Integration of preference elicitation and the development of alternative forest plans: focusing on the requirements of the decision maker

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Academic dissertation

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ABSTRACT

Modern forest management frequently revolves around the concepts of developing strategic, tactical and operational level plans. These plans are developed through the use of simulation and optimization software, based on scientific models and mathematical programming. The optimal management schedule depends upon the decision maker(s) (DM) preferences. When developing forest plans for the DM(s) the method of acquiring preference information should be as value free as possible. To facilitate a DM-orientated approach, a selection of alternatives based on the acquired preferences should be made available to the DM so that a true choice can be made. The development of the forest plans should represent the desires and wishes of the forest owner at the time the plan is created. In order to balance the costs with the quality of the service provided, tools are required which develop client specific forest plans.

The first objective of this thesis is to analyse different preference elicitation methods and study the impacts of information content on the selection of a plan. In papers I and II, plans were selected using an a posteriori method of preference elicitation. For paper III, preference elicitation was done in an interactive fashion, to develop an acceptable forest plan using both a priori and a posteriori preference elicitation methods.

The second objective is to develop techniques for incorporating preference information into optimization methods. In paper IV, a series of goal programming models were used to incorporate the preference information from several DMs to generate a number of potentially desirable forest plans. Paper V develops a goal programming formulation which separates the treatment of different goals into two partitions; one strives to maintain the difference from the target for the goals in balance, the other strives to obtain the most efficient aggregate solution.

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Helsinki, August 2012

Kyle Eyvindson

LIST OF ORIGINAL ARTICLES

This dissertation consists of a summary and the five following articles, which are referred to by roman numerals I-V. Articles I, II and IV are reprints of previously published articles reprinted here with the permission of the publisher. Articles III and V are the authors versions of the submitted manuscripts.

I   Eyvindson, K., Kurttila, M., Hujala, T. and Salminen, O. 2011. An Internet Supported Planning Approach for Joint Ownership Forest Holdings. Small-scale Forestry 10:1-17.
doi: 10.1007/s11842-010-9123-1

II   Eyvindson, K., Hujala, T., Kangas, A. and Kurttila, M. 2012. Selecting a forest plan among alternatives: Consistency of preferences within decision support frameworks. Forest Policy and Economics. 15:114-122.
doi: 10.1016/j.forpol.2011.09.009

III   Eyvindson, K., Hujala, T., Kurttila, M., and Kangas, A. 2012. Interactive preference elicitation incorporating a priori and a posteriori methods. Manuscript.

IV   Eyvindson, K., Kangas, A., Kurttila, M. and Hujala, T. 2010. Using preference information in developing alternative forest plans. Canadian Journal of Forest Research 40: 2398-2410.
doi: 10.1139/X10-179

V   Eyvindson, K. 2012. Balancing equity and efficiency of Goal Programming for use in Forest Management Planning. Manuscript.

Authors' contributions

Kyle Eyvindson was the main author and fully responsible for the data analyses and writing for all of the articles. For article I, Mikko Kurttila led the designing of the study, and the preliminary and follow-up interviews were conducted by Mikko Kurttila and Teppo Hujala. Kyle Eyvindson and Teppo Hujala jointly constructed the research design for study II. Annika Kangas and Mikko Kurttila participated in designing the studies III and IV.

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INTRODUCTION

Forest planning decision process

The central figures in any decision making process are those individuals with the legal authority to take action. In forest planning, the decision maker (DM) is the forest owner. The owner could be the state, a company, a joint ownership or an individual. In this thesis, the focus will be on the latter two, although general principles will hold for the two former ownership types. When developing a forest management plan the owner is usually assisted by a professional forester, who provides suggestions as to what would consist of an efficient use of the forest resources. For the plan to be of real value to the forest owner, the scheduled forestry operations should relate directly to the preferences of the DM. Thus, the professional forester should use techniques to elicit the DMs preferences, and develop plans which match those preferences as closely as possible (Pykäläinen 2000).

Developing a forest plan with clearly developed goals is a relatively straightforward task. Depending on how the DM wishes to portray their expectations, a wide variety of tools are available to develop potential solutions for the problem (Diaz-Balteiro and Romero 2008). Without clearly defined goals, the functionality of these tools becomes limited. Thus, when DMs do not have a clear set of preferences, the selection and implementation of different preference elicitation tools becomes very important. The elicitation tool should strive to obtain preference data which are not influenced by how the question is framed (Tversky and Kahneman 1981), or or not inadvertently influenced by the analysts (Tversky and Kahneman 1974).

Developing a forest plan can be thought of as a multicriteria problem, with a vast number of alternative Pareto efficient solutions possible amongst the criteria of interest. Within this set of solutions, there is not just one single optimal plan which can be identified; rather the optimal plan depends specifically on the preferences of the DM. Since the DM usually needs to reflect and explore the decision situation, an appropriate set of alternative plans should be created and presented. The role of the DMs preferential information in solving multicriteria optimization problems has been classified by Hwang and Masud (1979) and further by Miettinen (1999).

Depending on the participation of the DM, Miettinen (1999) separates the roles into four different preference elicitation categories, non-participation, a priori elicitation, a posteriori elicitation and interactive methods. Non-participation occurs when there is no DM, or the DM does not wish to participate in the optimization process. A common example is to assume that the DM wishes to maximize the net-present value of the forest (Pukkala et al. 2011; Öhman et al. 2011). For a priori methods, the DM states their desired preferences and a solution is generated based on those stated preferences. This can be used in forestry where the DMs preferences are very clear. For example, Kangas and Pukkala (1992) derived the preferences of the DM through the use of the analytic hierarchy process (AHP), which were then incorporated into a goal programming model. In a posteriori methods, a representative set of alternative solutions is shown to the DM, and from that set the DM is to select the most appropriate solution. As examples, Kangas (1993) used AHP to define a hierarchical structure to evaluate

different plans; Hiltunen et al. (2008) used voting methods to evaluate different forest plans in a participatory planning setting. Interactive methods include the DM throughout the entire process, and it is expected that as the process continues that through a reflective process the DM learns about the feasible solutions and develops a more concrete set of realistic preferences. Pykäläinen and Kurttila (2009) and Pykäläinen et al. (2007) use interactive processes to involve the DM into the development of forest plans, and they noted the need for tools which developed plans quickly based on updated preference information.

Developing a decision support tool which is acceptable and useful to both the decision maker and the consultant is a difficult task (Belton and Hodgkin 1999). The DM may not have previously made long-term decisions, or decisions with a wide variety of possible alternatives (Beshears et al. 2008). The aim of the consultant should be to provide the DM with a specific plan, which strives to achieve the goals set by the DM. In order to achieve this goal, the consultant must either guess at the DMs preferences, substitute his/her own goals for the DM, conduct a value free interview with the DM, or use decision support tools to help define the DMs preferences. Decision support tools have the advantage of being process based, and can be subjected to critical review in a way the alternatives cannot. Regardless of which decision support tool is used, the method must require the DM to consider the tradeoffs required and should not lead the DM towards any pre-determined alternative.

Decision maker's preferences

The task of obtaining preferences from a DM is fraught with complications. If we were relying on traditional economic theory where "each individual has stable and coherent preferences" (Rabin 1998), the task would be as simple as either observing the decision maker, or asking the DM to describe his/her preferences. Psychological research challenges this assumption (Kahnemann and Tversky 1982) and suggests that either the preferences are hidden and need to be carefully revealed (Gregory et al. 1993) or that preferences are constructed for the task at hand (Payne et al. 1999). Regardless of whether preferences are hidden or constructed, all preferences can be influenced by intended or accidental persuasion. In a forest planning context, preference information may be influenced by the forestry professional's assumption that the forest owners should maximize income, or by the DMs belief that s/he would prefer conducting 'good' silviculture when income is more important. These assumptions may influence the DM towards selecting a plan which is not optimally suited to what they really want.

