests is 1593 ha; i.e. the forests are quite old, and thus the ecological potential of the area for many vulnerable and rare species persisting in the region can be expected to be high. However, the total volume of dead stem wood is approximately only 1600 m^3. The age distribution of forest stands is two-fold: in addition to old forests there are plenty of stands younger than 40 years.

The forestry sector is important for the regional economy and employment. Thus, it is also important to secure the timber cutting possibilities. From the sociocultural viewpoint, the area's most important activities are related to recreational use of forests and nature tourism. For example, fishing and hunting are important not only for local inhabitants but also for the tourism business. Within the area, there are pressures to continue effective timber production with cuttings of old forests, to maintain and increase biodiversity, and to manage forests so that they serve well as the platform for nature tourism and other recreation activities.

The area in question had previously been inventoried for its soil and growing-stock data as well as data related to recreational use with reference to the special ecological sites and coarse woody debris (Näpänkangas et al., 1998). In regard to the recreational-use potential, the existing data were supplemented by data collected in separate field inventories. The foremost item related to recreational use in the study area was a popular hiking route passing through it including lean-tos and campfire sites, for instance. Of prominent ecological value were the numerous small water systems in the area and the associated diverse shoreline forests.

3.2. Producing socioecological networks and alternative forest plans

Three networks related to sociocultural objectives, and three networks of ecological items were drawn up (Fig. 1) and merged within a GIS application. As combinations of them, altogether nine socioecological network alternatives could be produced (Fig. 2). They combine ecological and recreational-use values and serve as the starting point for the production of alternative socioecologically oriented landscape plans.

The first ecological network alternative included only habitats of great ecological value, determined by experts on boreal forest biodiversity. Shoreline forests, spring habitats, rock outcrops and cliffs, old-growth forests, and individual forest islets surrounded by mires are examples of these. In order to produce an ecological network, the statutory

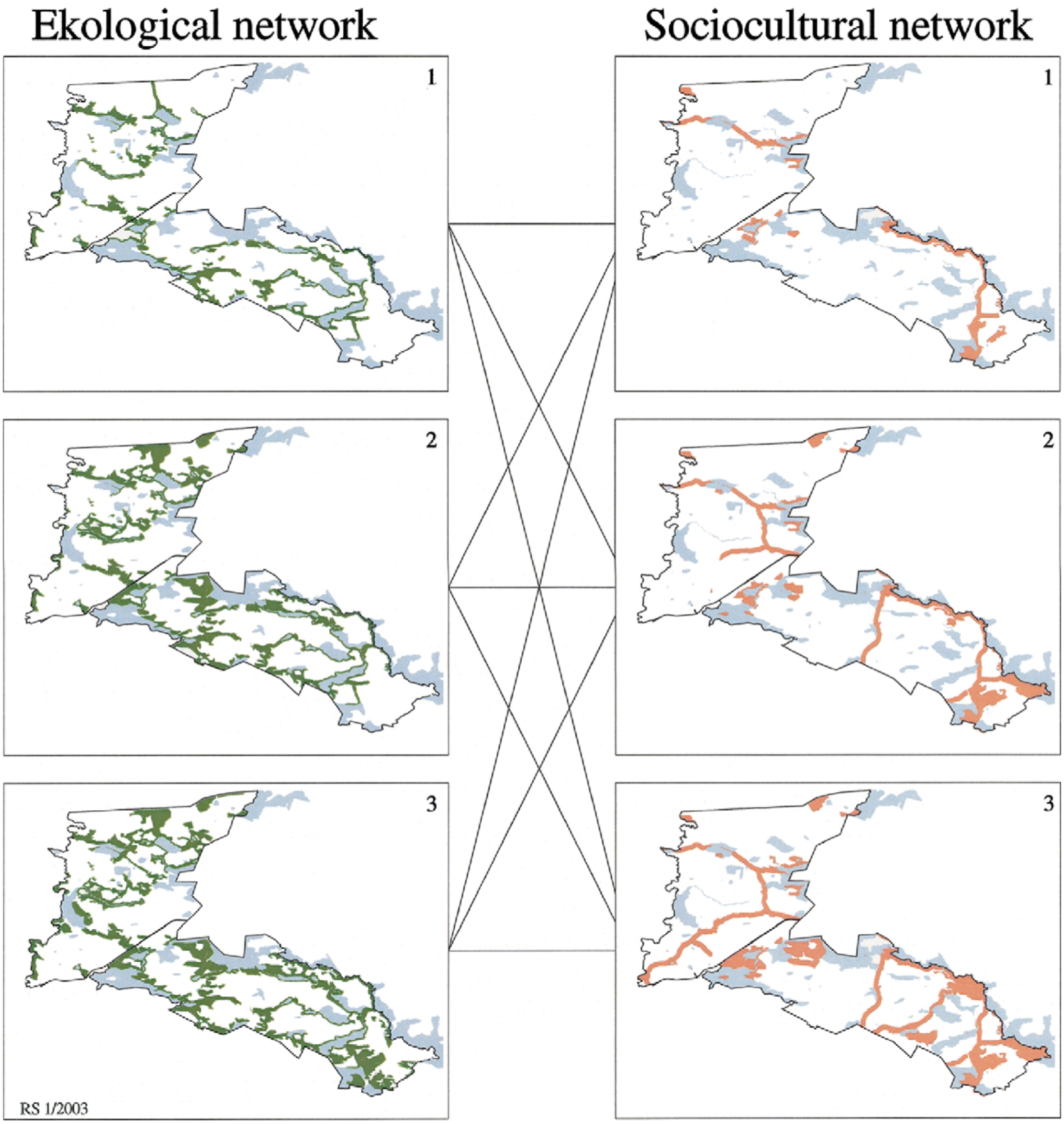

Fig. 1. The three ecological networks and the three sociocultural networks in the case study.

ecological items were supplemented as necessary by forest compartments serving as ecological corridors and stepping-stones.

In the second stage of the ecological solution, i.e. for producing the second ecological network alternative, the area of the network of items to be set aside was increased by, for example, extending the buffer zones drawn around streams. Moreover, new items were included in the second network alternative: e.g. more old forests and stands with