If preferences are constructed or discovered, the DM should be given opportunities to learn about the range of alternatives available when considering the plan for the forest. Through the development of preferences by supporting learning, the decision support tool contributes to both the satisfaction of the planning process and promotes awareness of the requirements of the planning task (Leskinen et al., 2009a; Hujala and Kurttila, 2010). In order to enhance the possibility of learning, the support tool could be tailored to the different learning styles (Kolb 1984) of different forest owners. As such, the elicitation of preferences could be considered as an 'education of possibilities' and / or a 'survey of opinions'. Through the process of education and learning, it should then

be possible to guide the DM to formulate the preferences in a way which captures the true preferences of the DM and at the same time can be integrated for use into a decision support tool. If the process proceeds smoothly, then ideally the preferences should appear as though they have been elicited from a DM with 'stable and coherent preferences' and these preferences would be able to be smoothly integrated into a decision support tool and develop a suitable solution.

The integration of preference information into a decision support tool is accomplished through the modification of the objective function and the set of constraints. Different optimization methods require the use of specific objective functions, thus the optimization method will depend on the preference information obtained from the DM. For instance, if a DM wishes to maximize profits while ensuring a set level of environmental standards, then linear programming (Dantzig 1963) would be appropriate. Or if a DM has a set of threshold requirements for a set of criteria, and s/he wishes to maximize the positive deviations from the thresholds, then weighted goal programming (Ignizio 1976) would be appropriate. The role of the decision consultant is to translate the preferences and wishes of the DM into a 'planning language' whereby appropriate analytical techniques can be applied.

The general premise behind linear programming (LP) is to maximize or minimize a linear function, subject to a set of given constraints and non-negativity restrictions (Steuer 1986). LP is well suited to determining the maximum sustainable harvesting levels while ensuring an even harvest flow or to minimize cutting levels subject to income requirements. A comprehensive description of applying LP to forest related problems is found in García (1990). Requiring DMs to structure their preferences in a form which can be solved in a LP format can be challenging. The use of LP is usually done by a professional, and the translation of preferences from a verbal concept to a strict mathematical formulation may misrepresent the DMs preferences. For instance, the constraints used in LP are very firm, and in a sense can 'out-weigh' the importance of the objective function.

Goal programming (GP) is a variant of LP, which allows the DM to specify targets directly for multiple criteria into a single objective function. The flexibility of GP allows for the incorporation of several different kinds of preference information into a single formulation. The minimum threshold value (a value which the DM does not want to go below for a specific criterion) can be used as a baseline, while the aspiration levels (the most preferred value for a specific criterion) can be used to distribute the positive deviations in a systematic fashion. In the event of multiple DMs, the GP formulation can incorporate the preferences of the different DMs (Gonzáles-Pachón and Romero 2007). In forest planning, and natural resource management in general, multiple sets of preferential opinions can be quite common place which makes GP a very suitable mathematical programming tool.

Preference elicitation

There are two general techniques which can be used for preference elicitation. The simplest technique is to obtain a stated preference by directly asking what his /her preferences are. These preferences may be considered to be more of an idealized version

of the DMs normative preferences, which represent the DM's true interests (Beshears et al. 2008). A more complicated and time consuming technique is to observe and measure the actions of the DM and uncover the revealed preferences of the DM. Revealed preferences are constrained by relying on past observations and they can be influenced by the structure of the observation and measurement procedures used.

Obtaining preference information requires diligent care during the elicitation process. A poorly formed question may directly influence the response given by the DM (Dillman et al. 2009). When structuring the elicitation process, several different structural options need to be carefully considered. Research into the elicitation of preferences has shown that the frame of the question (Tversky and Kahneman 1981), the presence of pre-defined initial values (or anchors, Tversky and Kahneman 1974) and cues which implicitly guide the DM (Solvic et al. 2007) can influence the response provided by the DM and thus questions the accuracy of the preferences obtained. For instance, preset defaults can direct a procrastinating DM towards selecting the default (Choi et al. 2006). The accuracy influences how the different mathematical formulations operate, and result in different plans depending on the input. Even though the preference information may have been either directly or indirectly influenced, and thus may be inaccurate, they are not necessarily invalid. While the specific value of the preference may be distorted, the relative order of the preferences can remain stable (Ariely et al. 2003).

The specific format of the preference information obtained has a direct impact on the future uses of the information. Among the many options for eliciting preference information are techniques which elicit specific weights for each criterion (Kangas and Pukkala 1992), elicit criteria specific aspiration levels (Lara and Romero 1992) and which set minimum thresholds for each criterion (Hiltunen et al. 2009). Each elicitation technique has strengths and weaknesses. Weights are easy to incorporate into optimization methods. The simplicity of the weights ignores the complexity of preferences and the potential variability in preferences as the DM becomes satisfied with the solution. Aspiration levels can be easy for DMs to understand, however the DM may provide targets which are either too pessimistic or optimistic. This requires that the DM understand the wide range of potential solutions for the problem. Minimum threshold values can provide a starting point from which the DM will be satisfied. Determining the minimum threshold values requires a set of predefined plans as a baseline, and this baseline may have an influence on the preferences of the DM.

While the technique of eliciting the preferences is important to the development of an appropriate solution, the compatibility of the preferences with the optimization or mathematical programming tool also needs to be considered. The selection and design of different achievement functions will impact the development of the solution. Thus, the forestry professional should understand the basic preferential structures contained within the achievement functions (Diaz-Balteiro et al. 2011), and they should be able to develop an achievement function which accurately reflects the preferences of the DM.

For a solitary DM, eliciting appropriate preferences can be rather complicated. Conducting the planning process in a participatory setting complicates the preference elicitation process and introduces other issues such as to how to aggregate the preferences. In previous research, the focus has been on how to aggregate preferences to indicate which solution should be selected. During the planning process for an urban forest holding, Nordström et al. (2009) combined the use of AHP and goal programming

to suggest a creative method of aggregating preferences. Through the use of different variables for the goal programming formulation, they developed several sets of rankings for the plans.

The decision making process for a forest holding can vary for a wide variety of reasons. The process can be different depending on the forest structure, the forest ownership structure, the personal situation of the DMs, the individual values each DM holds and the depending on the preferred method the DM likes to make decisions (Hujala et al. 2007; Hujala et al. 2009). Thus the tools used to support the decision making process, and the elicitation of preferences needs to be flexible and accommodating for these differences. The process should allow the DM to contemplate about his/her personal desires and to reflect if these desires are both possible and reasonable considering the current state of the forest holding.

OBJECTIVES

The general objective of this study is to develop methods and process outlines which incorporate the opinions of the DM in an integrated fashion for the development of forest plans and the choice between them. In order to accomplish this, it is necessary to analyze potential methods of how preference information can be elicited from the DM and how that information can then be used in the planning process. The integration of the elicited preference information into a mathematical model can occur in a multitude of different ways, with each method creating a different alternative plan. In order to generate a specific plan which matches the specific preferences of the DM, the method utilized should incorporate the DMs criteria specific preference and the DMs preference with respect to preferential structure implied by the mathematical model used. These sub-objectives were covered in a series of different papers.

Paper I describes a decision making process and preference elicitation approach facilitated by an internet based program on a jointly held forest holding. Paper II compares how consistent DM's preferences are when they are provided different levels of information. Paper III develops an interactive method which uses a priori preference information to develop alternative forest plans, and then provides the DM an opportunity to give a posteriori preference information by comparing the developed plans. Paper IV utilizes goal programming to generate a set of alternative forest plans based on preference information obtained from a decision support system. Paper V suggests a goal programming approach which balances efficiency and equity between different sets of criteria.

MATERIALS

Forest data

In this study, forest data from three different holdings were utilized. For papers I, IV, and V, the forest holding was a jointly owned holding in North Karelia, Eastern Finland. There were four legal owners, one of whom lived nearby the holding, and three others who lived up to 450 km away from the holding (Jyväskylä, Oulu and Helsinki). The forest inventory was conducted by the North Karelian Forestry Center in 2008. The forest holding was 57.8 ha with a fairly even age structure and consisted mainly of Norway Spruce.

The forest data set for paper II was an extraction of a holding used by the University of Helsinki for research and teaching purposes, and managed by Metsähallitus in Juupajoki, Tampere region (Central Southern Finland). For the purposes of the study, a selection of forest stands was chosen to represent a privately owned forest holding. The aim was not to generate a forest holding which represents the median forest holding, but just to present a reasonably possible non-industrial private forest holding. The selected stands represented a holding which was 53.5 ha, had an age structure slightly skewed towards younger stands, and had slightly more Scots Pine (51%) stands than Norway Spruce stands (43%). The inventory was conducted by Metsähallitus in 2008.

Paper III tested the idea of interactive forest planning with a real forest owner. The forest owner had recently purchased a forest plot from Metsähallitus in North Karelia, Eastern Finland. Prior to selling the property in 2010, Metsähallitus conducted an inventory detailing the forest holding for sale. This inventory information was used in the development of alternative forest plans. The holding was rather young, with almost 75% of the holding under 40 years old. The holding consisted of mainly Scots Pine, with some stands of Norway Spruce and two varieties of birch.

Preference data

For this study, preferences were elicited directly from stated preferences. We elicited stated preferences since revealed preferences are not generally available from private forest owners. This is because forest management activities occur only rarely and the introduction of new policy mechanisms or new silvicultural options would invalidate those available revealed preferences, since they would no longer be representative of the current situation. Stated preferences were required for several different purposes. One purpose was to determine which criteria the DM thought were important, another was to determine the relative importance of each criterion, and additionally stated preferences were used to determine the specific value requirements the DM had for each of the selected criterion.

The criteria specific preference data were collected in slightly different ways for the studies. For paper I the preference data was collected without direct interaction with the forestry professional. A detailed description and user-guidelines of the MESTA decision support tool (Pasanen et al. 2005) were provided to the owners, and each forest owner

was allowed time to use the internet program on their own time. Three of the forest owners were able to use the program independently; one required assistance, which was received from another forest owner. This preference data was also used to test the goal programming formulations in paper IV.

In paper II, 50 participants provided preference information in two different ways. First, each participant was asked to select a single suitable forest plan based on a comparison of brief written descriptions. Then as an alternative, each participant was directed through the use of MESTA and selected a plan which met their minimum preferences. The participants were assisted to use the MESTA program in a controlled experiment. The participants were given as much time as required to complete the task, but most of the participants provided their MESTA preferences in about 20 minutes.

For paper III, the individual forest owner provided three different forms of preference information. The participant first provided an initial preference value, which was framed between the theoretical minimum and maximum values. In addition, he provided a linguistic weight for each of the criteria. With this information, a set of alternative plans were generated, and then the MESTA program was used to derive the second set of preferences. Had the DM been not satisfied with any of the generated plans, the process would have gone through a second iteration. In paper V, the hypothetical preference information was generated by the author for illustration purposes and did not reflect the real forest owners' preferences.

METHODS

The selection of important criteria was done in different ways for each paper. The method used in study I was to have an analyst select typical important criteria, and then ask the forest owner if these were acceptable criteria. This method is easy for both the DM and the analyst. The variables selected by the analyst could be a set of variables which are representative of different forest values. For paper II, since the purpose was to test if the participants could select the same forest plan with varying levels of information, the criteria sets were predetermined by the authors. Another method used in paper III was to provide a long list of possible criteria, and have the DM select from the list. The analyst suggested a small set of 'essential' criteria which would provide at a minimum a representative set of different forest values.

The relative importance of each criterion was determined both explicitly and implicitly. For paper I, the implicit importance of the criterion was uncovered through the use of MESTA (Pasanen et al. 2005). Through the iterative approach, the DM was asked to modify the minimum threshold value to a point where they were feasibly possible; those criteria which were not as important were more readily modified. In paper III the determination of relative importance was done explicitly. The DM was provided an opportunity to select from a linguistic scale how important each criterion was.

The specific value requirements from the DM were determined in two ways. The first was through the use of MESTA, a multi-criteria decision support (MCDS) tool used to compare different forest plans in an a posteriori manner (Pasanen et al. 2005;

Hiltunen et al. 2009). The MESTA tool allows for the simultaneous comparison of a set of forest plans based on a set of relevant criteria. The plans are compared through a setting of an acceptance threshold, where plans which have at least a certain value are accepted, and those below are not accepted. The process is iterated for each criterion, until a single plan is considered acceptable. Through the iterative process, the DM is provided an opportunity to contemplate why certain trade-offs are required. The second method, used in paper III, asked the DM to provide a value for each criterion, framed between the minimum and maximum theoretical value. In this way, each criterion had a theoretically feasible value, which may lead to a set of criteria which is concurrently infeasible.

Generating forest plans

In order to develop forest plans based on the preferences of the DMs, first a simulation of the potential future conditions for each forest stand was created. There are several simulation programs which incorporate models for the Finnish forest conditions. The two most commonly used in Finland are the MELA program (Redsven et al. 2011), and the SIMO program (Rasinmäki et al. 2009). Both programs can be partitioned into two components, forest simulation system and an optimization system. The MELA program requires forest data on a stand level (MELASIM), and for optimization uses a linear programming system (MELAOPT) based on the JLP program (Lappi 2004). The SIMO program has been designed with a modular approach, so that the system can be easily adapted to a variety of simulation forms and optimization methods. In this study, the forest simulations were generated using the MELASIM program, and the forest plans were created by using linear programming with the MELAOPT program (papers I and II) or by using goal programming with the JLP program (papers III, IV and V).

Goal programming

Goal programming (GP) is an extension of linear programming, developed by Charnes et al. (1955) and Charnes and Cooper (1961). The basic premise of GP is to solve an objective function which, for a set of criteria, minimizes the distance between a target and the achievement for each criterion. The concept is based on the Simonian satisficing logic (Simon 1955, 1965), which suggests that human decision makers operate based on finding a solution which satisfies their requirements, rather than striving for an optimal solution. As a result, if the DM sets the goals too pessimistically, the solution found by GP may not be efficient in a Pareto sense (Jones and Tamiz 2010). This limitation can be overcome by either changing the objective function, or by having the DM set more optimistic goals (Tamiz and Jones 1996).