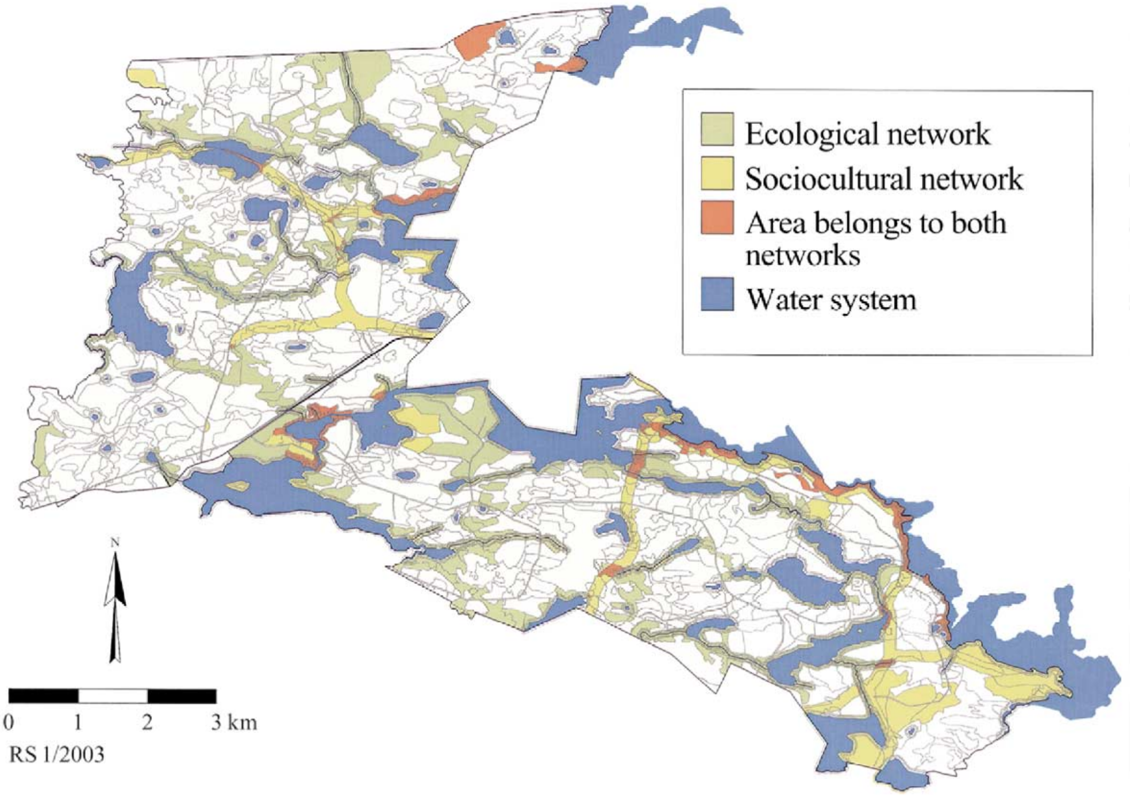

Fig. 2. An example of the nine combinations of ecological and sociocultural networks.

plenty of coarse decayed woody debris, and the capercaillie (*Tetrao urogallus*) leks. The third and most intensive network was produced both by including new items and corridors as well as by extending the width of buffer zones.

The basis for the social-considerations-related networks was provided by the hiking route passing through the area. The first stage consisted mainly of recreational structures already in place in the planning area: of hiking routes, a sports-fishing area, a camping area and campfire and lean-to places. Also, some scenically important places were included in the network. They were sought out using a GIS application and aided by visibility analysis. Participatory citizen feedback was utilised in the determination of places of great sociocultural interest (Hytönen et al., 2001).

For the more intensive sociocultural network, the number of areas that were set aside for the recreational use was extended primarily by enlarging the path network. The objective was to select paths joining up with the main hiking route and thereby forming a network around it. Scenic aspects were taken tender care of in buffer zones along paths. In the third stage, the network was expanded by both adding new paths and by adding individual recreational-use items (e.g. game items and cloudberry [*Rubus chamaemorus*, a valued wild berry] mires).

The forest plans covering all the stands in the area, and their treatment programmes, were finally produced such that each basic solution compliant with the combinations of ecological and sociocultural networks was provided with a wood-production programme that was sustainable in economic terms of wood production. This resulted in a number of alternative plans P*ij*, *i* and *j* indicating the ecological and sociocultural network applied,

Table 1
Some characteristics of alternative forest plans in the case study

Plan	P11	P12	P21	P13	P31	P22	P32	P23	P33
Area in timber production, ha	2472	2343	2256	2099	2161	2159	2067	2011	1923
Area belonging to the recreation network, ha	217	414	217	710	217	414	414	710	710
Area belonging to the ecological network, ha	565	565	984	565	1101	984	1101	984	1101
Total area of 'protected' patches, ha	733	921	1132	1187	1229	1287	1380	1455	1543
Net income from cuttings, mill.euros	3834	3856	3850	3498	3498	3495	3091	3091	3091
Area of old-growth forests after the period, ha	1725	1664	1678	1692	1659	1630	1700	1702	1626
Volume of deadwood after the period, m^3	8373	8607	8478	8760	8680	8777	8919	8810	8989
Volume of standing dedicuous trees after the period, m^3	13 778	14 128	13 815	13 775	13 440	14 099	14 005	14 474	14 014
Length of 'protected' shorelines with buffer zones, km	58.6	66.0	65.6	69.9	68.4	72.0	74.3	73.4	75.6
Length of 'protected' paths with buffer zones, km	12.6	20.0	14.2	29.6	15.0	21.4	22.8	30.4	31.4

respectively (Table 1). The wood-production programmes were compiled using simulation of forest development and numerical optimisation, more closely the HERO heuristics (Kangas et al., 2001a) as applied in the MONSU multi-objective forest planning package (Pukkala, 1999). Net income during the planning period and volume of the retention growing stock were used as objective variables in optimisation calculations. The principles of producing different alternative wood-production programmes, followed in this study, too, are more closely presented in Kangas et al. (2000).

3.3. Multiple criteria evaluation of alternative plans

The main purpose of the multiple criteria evaluation phase here is just to show how the socioecological landscape planning process proceeds. In principle, any MCDA method could be used in the holistic evaluation of alternative plans. In an actual planning process, the choice of the MCDA method is up to the characteristics of the planning situation (data available, decision makers, other stakeholders involved, planning tools and analyses possible to utilise, expertise of the consultants, etc.).

In our illustrative case study, ordinal rankings of alternative plans with respect to 'upper level' decision criteria were applied (Table 2). These 'upper level' decision criteria were economic sustainability of timber production (Timber Production), ecological sustainability (Ecology), and the recreational considerations of forest management (Recreation). Recreation represented the social dimension of forest use, and it was taken as an indicator of the priority of the forest area for nature tourism business, too, among others. Multiple criteria decision aid was required for enabling holistic comparison of decision alternatives. Rankings were carried out by utilising all the numerical data and calculation results available on the plans, thematic maps presenting the distributions of different variables and patches of different kinds within the area, as well as versatile descriptive information on the area.

As the result of the evaluation process, only ordinal information on the priorities of alternative plans with respect to timber production, and to ecological and recreational considerations was available. Thus, an MCDA method capable to make use of that kind of low quality evaluation information was needed. To solve the multiple criteria decision problem at hand, we applied the stochastic multiple-criteria acceptability analysis with ordinal information (SMAA-O) (Miettinen et al., 1999; Lahdelma et al., 2003), specially developed for dealing with ordinal or mixed data in decision analyses.

Table 2
Rankings of alternative plans with respect to the criteria applied in the analyses

Criteria	Ranking
Timber Production	P11>P12>P21>P31?P22>P13>P32>P23>P33
Recreation	P33?P23>P13>P22?P32>P12>P31>P21>P11
Ecology	P32>P33>P23?P31>P22?P21>P13?P12?P11

SMAA-O belongs to the family of SMAA methods (stochastic multicriteria acceptability analysis). SMAA methods have been developed for discrete multicriteria problems, where criteria data are uncertain or inaccurate and where it for some reason is impossible to obtain accurate or any weight information from the decision makers (Lahdelma et al., 1998; Hokkanen et al., 1999; Lahdelma and Salminen, 2001). The SMAA methods are based on exploring the weight space in order to describe the valuations that would make each alternative be the preferred one, or that would give a certain rank for an alternative.

SMAA-O represents inaccurate or uncertain cardinal criteria values by a joint probability distribution. Decision-makers' unknown or partly known preferences are at the same time simulated by choosing weights randomly from appropriate distributions. The main results of the SMAA-O analysis are *rank acceptability indices*, *central weight vectors* and *confidence factors* for different alternatives.

The rank acceptability indices describe the variety of different preferences resulting in a certain rank for an alternative; in other words, it is the probability of the alternative getting that rank. An acceptability index of one indicates a dominant alternative (it is the best irrespective of the weights); an index of zero or near zero indicates an inefficient alternative (irrespective of the weights, some alternative is always better than the alternative considered). Computationally, the analysis is carried out so that random weight and criteria vectors are generated from their distributions, and acceptability index is the proportion of these realisations giving the alternative the first rank (Miettinen et al., 1999).

The central weight vectors describe the typical preferences favoring each alternative (among the weight space limited by the problem parameters; e.g. by the importance order of the criteria). The confidence factors measure whether the criteria data are sufficiently accurate for making an informed decision: it is the probability of the alternative getting the first rank if the central weight vector favoring it is applied.

The holistic acceptability index aims to measure the 'overall acceptability' of alternatives. It is calculated as a weighted sum of the rank acceptability indices using so-called *meta-weights*

Table 3
Results of the SMAA-O calculation with no importance order for the criteria

Plan	$R1$	$R2$	$R3$	$R4$	$R5$	$R6$	$R7$	$R8$	$R9$	HAI	CF
P11	12.3	7.2	4.1	3.6	4.3	3.9	8.7	12.4	43.6	24.2	61.0
P12	9.6	13.1	6.1	5.4	7.5	20.7	19.0	17.7	0.9	32.9	47.0
P21	2.0	3.6	10.8	7.7	9.2	18.2	12.9	27.9	7.7	22.1	16.2
P13	0.7	1.4	8.5	8.5	16.3	15.3	15.7	10.1	23.3	18.9	7.6
P31	2.2	4.4	6.2	18.5	22.5	16.3	20.0	6.4	3.5	26.8	18.5
P22	9.0	8.4	14.1	36.5	23.9	5.5	1.6	0.9	0.0	41.6	44.1
P32	24.2	9.6	21.1	5.5	4.1	5.0	8.2	13.2	2.7	49.7	76.3
P23	16.0	24.2	21.1	5.5	4.1	5.0	8.2	13.2	2.7	47.7	50.0
P33	23.9	28.1	7.7	4.5	3.8	3.7	5.4	7.7	15.2	50.4	67.4

Ri = rank acceptability index for rank i (i = 1,... 9), HAI = holistic acceptability index, CF = confidence factor.