The use of GP in forestry applications has a history spanning nearly four decades. The first application of GP in forestry was carried out by Field (1973) in a land planning application. Hotvedt (1983) applied GP to a harvesting scheduling problem. Kangas and Pukkala (1992) linked the analytic hierarchy process (Saaty 1980) to GP as a means to estimate weights to be assigned to the deviation from the target level for the relevant

criteria. More recent uses of GP include the aggregation of preferences from different stakeholders participating in an urban forest planning process (Nordström et al. 2009), and the ranking of sustainability of different forest management plans (Diaz-Balteiro and Romero 2004).

There are several different versions of GP formulation. The three most commonly used are the Weighted GP (WGP, Ignizio 1976), Minimax GP (MGP, Flavell 1976) and Lexicographic GP (LGP, Ignizio 1976). The WGP formulation minimizes the aggregated difference from targets for all of the goals. The MGP formulation minimizes the maximum difference from the targets. Both of these formulations minimize the distance away from the targets; WGP minimizes the distance the aggregated distance, while MGP minimizes the maximum distance from the target (in L^p space, WGP minimizes L^1 space while MGP minimized L^∞ space (Tamiz et al. 1998)). The LGP formulation minimizes the distance depending on the form selected by the DM, and requires that the DM provides priority groups for the importance of the criteria. Each priority group includes those aspects which a DM considers are of equal importance. The LGP formulation does not allow compensation between priority groups.

The mathematical formulation for the WGP is as follows:

Objective function:

$$\min z = \sum_{i=1}^{q} (\alpha_i n_i + \beta_i p_i) \tag{1}$$

Goals and constraints:

$$f_i(x) + n_i - p_i = b_i, i \in \{1, \ldots, q\} \tag{2}$$

$$n \geq 0, p \geq 0 \tag{3}$$

Where q is the total number of criteria used; b_i is the target value for the ith goal; n_i and p_i are negative and positive deviations, respectively, from the target value b_i; $\alpha_i = w_i^+ k_i$ if n_i is unwanted, otherwise $\alpha_i = 0$; $\beta_i = w_i^- k_i$ if p_i is unwanted, otherwise $\beta i = 0$; the parameter w_i is the weight-reflecting preference for a particular goal i; and k_i is the normalization weight attached to goal i.

The mathematical formulation for the WGP is as follows:

Objective function:

$$min\ D \tag{4}$$

Goals and constraints:

$$(\alpha_i n_i + \beta_i p_i) - D\ \text{''}0 \tag{5}$$

and subject to equations 5 and 6; D is the maximum deviation away from all of the targets i.

The mathematical formulation for the LGP is as follows:

$$Lex\ (min\ z) = \left[\sum_{i\in_1} \alpha_i n_i + \beta_i p_i\ , \dots, \sum_{i\in_r} \alpha_i n_i + \beta_i p_i\ , \dots, \sum_{i\in_Q} \alpha_i n_i \right.$$

$$\left. + \beta_i p_i \right], r \in \{1, \dots, Q\} \tag{6}$$

and subject to equations 5 and 6; h_r represents the index set of goals placed in the rth priority group.

Further developments of these GP formulations have enhanced the customizability of the formulations. Romero (2001) has connected the WGP and the MGP formulations, in a formulation called Extended GP (EGP) through the introduction of a parameter (λ). The parameter is user controlled, and belongs to [0,1]. When λ is set to 0, EGP is identical to MPG; when it is set to 1, EGP is identical to WGP. Vitoriano and Romero (1999) have introduced the possibility to set the goal to be an interval rather than just a point. This allows an opportunity for the DM to provide a range where they would be satisfied. In addition, it provides for the introduction of a piecewise linear penalty function. This allows for small deviations from the goal to be treated less harshly than larger deviations. Romero (2004) has developed a general structure (extended lexicographic interval GP, ELIGP(K,K') which incorporates the penalty function, the EGP and LGP formulations.

When incorporating the preference information into the goal programming formulation, the analyst must be aware of the preferential structure of the formulation itself (Diaz-Balteiro et al. 2012). Without eliciting additional information from the DM, the goal programming formulation will solve the problem in an equivalent fashion for each criterion. If the DM is able to set priority groups for the criteria, then the use of lexicographic GP can be justified (Jones and Tamiz 2010). If a single goal programming formulation is to be used, then the analyst should ask pertinent questions to derive which formulation best suits the preferential structure of the DM.

The GP formulation developed in paper V directly considers the DMs preferences for how each criterion is to be treated. The formulation combines the WGP and the MGP formulations through a partitioning of the goals. The paper develops two separate formulations. The first formulation requires the DM to specifically state the partitioning of the goals. The second formulation integrates a binary variable into the formulation, which should make it easy to create alternative plans when no preferences are given for the partitioning of the goals. Both formulations will generate the same plan if the goals are partitioned in the same way, so for simplicity's sake only the first formulation will be highlighted.

We have q goals, which are partitioned as follows:

$$q = q_1 + q_2 \tag{7}$$

With: $q_1 = 1, 2, \ldots, q_1$ goals to be satisfied with the perspective of optimizing the average achievement and:

$q_2 = q_{1+1}, q_{1+2}, \ldots, q_2$ goals to be satisfied with the perspective of optimizing the balance achievement.

The mathematical formulation of the achievement function:

$$\min D + \sum_{i=1}^{q1} (\alpha_i n_i + \beta_i p_i) \tag{8}$$

Subject to:

$$\alpha_i n_i + \beta_i p_i - D'' 0, i \in (q_{1+1}, q_{1+2}, \ldots, q_2) \tag{9}$$

$$f(x) + n_i - p_i = b_i, i \in (1, \ldots, q_1, q_{1+1}, \ldots, q_2) \tag{10}$$

The concept behind this GP formulation encourages the differentiation of promoting balance between some criteria and the promotion of maximum aggregated value for other criteria. In natural resource management, this idea can be rather salient and important. For instance, many forest managers may be interested in maximizing the efficiency of economic criteria while maintaining the balance between a set of ecological criteria. The partitions provide the DM with a clear statement on how the criteria are treated, and the partitions describe how the preferences are structured. Since the partitions are merged into a single objective function, compensation can occur both between the different criteria and goal partitions. Through the DMs partitioning of criteria into groups a clear preferential structure can be expressed.

RESULTS

Process

In general, the forest owners who had participated the internet based planning process trial of paper I considered this kind of approach to be beneficial. They were pleasantly surprised that all of them generally agreed on the general forest management strategy, even though they did not discuss this prior to using the decision support system. Even though the planning approach was facilitated through the internet, the forest owners considered the role of the consultant important in the successful implementation. The owners also suggested that with the common experience of selecting between forest

plans, it should be easier to promote joint decisions regarding forest operations in the future.

Different decision support tools guide the DM towards selecting a plan through a variety of methods. In paper II, the consistency of individual preferences in selecting a forest plan is evaluated. The study focused on the decision making process, and whether or not the participants were able to make consistent choices with varying amounts of information. In general, most of the participants were able to select relatively similar plans (not necessarily the same plans) in the different choice scenarios.

Individual DMs prefer to make decisions or prefer to be assisted in the decision making process with different methods. Some DMs prefer to use qualitative methods when selecting between forest plans, while others prefer quantitative methods. In paper II, the participants were asked to provide feedback for each decision choice method as to the confidence with the method and simplicity of the method, as well as which decision choice method they preferred. An interesting finding was that even though some participants found selecting a plan through qualitative methods easier and were more confident with their choice than through the quantitative methods, in the end they preferred the quantitative method. The reasoning behind the thought process was that the DM had begun to realize the complexities of forest planning, and would rather face these complexities in the decision making process directly.

When examining the choices and specific quantitative preference values, it was noticed that the selection criteria should highlight the key differences between the different plans. In the study, subsets of 3 randomly selected groups were given a different set of 3-criteria to compare the different plans. One of these subsets had a much lower success rate of selecting the same forest plan. The main difference between the criteria set and the others was that for a single plan, all of the values for the three criteria were high, and in a way this caused the plan to dominate most of the other plans. This highlights the requirement for care to be put into the criteria selection, and that the criteria set should accurately describe the differences between the plans.

Acceptability of the generated plans

Integrating the DM into the early phases of forest planning should promote acceptance of the final plan and increase ownership of the plan (Appelstrand 2002). In paper III the DM was able to set all of the key factors which were involved in the design of a forest plan. The aspiration levels set by the DM were rather realistic, and most of the plans were mainly acceptable. The methods used to generate the forest plans minimized the distances from the preferences to the production possibility frontier. Thus, for those DMs with preferences near the frontier, the differences between the generated plans will be rather small.

In general, two different modes of arriving at an acceptable forest plan can be highlighted with the interactive method. The first is the situation when the DM has unrealistically high demands of the forest resources. The process in paper I guides the DM to realize that trade-offs between criteria are required, and that perhaps a moderation of expectations is required. This may cause the DM some disappointment, as expectations were formed during the elicitation processes which were impossible to

achieve (Klamroth and Miettinen 2008). The second situation is when the DM requires too little from the forest. The possibilities of the forest can be opened up to this kind of DM, and the potential forest management alternatives which suit their desires can encourage them to take more advantage of the forest.

As highlighted in paper III, individual DMs proceed differently when selecting between several solutions. In most cases, the decision making process is not determined solely on the preferences of the DM, but consideration of technical issues surrounding the planning process may be a limiting constraint (Kangas et al. 2001). In order to meet the challenges of the planning situation, appropriate modifications to the decision support techniques may be required (Chen et al. 1999; Kangas and Store 2003). For the specific case (Paper I) of having the DMs living in different cities, the use of a decision support tool, facilitated without face-to-face contact and supported by the internet, can be useful in selecting an acceptable forest management plan.

Technical Aspects

Guiding the DMs to choose a satisfactory plan from a very limited finite set of plans could be considered as limiting choice when the potential number of alternatives is vastly more. In paper IV, the planning process continued in the development of potentially more satisfactory forest plans. Through the use of several GP variants, the preference information of the different participants was combined to produce a variety of different plans, all of which were more specifically related to the DMs elicited preferences. Since the preference information provided represented the minimum threshold limits, the focus of the plan development was to be above that level. Some of the GP variants did produce plans which had values below the minimum values for some of the participants, but this was due to structure of the GP variant allowing for values above the minimum to compensate for values below the minimum. The compensation was not at a one-to-one level, but was dependent on the weight value given to the different variants.

A proposed method of integrating the acquisition of preference information and the generation of new alternative forest plans was developed in paper III. By incorporating the preferences directly into the development of forest plans, the hope is that the plans will provide a more accurate representation of the actions the forest owner will conduct in the future. The sequence of events (Figure 1) consists of four steps, of which three require actions from the owner. Two of the steps are related to the acquisition of preference information, one relates to how the DM wishes to proceed with the process and another relates to the creation of alternatives used in the analysis.

There are a few key attributes worth noting in this interactive process. The first is that the process is designed to provide a great deal of control over the construction of the plans in general. In step one, the selection of criteria is limited only to the data available, and the simulation program used. The subsequent preference elicitation is framed only by the theoretical minimum and maximum values for the selected criteria. Only in step three, does the DM need to consider more practical levels of threshold preference values. The second key attribute is that this process could be conducted through the internet with no direct face-to-face contact with the forest professional. The

entire process could provide the forest owner with a customized product, for a reasonable cost. The third key attribute is that all of the generated forest plans are directly related to the DMs preferences. By relating the preferences directly to the generated plans, the task of selecting a plan will be focused on a narrower range of alternatives. Rather than generating plans which span the production frontier, in this process the plans should span the production frontier within the interests of the DM, thus reducing the number of 'uninteresting' plans the DM needs to sort through.

The GP variant developed in paper V can create new alternative plans which treat the criteria in a very specific preferential manner. This variant differs from EGP in that while EGP finds solutions which merge WGP and MGP together directly for all of the criteria, this new variant can treat groups of goals in a different preferential structure, without requiring a strict prioritization of the different goals. For those DMs who can specify directly how they want the model to treat their preferences between criteria can find a direct solution. If the DM would like to analyze the differences between the potential alternatives, all of the plans can be generated and then a subset of the most different plans could be portrayed to the DM.
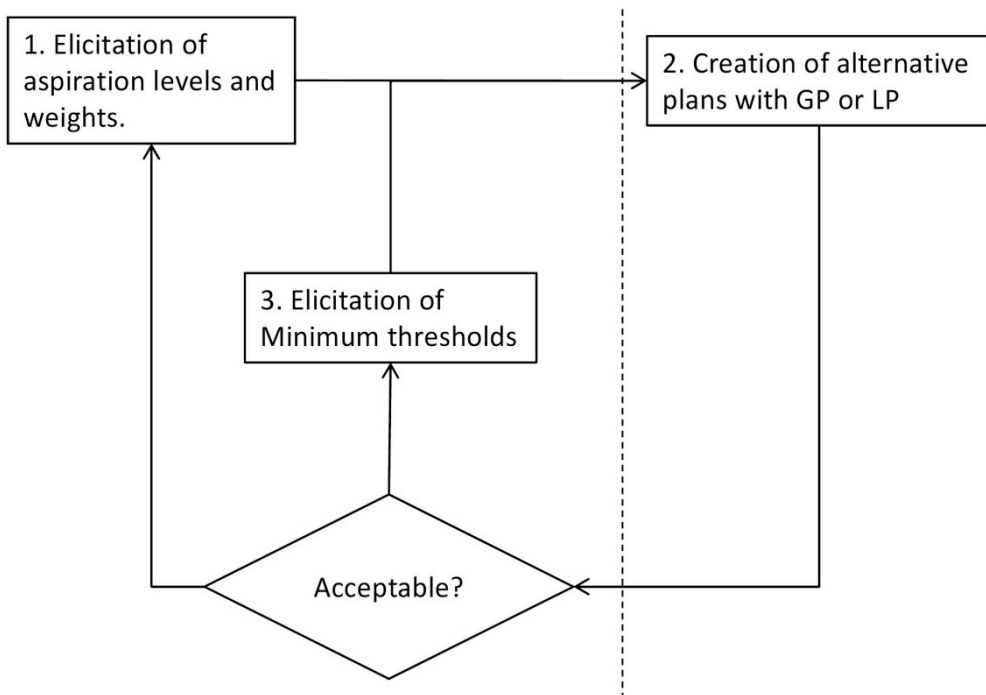

Figure 1. Activity flow chart: divided into steps which require involvement from the decision maker, and those which can be automated. (Paper IV)

DISCUSSION

Utilizing within a Decision Support System (DSS) framework

New decision support tools and new methods of providing decision support services should be developed to meet the challenges and demands from different forest owners. In the recent past, Finnish forest owners generally lived near to the forest and had a detailed understanding of his/her personal needs and the potential resources which could be obtained (Karppinen et al. 2002). Expectations in Finland are that a growing fragment of the next generation of forest owners will be primarily living away from the forest holding, in largely urban centers. This trend of urbanization of forest owners is not limited to Finland, but is also occurring in many other societies (Wiersum et al. 2005). Paper II implicitly addresses the challenge that this shift in forest owners will require a shift in how forest services and products are provided, and they should be suited to the urban professional's lifestyle. Thus, while the service may be conceptually demanding, this should be eased through the removal of forestry specific jargon.