$1 \geq \alpha_1 \geq \alpha_2 \geq \ldots \geq \alpha_m \geq 0$. There are many ways to choose the meta-weights (Lahdelma and Salminen, 2001). In this study we assigned $\alpha_m = 0$ and used $m-1$ dimensional centroid meta-weights for the remaining α_r.

Ordinal data are converted into stochastic cardinal data by simulating mappings between ordinal and cardinal scales that preserve the given rankings. This is done by generating random numbers from a uniform distribution in the interval [0,1], sorting the numbers into descending order and assigning each rank a number, in order to obtain one realisation of the possible underlying cardinal criterion values. This way, the obtained cardinal values include uncertainty of the actual values, but the ranking is assumed to be 100% sure. It would, however, also be possible to assume that the ranking could be incorrect with some small, say 5%, possibility (Leskinen et al., 2003). The method works well also with mixed ordinal and stochastic cardinal data. The mapping phase is then applied only for ordinal criteria. For more details of the method, readers are referred to Miettinen et al. (1999) and Lahdelma et al. (2003); and for forestry application to Kangas et al. (2003) and Kangas and Kangas (2003).

3.4. Calculation results in the case study problem

When applying SMAA methods, a calculation without any criteria weights or importance was first performed. In our case, all the forest plans proved to be efficient ones among the set of alternatives examined. Rank acceptability index for the first rank was more than zero for all the plans, indicating that for each plan there exists a weight vector that supports the choice of the plan. However, according to the rank acceptability indices, holistic acceptability indices, and confidence factors, it could be concluded that plans P11, P23, P32, and P33 had most potential over all the possible weightings (Table 3).

Studying the central weight vectors showed that emphasizing different criteria would favor different plans (Table 4). For example, it seems that P11 would be the recommended choice, if Timber Production were emphasised as the only significant criterion. Correspondingly, choosing P23 would reflect prioritizing recreation aspects over other criteria, and taking ecological objectives as the most important criterion would most probably lead to the choice of P32. P33, the fourth potential alternative as defined above on grounds of the measures presented in Table 3, in turn, can be taken as a choice that nearly ignores Timber Production as a decision criterion but at the same time provides a compromise solution between Recreation and Ecology.

Table 4
Central weight vectors for the first rank for the plans according to the SMAA-O calculation with no importance order for the criteria

Plan	Timber Production	Recreation	Ecology
P11	0.708	0.115	0.177
P12	0.599	0.261	0.140
P21	0.548	0.090	0.363
P13	0.390	0.539	0.070
P31	0.469	0.095	0.436
P22	0.459	0.353	0.188
P32	0.229	0.175	0.596
P23	0.232	0.574	0.194
P33	0.131	0.502	0.367

Table 5
Results of the SMAA-O calculation with the importance order Ecology>Timber Production>Recreation

Plan	$R1$	$R2$	$R3$	$R4$	$R5$	$R6$	$R7$	$R8$	$R9$	HAI	CF
P11	1.1	2.8	3.2	4.0	6.9	7.7	27.4	34.0	13.0	15.6	6.8
P12	0.6	1.7	3.0	5.0	7.9	11.7	38.2	29.8	2.1	16.8	2.4
P21	2.6	5.1	7.8	11.3	19.2	36.4	8.9	6.3	2.4	27.3	8.7
P13	0.0	0.0	0.1	0.2	0.8	1.6	5.9	11.8	79.7	2.4	0.0
P31	5.7	13.0	15.1	33.3	16.7	9.1	3.9	2.5	0.6	39.8	13.0
P22	3.4	7.8	11.5	20.5	31.5	16.5	5.0	3.9	0.0	33.5	9.7
P32	76.3	11.5	5.5	3.8	1.3	1.3	0.2	0.1	0.0	88.3	89.7
P23	3.3	14.1	37.2	13.7	8.7	9.2	5.3	7.4	1.2	40.1	9.7
P33	6.8	44.1	16.8	8.2	7.2	6.5	5.1	4.2	1.0	50.3	16.2

Ri = rank acceptability index for rank i (i = 1,... 9), HAI = holistic acceptability index, CF = confidence factor.