For forest holdings jointly held by family members it may be difficult to find a common time to devote to the management of forest resources. When they do meet, the focus of the reunion will probably not include the aim of determining an appropriate management scheme for the forest. Allowing the owners an opportunity to conduct the forest management discussions with potentially no or limited requirement for face-to-face meetings, should promote a shared understanding of the forests importance for the owners. The focus of the discussions should hopefully lead to a written forest management plan, which would greatly assist the operations when practical decisions need to be made (such as actions taken in response to timber price changes). Currently there is no such service in practice, however paper I highlights the potential for development in the style of decision making.

Any DSS tool should be user friendly, have a short learning curve and stimulate the interest of the user so that it can be of use to a wide variety of participants. The results from paper I shows the possibility of utilizing a DSS in a participatory process for forest management. For this particular group of forest owners, the use of the MESTA alone provided enough assistance to find a feasible solution for a forest plan. The reason for this success was primarily due to the common interests of the forest owners, as MESTA would not have been able to recommend a suitable plan had the owners had divergent goals. The approach did stimulate ideas regarding how the approach could be modified when disagreements between goals were too great for a common plan to be acceptable.

A delicate balance needs to be found between maintaining the tools simplicity and enhancing the tools functionality. In paper I, the use of MESTA was simple enough for most of the participants to use independently. Only one participant who had limited computer skills required assistance from another participant. One of the participants suggested the addition of extra features, such as describing the effects of price changes on the income obtained from the cuttings. For those participants who require additional functionality, the compromise to maintaining simplicity may prevent more productive use of the system (Mahmood et al. 2000; O'Keefe et al. 2000; and Kangas and Store

2003). Thus, if there is demand for additional functionality, it should be done in a way which does not significantly add to the complexity of the system.

The approach to utilizing decision support tools describe in paper III could be implemented in a variety of different ways. While the study was conducted with a facilitator who controlled the different programs, speedy functionality could be provided with increased automation. This would limit the chance for imputation errors, and if a facilitator is present, his/her time could be better used providing explanations regarding the procedure in general and different information requirements. With increased automation, it would be possible to move the process to an internet based system, with the facilitation conducted over distance. Through integrating different kinds of preference information, and developing alternative plans which match the preferences, it can be expected that the DM would appreciate being able to not only select the plan, but to directly influence the development of the plan.

The possibility to select an appropriate set of criteria is a reasonable requirement when utilizing a quantitative decision support tool. Paper II highlighted the concept that for the participants to feel comfortable with the decision being made, they should also be comfortable with the associated elements of the decision support tool. However, the actual selection of the criteria may be difficult for a participant with little knowledge of forestry. For these participants, a predetermined set of criteria may be beneficial, by providing a general frame of criteria which considers the most important factors of forestry. Framing issues (Maule and Villejoubert 2007) need to be considered prior to providing the set of criteria to the DM, and the DM should be allowed an opportunity to add or remove criteria used in the analysis.

The ability of the participant to describe their preferences with the tools available should not be underestimated. Problems in preference elicitation occur when the DM cannot provide even an approximation of the preferences with the tool provided. This is exacerbated if the DM has not thought through his/her preferences or was not provided the opportunity to properly consider his/her preferences. While there are issues which impact the actual value provided by the DM (Tversky and Kahneman 1974; Tversky and Kahneman 1981; Solovic et al. 2007), the relative importance between the different criteria can provide an accurate representation of the relative preferences (Ariely et al. 2003). In order to promote the comprehensive acquisition of preferences, a reflective set of criteria covering the pertinent dimensions of the problem should either be selected independently by the DM or suggested by the forest professional.

The complexity of a decision support tools can impact how confident the DM is with his/her choice (paper II). Some DMs are more confident with making decisions based on a qualitative description of the plan, and less confident with quantitative evaluation of the plans. This could be because the decision was made in a familiar way. As a result, the DM may prefer written descriptions which provide a general outline of what the plan encompasses (paper II). This could indicate a difference between rule based decision making for the qualitative written descriptions and a utility maximizing behavior for quantitative numerical decision support methods (March 1994). The majority of decisions people make on a regular basis generally do not require a numerical analysis, and this may be reflected in the confidence levels concerning forest planning. In paper II, a few of the participants were equally confident when making the choice with the different tools, but selected completely different plans. This may indicate a kind of disconnect between the interpretation of the qualitative description and the criteria

values which were used to represent the different forest plans quantitatively. So while it may be beneficial for the DM to be confident in the decision, the confidence in itself may not reflect thoughtful and attentive decision making.

Generation of Alternative forest plans

The generation of a variety of alternative forest plans is typical when using a posteriori methods of preference elicitation. The information obtained from these methods is typically used to select the most preferred alternative within the set. The use of the preference information can provide for a two-stage model, where the DM learns about the production possibilities of the forest and then new plans are generated to narrow the gap between the DMs preferences and reality. This may lead to a reduction of preferential uncertainty in the second stage (Kangas 2006; Leskinen et al. 2009b), and thus provide a more preferred solution. The primary drawback of a two-stage model is the lag time after the elicitation of updated preferences and the creation of alternatives. Thus the interactive process should be automated, and it should be easy and quick to update the preference information.

For the cases when the DM provides a very limited set of preferences, or an incomplete set of preferences, several methods can be used to quantify the potential preferences. One method is to use stochastic estimations for the unknown preferences (Lahdelma et al. 1998). In a forestry context, Kangas et al. (2003) utilized Stochastic Multicriteria Acceptability Analysis with Ordinal Criteria (SMAA-O) to convert preferences of the criteria given in an ordinal fashion to a cardinal fashion. More recently Kurttila et al. (2009) evaluated the influence of preferential uncertainty has on forest management planning at both the stand and holding level. This method could be extended by incorporating the ideas of robust portfolio modeling (Liesiö et al. 2007; Liesiö et al. 2008).

In paper III, different forms of preference information were integrated into a system which generates alternative forest plans. Even with the same preference information it is possible to create a variety of different forest plans. If the preferences are not conflicting, and the preference values are close to the production potential frontier, the variation between plans should be small. However, if the preferences conflict (i.e. the DM wishes to maintain a high percentage of volume in the forest while demanding large short term income) then there will be a large potential for variation between the plans. Even though the plans are generated with the same preference information, the details of how these preferences should be interpreted is missing. The hope is that if the DMs reflect on the alternative forest plans, that they will be able to provide additional preference information which can focus which requirements are the most important.

When dealing with a participatory planning approach, the generation of alternative forest plans must consider both the balance between the individual participant's preferences, and the preferences between participants. In this situation, it may be beneficial for the facilitator to use a preference elicitation technique which elicits only preferences which are either equal to or less than the production potential frontier (Klamroth and Miettinen 2008). The reason for this is to limit the disappointment felt by the participants, since it is very rarely the case that in a participatory planning situation

all participants will have their preferences met. To avoid complicated computational normalization procedures, such as in Fan et al. (2006), the preferences for each participant should be elicited in a similar fashion, thus giving the preferences a similar structure; even if the values are not similar. The aggregation of preferences would be much more challenging if one participant provided a minimum threshold preference value, while the other provided an aspiration preference value.

The role of the forest planning professional will need to undergo a period of transformation if a system which automatically generates forest plans based on the forest owner(s) preference information is found to be useful to the DMs. The service provided by the professionals will shift towards more personalized service, directing the forest owners to learn about their forests and to assist in the decision making process. By focusing on the consumer, the goal should be to provide a service which the forest owner appreciates, and which guides the forest owner to make actual decisions regarding the treatment of the forest.

The GP formulation developed in paper V can generate a large number of alternative plans, and each plan can be directly linked to the preferences of the DM. However, this model is only suited for problems with six or more criteria. For problems with fewer criteria, a different model should be used. When the set of criteria is limited there is not sufficient space on the efficiency frontier to develop coherent and efficient solutions. In addition, when dealing with a very limited set of criteria, the separation of criteria into groups may not be sensible. As well, for each partition, the number of criteria must be at least two or greater. Finding the efficient balance of a single criterion is pointless; as well it is unreasonable to find the minimum aggregation of deviation for a single criterion.

Reflection

In general the methods developed in this study can be used to incorporate the DM into the development and selection of an appropriate forest plan. The central idea of this thesis is 'how can preferences obtained from the DM be incorporated in a pragmatic manner into an operations research tool'. The tool utilized for this analysis was goal programming, which can flexibly manage the use of a wide variety of preference information. Other operations research tools, such as the use of nonlinear optimization (Miettinen 1999) could have also been used.

The benefit of this approach is that the DM is encouraged to think clearly about what are his/her priorities regarding the forest, at the present time. So, for the current situation, the plan may be optimal, but as time progresses and priorities change, the actual decisions taken in the forest may not resemble the prescription found in the forest plan. Thus the criteria to evaluation the success of a planning system cannot be an evaluation of how closely the plan matches reality. Rather, the evaluation should be soft measures, such as how pleased the DM is with the planning process or how easily the DM can generate and modify operational decisions with the aid of the plan and knowledge created in the decision support process. Perhaps the ultimate measure of success would be that if the DM realizes that his/her preferences have dramatically shifted, that they would undergo an updated planning process.

The major limitations of this study are the number of real case studies used to evaluate if DMs value the tools. Different DMs may prefer to use different decision support tools; by analyzing the opinions of a larger number of DMs would be useful in qualitatively evaluating the tools effectiveness. For paper II, forestry students were used as a proxy for real forest owners, due to the time and cost constraints if a similarly sized study were to be conducted on real forest owners. The use of students as proxies has a fairly long history in the literature (Remus 1986). The interpretation of results must be done carefully, and only those factors which are comparable should be studied (Henrich et al. 2010; Rozin 2009).In addition, it could be useful to have the DMs compare between the current system of forest planning and the system developed.

The key features of this study are to present a few alternatives which highlight the potential directions that forest planners can move towards providing a DM orientated service. Some of the tools used in this study have been used in practical settings, generally in a group decision making scenario. Shifting the use of these tools towards a larger audience will require attention to the usability, reliability and flexibility of the tool in general.

Directions for future research

The conduct of actual forest management may differ dramatically from what was decided during the planning phase. Events can happen during the course of the planning period which may require adjustments in the management plan of the forest holding. By creating a forest plan which accurately reflects the owner(s) preferences, these modifications should be minor. However, a forest plan should not be rigidly followed, but should be used as a guide for deriving the most benefit from the forest.

A possible area of research could be to compare the differences between what was planned for the forest and what actually has occurred in the holding (Niskanen 2005). It is possible that there may be a benefit for describing to the DMs how their planning process corresponded to the actual operations. One method which may be useful in this approach could be the Data Envelopment Analysis (DEA) (Charnes et al. 1978). DEA has been used in forestry, for example to compare the efficiency of forest management operations at the regional level in Taiwan (Kao et al. 1993), to compare the efficiency of public forestry organizations in Finland (Viitala and Hänninen 1998) and more recently to assess the productivity and efficiency of the wood industry in Canada (Salehirad and Sowlati 2006).

The use of DEA may be useful in the evaluation of the efficiency of the planning process. The actual decisions of operations conducted could be compared with the production potential frontier derived from the initial data set used to generate the forest plan. To conduct this research, documentation regarding the actual operations taken in the forest would be required from the planning period. A simple evaluation between the actual events and the plan would be simple to do, but would not be very informative. Rather, through use of DEA and the development of a series of optimized forest plans based on the initial data, the preferences of the DM could be evaluated in an a posteriori fashion. In this way, we could compare the differences between the stated and observed

preferences. In this way the DM could critically reflect on the reasoning behind how (s)he set the stated preference values.

This kind of analysis may provide a greater benefit for participatory planning approaches. For instance, Metsähallitus develops regional forest plans for a ten-year period for each region and conducts an evaluation in the middle of the period. Since the forests are publically owned, participatory processes are integrated into the plans development (Metsähallitus 2005). The participants have their preferences elicited through their evaluations from a set of forest plans, and at the end of the process a single forest plan is selected. Through the use of the DEA method, it would be possible to evaluate how connected reality is to the previously selected forest plan, and in which direction the actual operations took the forest. The result would be that Metsähallitus and the participants of the process would gain a more comprehensive understanding how the planning process impacted the actual operations.

In a participatory planning process, the development of alternative forest plans should be given more attention. For those participatory processes which have intentions of provide participants a level of influence above the step of "consult" (International Association of Public Participation 2007), then the participants should be provided an opportunity to influence real choice. It could be argued that a posteriori methods for providing interaction to participants would not meet the metric for providing for influence of a real choice. While the selection between plans does provide options for choice, there is no opportunity provided to allow for the development of alternative plans. The participatory process could be interpreted as facilitating the support for one of the pre-defined plans.

One example of a facilitated participatory process which has allowed for the generation of specific alternative plans is the expansion of the Wabakimi Wilderness Park (Duinker et al. 1998) in central Ontario, Canada. The focus of the planning process was focused on a single factor, and the output of the process was for the group to propose an agreed upon updated park boundary. The process highlighted how the effect of negotiation and education can have on the individual preferences of the stakeholders, and how they can impact the overall plan.

Another aspect for further research is how to incorporate uncertainty into the planning process. Forest plans are very deterministic in nature, providing seemingly concrete values for future events. Profits are estimated through a constant timber price, growth models are based on historical averages and there is little mention of this uncertainty in the planning process. Current methods of estimating this uncertainty are available (Härkonen et al. 2010; Holopainen et al. 2010) and could be provided to the DM during the planning phase. Of course, the information should be provided in as comprehensible a fashion as possible. By providing an accurate representation of the uncertainties related to the forest, it is hoped that the forest owner would gain a more comprehensive understanding about the forest and be able to make better decisions.

Decision making under uncertainty is not necessarily a simple task, and incorporating the DMs personal preferences can make the process of decision making even more challenging. The role of the forestry professional should be to assist the DMs and guide them so that they can overcome the uncertainty and utilize the forest resources in a thoughtful manner. The improvement of forest inventory techniques, forest growth models and forest price forecasts should reduce the uncertainty encountered by forest owners. Determining the actual use of forest resources is

dependent on the preferences of the forest owner. Through learning about the forest and understanding the processes within the forest the forest owner should be more able to make decisions which reflect his/her current preferences.