The confidence factors show that also some other alternatives, beyond the ones determined above as having most potential, could be reasonable choices. For example, CF 47.0 for P12 means that this alternative has the 47.0% probability to be the best one if the corresponding central weight vector is applied. It also has a greater holistic acceptability index than P11, for instance. The reason for this, or more accurately: reason for the low holistic acceptability index for P11, is that P11 is a ‘corner solution’ with great emphasis on Timber Production and bad consequences with respect to other criteria. Weighting Recreation and Ecology would lead to low ranks for P11. As a result of this, P11’s rank acceptability index for the lowest rank is great. Accordingly, P11 would be a very risky choice if no information on the criteria weights were available.

In a planning process, or at least in the final decision making, some importance should be allocated for the criteria. Each choice would inherently reflect some mutual weighting of the criteria. In our case study, the decision situation and the study area were real, but at this phase of the actual planning process, no final decisions were to be made. Instead, the main task was to preliminarily test the application potential of the socioecological planning approach and the SMAA-O method within it. For illustrative purposes, we also performed a SMAA-O calculation with the following importance order for the criteria: Ecology>Timber Production>Recreation. The results showed the superiority of P32 with this importance order for the criteria (Table 5).

4. Discussion and conclusion

The socioecological landscape planning approach has been developed for supporting complex multiple criteria decision-making processes within the field of natural resource management. In the application described above, the approach has been fine-tuned for suiting the planning needs particularly in boreal coniferous forests. The principles of forming ecological networks might particularly need some elaboration in other regions. However, we think that the very ideas of the approach might be applicable elsewhere, too.

So far, the socioecological landscape planning approach has not been widely applied in practical forestry. However, the Finnish Forest and Park Service (FPS), governing the vast majority of State-owned lands in Finland (approx. 9 million ha), has decided to apply the very ideas of the approach in natural resources planning. The practicability of the approach will be further tested within a pilot project that has already started in Kainuu region, eastern Finland. Our case study area falls within this region. On the grounds of the experiences gained in the pilot project, the approach as well as methods and techniques adopted will be elaborated, if necessary, before expanding their use to all the forests governed by FPS. For example, different decision analysis methods will be considered.

It must be emphasised that we did not organise any large public participation process in this first test of the socioecological planning approach. Applying any MCDA method does not replace the assessment by different groups of stakeholders; at best they can complement each other. A proper participation process requires also other means to facilitate information exchange, communication and collaboration. Anyway, the socioecological planning framework may serve as a platform for different kinds of analyses within a participatory process. The idea is that participatory feedback is taken into account when forming alternative sociocultural networks, and MCDA methods can be employed in incorporating preferences of interest groups and citizens into the prioritisation of alternative plans.

In the case study, an alternative that emphasised ecological objectives (P32) was chosen when the importance order Ecology>Timber Production>Recreation was applied. This was not a surprise after studying the results of the basic analysis with no importance order for the criteria. On the grounds of the rank acceptability indices and confidence factors of the basic analysis it could already be deducted that P32 was a potential alternative. The central weight vectors, in turn, showed that emphasizing Ecology as a decision criterion would easily lead to P32 as the recommended choice. P32 had the greatest confidence factor of all alternatives, 76.3, indicating that with the central weights 0.229, 0.175 and 0.596 for Timber Production, Recreation, and Ecology, respectively, P32 would be the best choice with 76.3% probability.

Although the main purpose of the case study was to illustrate the planning approach and acquiring high quality evaluation information was not a priority, the same kind of situations might be common in practical multi-objective forest planning where ordinal and more or less descriptive evaluation data are frequently faced. Especially when ecological and sociocultural objectives are involved, cardinal evaluations are usually not available regarding all of them. Also, criteria weights are often hard to assess on ratio scale. In our case only the importance order for the criteria was determined instead of cardinal weights.

However, it often makes sense to invest in acquiring higher quality and more accurate information concerning both evaluation data and preferences, and apply corresponding analysis methods (Kangas et al., 2001b). This is particularly the case in conflict management situations where versatile trade-off analyses are needed (Martin et al., 1996). In a complex practical planning process it might also be useful to apply more than just one MCDA method, or hybrids of them, in order to gain more versatile and deeper insight in the planning problem (Belton and Stewart, 2001; Kangas et al., 2001b).

In the decision analysis phase of the socioecological landscape planning process above, we applied the SMAA-O method. It enabled the utilisation of the rankings in the holistic evaluation of alternative plans, as was required in the application presented. However, depending on the characteristics of the planning situation in question, other MCDA methods might be applied. For example, in the Kainuu Pilot Project, methods based on voting theory (Shields et al., 1999; Laukkanen et al., 2002) will be applied in the participatory decision support phase, but also SMAA-O and the combined use of voting methods and SMAA-O (Kangas and Kangas, 2003) will later be tested.

As the main purpose of our case study finally was to illustrate the new socioecological landscape planning approach, we found it reasonable to be satisfied with the information quite readily available. In order to produce simple enough an example and to avoid unnecessarily complicated calculations, we also were content with just one wood production programme per each combination of ecological and sociocultural networks. It would be possible, and normally it would also be recommendable in practical planning processes, to produce a host of different wood-production programmes per each socioecological solution.

The socioecological landscape planning approach was rather briefly and straightforwardly presented in this paper. However, there are versatile application possibilities of the approach and its different phases, especially the different layers of socioecological networks. For example, the areas, which are subject to pressures by more than one objective, can be pinpointed by analysing the network alternatives formed by means of GIS applications. When selecting items to be set aside, this information can be used to favour areas, whose objectives can be interconnected observing the principles of overlapping use. When this is done, several different functions will be simultaneously practised in the same area, e.g. hiking, game management and preservation of the local ecology. However, the method serves as an aid in managing conflict because it can be used to pinpoint areas, which are potential sources of the conflict. The measures compliant with the objectives in these areas are in mutual conflict, which means that the use forms must be differentiated regionally (e.g. concerted recreational use and an ecologically sensitive area).

Applying ideas of socioecological landscape planning in forest management does not necessarily mean strict conservation of areas belonging to the networks set aside from timber production purposes. Nevertheless, in our case study no cuttings were carried out in them during the ten years planning horizon. Even the network of ecologically valuable areas and connections between them need not to be taken as conserved forever. Maintaining biodiversity may also require some treatments be applied in some ecologically valuable patches, to say nothing about the management of scenically sensitive forest stands. Furthermore, the 10-year time horizon as applied in the case study, although typical for tactical forest planning, does not allow the examination of forest dynamics in the long run. Taking the spatial considerations and long-run forest dynamics more accurately into account both from the viewpoint of ecology and sociology in planning are important topics for future studies.

Acknowledgments

The research work reported in this paper was funded by the Academy of Finland (decision number 73392), the Finnish Forest Research Institute and the Ministry of Agriculture and Forestry of Finland.

References

Belton, V., Stewart, T.J., 2001. Multiple Criteria Decision Analysis: An Integrated Approach. Kluwer Academic Publishers, Dordrecht.

Bouyssou, D., Machant, T., Pirlot, M., Perny, P., Tsoukias, A., Vincke, Ph., 2000. Evaluation and Decision Models. A Critical Perspective. Kluwer Academic Publishers, Boston.

Grumbine, R.E., 1994. What is ecosystem management? Conservation Biology 8, 27–38.

Hokkanen, J., Lahdelma, R., Salminen, P., 1999. A multiple criteria decision model for analyzing and choosing among different development patterns for the Helsinki cargo harbor. Socio–Economic Planning Sciences 33, 1–23.

Hytönen, L., Leskinen, P., Store, R., 2001. A spatial approach to participatory planning in forestry decision making. Scandinavian Journal of Forest Research 17, 62–71.

Kangas, J., Kangas, A., 2002. Multiple criteria decision support methods in forest management: an overview and comparative analyses. In: Pukkala, T. (Ed.), Multi-objective Forest Planning, Managing Forest Ecosystems, Vol. 6. pp. 37–70.

Kangas, J., Store, R., 2002. Socioecological landscape planning: An approach to multi-functional forest management. Silva Fennica 36, 867–871.

Kangas, J., Kangas, A., 2003. Multicriteria approval and SMAA-O in natural resources decision analysis with both ordinal and cardinal criteria. Journal of Multi-Criteria Decision Analysis. In press.

Kangas, J., Store, R., Leskinen, P., Mehtätalo, L., 2000. Improving the quality of landscape ecological forest planning by utilizing advanced decision-support tools. Forest Ecology and Management 132, 157–171.

Kangas, J., Pukkala, T., Kangas, A.S., 2001a. HERO: heuristic optimisation for multi-criteria forestry decision analysis. In: Schmoldt, D., Kangas, J., Mendoza, G.A., Pesonen, M. (Eds.), The Analytic Hierarchy Process in Natural Resource and Environmental Decision Making, Managing Forest Ecosystems Vol. 3. Kluwer Academic Publishers, pp. 51–65.

Kangas, J., Kangas, A., Leskinen, P., Pykäläinen, J., 2001b. MCDM methods in strategic planning of forestry on state-owned lands in Finland: applications and experiences. Journal of Multi-Criteria Decision Analysis 10, 257–271.

Kangas, J., Hokkanen, J., Kangas, A., Lahdelma, R., Salminen, P., 2003. Applying stochastic multicriteria acceptability analysis to forest ecosystem management with both cardinal and ordinal criteria. Forest Science 49, 928–937.

Karvonen, L., 2000. Guidelines for Landscape Ecological Planning, Vol. 36. Forestry Publications of Metsähallitus, pp. 46.

Lackey, R.T., 1998. Seven pillars of ecosystem management. Landscape and Urban Planning 40, 21–30.

Lahdelma, R., Salminen, P., 2001. SMAA-2: stochastic multicriteria acceptability analysis for group decision making. Operations Research 49, 444–454.

Lahdelma, R., Hokkanen, J., Salminen, P., 1998. SMAA-Stochastic multiobjective acceptability analysis. European Journal of Operational Research 106, 137–143.

Lahdelma, R., Miettinen, K., Salminen, P., 2003. Ordinal criteria in stochastic multicriteria acceptability analysis (SMAA). European Journal of Operational Research 147, 117–127.

Laukkanen, S., Kangas, A., Kangas, J., 2002. Applying voting theory in natural resource management: a case of multiple-criteria group decision support. Journal of Environmental Management 64, 127–137.

Leitao, A.B., Ahern, J., 2002. Applying landscape ecological concepts and metrics in sustainable landscape planning. Landscape and Urban Planning 59, 65–93.

Leskinen, P., Kangas, A., Kangas, J., 2003. Rank-based modelling of preferences in multi-criteria decision-making. European Journal of Operational Research. In press.

Martin, W.E., Shields, D.J., Tolwinski, B., Kent, B., 1996. An application of social choice theory to U.S.D.A. Forest Service decision making. Journal of Policy Modelling 18, 603–621.

Miettinen K., Lahdelma, R., Salminen, P., 1999. SMAA-O – Stochastic Multicriteria Acceptability Analysis with ordinal criteria. Reports of the Department of Mathematical Information Technology, Series B, Scientific computing No. B 5/1999. University of Jyväskylä.

Näpänkangas, J., Meriruoko, A., Tolonen, A., Vainio, M., Jäntti, R., Juntunen, H., Herttuainen, E., 1998. Vuokin alue-ekologinen suunnitelma. [Landscape ecological plan of the Vuokki area. In Finnish] Metsähallituksen metsätalouden julkaisuja 19. p. 78.

Pirot, J., Meynell, P., Elder, D. (Eds.), 2000. Ecosystem Management: Lessons from Around the World – A Guide for Development and Conservation Practitioners. Gland, Switzerland. p. 132.

Pukkala, T., 1999. Monikäytön suunnitteluohjelmisto MONSU. [Multiple-use planning package MONSU. In Finnish]. Mimeograph. University of Joensuu. p. 45.

Shields, D.J., Tolwinski, B., Keny, B.M., 1999. Models for conflict resolution in ecosystem management. Socio–Economic Planning Sciences 33, 61–84.

Store, R., Kangas, J., 2001. Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling. Landscape and Urban Planning 55, 73–93.