The development of a forest plan is influenced by a wide variety of factors, and is essentially only a guide from which DMs can make real decisions. The selection of an appropriate forest plan may be just the first decision in a series of forest management related decisions. Thus the benefit of the forest plan is not just so that it can be used to determine actions in the forest, but also as a learning tool so that the DMs can feel more confident with the choices they make regarding the management of their forests.

REFERENCES

Appelstrand, M. 2002. Participation and societal values: the challenge for lawmakers and policy practitioners. Forest Policy and Economics 4, 281–290.

Ariely, D., Loewenstein, G. and Prelec, D. 2003. Coherent Arbitrariness: Stable Demand Curves Without Stable Preferences, Quarterly Journal of Economics 118, 73 – 106.

Belton, V. and Hodgkin, J. 1999. Facilitators, decision makers, D.I.Y. users: Is intelligent multicriteria decision support for all feasible or desirable? European Journal of Operational Research 113(2): 247–260.

Beshears, J., Choi, JJ., Laibson, D. and Madrian, BC. 2008. How Are Preferences Revealed? Journal of Public Economics, 92 ,1787–1794.

Charnes, A., Cooper, W.W. 1961. Management Models and Industrial Applications of Linear Programming, Wiley, New York.

—, Cooper, W.W. and Ferguson, R. 1955. Optimal estimation of executive compensation by linear programming, Management Science 1 pp. 138–151.

—, Cooper, W.W. and Rhodes, E. 1978. Measuring the efficiency of decision making units. Eur J Oper Res 2:429-444.

Chen, W.C., Hong, T.P., Jeng, R. 1999. A framework of decision support systems for use on the World Wide Web. Journal of Network and Computer Applications 22, 1-17.

Choi, J.J., Laibson, D., Madrian, B.C., and Metrick, A. 2006. Saving for retirement on the path of least resistance. In: E. McCaffrey and J. Slemrod, Editors, Behavioral Public Finance: Toward a New Agenda, Russell Sage Foundation, New York. pp. 304–351.

Dantzig, G.B. 1963. Linear Programming and Extensions, Princeton, New Jersey: Princeton University Press.

Diaz-Balteiro L. and Romero, C. 2004. Sustainability of forest management plans: a discrete goal programming approach. J. Environ. Mange. 71, 351-359.

— and Romero, C. 2008. Making forestry decisions with multiple criteria: A review and an assessment. Forest Ecology and Management. 255:3222-3241.

—, González-Pachón, J. and Romero, C. 2012. Goal programming and the Decision-Maker's Preferences: Some Interpretations from a forest Management Perspective. Manuscript.

Dillman, D., Smyth, J., and Christian, L. 2009. Internet, Mail and Mixed-Mode Surveys: The Tailored Design Method. 3rd Edition. Wiley & Sons, Inc.

Duinker, P., Armstrong, T., Hyer, B. & Peterson, B. 1998. Using caribou knowledge in expanding the Wabakimi protected area. – Rangifer. 10: 183-193.

Fan, Z.P., Ma, J., Jiang, Y.P., Sun, Y.H. and Ma, L. 2006. A goal programming approach to group decision making based on multiplicative preference relations and fuzzy preference relations, European Journal of Operational Research 174: 311–321.

Field, D.B. 1973. Goal programming for forest management. For. Sci. 19: 125-135.

Flavell, R.B. 1976. A new goal programming formulation. Omega. 4(6): 731–732.

García, O. 1990. Linear Programming and Related Approaches in Forest Planning. New Zealand Journal of Forestry Science 20(3):307-31.

Gonzáles-Pachón, J. and Romero, C. 2007. Inferring consensus weights from pairwise comparison matrices without suitable properties. Ann. Oper. Res. 154(1): 123-132. doi:10.1007/s10479-007-0182-4.

Gregory, R., Lichtenstein, S., & Slovic, P. 1993. Valuing environmental resources: A constructive approach. *Journal of Risk and Uncertainty, 7,* 177-197.

Holopainen, M., Vastaranta, M., Rasinmäki, J., Kalliovirta, J., Mäkinen, A., Haapanen, R., Melkas, T., Yu, X. and Hyyppä, J. 2010. Uncertainty in timber assortment estimates predicted from forest inventory data. Eur J Forest Res 129:1131-1142.

Härkönen, S., Mäkinen, A., Tokola, T., Rasinmäki, J., Kalliovirta, J. 2010 Evaluation of forest growth simulators with NFI permanent sample plot data from Finland. For. Ecol. Manage. 259:573-582.

Henrich, J., Heine, S.J., Norenzayan, A. 2010. The weirdest people in the world? Behavioral and Brain Sciences, 33. Cambridge University Press, pp. 61-83. doi: 10.1017/S0140525X0999152X.

Hiltunen, V., Kangas, J. and Pykäläinen, J. 2008. Voting methods in strategic forest planning—experiences from Metsähallitus. For. Policy Econ. 10, 117–127

—, Kurttila, M., Leskinen, P., Pasanen, K. and Pykäläinen, J. 2009. MESTA: An internet-based decision-support application for participatory strategic-level natural resources planning. Forest Policy and Economics, 11(1):1-9.

Hotvedt, J.E. 1983. Application of linear goal programming to forest harvest scheduling. Southern J. Agric. Econ. 15(1): 103-108.

Hujala, T. and Kurttila, M. 2010. Facilitated group decision making in hierarchical contexts. In: Kilgour, D.M. & Eden, C. (eds.). Handbook of Group Decision and Negotiation; Advances in Group Decision and Negotiation Vol. 4. Springer Netherlands, p. 325–337.

—, Pykäläinen, J. and Tikkanen, J. 2007. Decision making among Finnish non-industrial private forest owners: The role of professional opinion and desire to learn. Scandinavian Journal of Forest Research 22(5):454-463.

—, Tikkanen, J., Hänninen, H. and Virkkula, O. 2009. Family forest owners' perception towards decision support. Scandinavian Journal of Forest Research 24(5) 448-460.

Hwang, C.-L. And Masud, A.S.M. 1979. Multi objective decision making – Methods and applications. Berlin: Springer-Verlag.

Ignizio, J.P. 1976. Goal Programming and Extensions. Lexington Books, Lexington, MA.

International Association of Public Participation. 2007. International Association of Public Participation, Spectrum of Public Participation. Available from: http://www.iap2.org/associations/4748/files/spectrum.pdf (accessed 15.07.11.).

Jones, D., Tamiz, M. 2010. Practical Goal Programming

Kahneman, D. and Tversky, A. 1982. The psychology of preferences. Scientific American, 246 , 160–173.

Kangas, A. 2006. The risk of decision making with incomplete criteria weight information. Can. J. For. Res. **36**(1): 195-205. doi:10.1139/x05-243.

—, Kangas, J. and Pykaäläinen, J. 2001. Outranking methods as tools in strategic natural resources planning. Silva Fenn. 35, 215–227.

Kangas, J. 1993. A multi-attribute preference model for evaluating the reforestation chain alternatives of a forest stand. For. Ecol. Manage. 59, 271–288.

— and Store, R. 2003 Internet and teledemocracy in participatory planning of natural resources management. Landscape and Urban Planning 62, 89-101.

— and Pukkala, T. 1992. A decision theoretic approach applied to goal programming of forest management. Silva Fenn. 26: 169–179.

—, Hokkanen, J., Kangas, A. Lahdelma, R. and Salminen, P. 2003. Acceptability analysis to forest ecosystem management with both cardinal and ordinal criteria. Forest Science, 49(6), pp. 928–937.

Kao, C., Chang, P. and Hwang, S.N. 1993. Data envelopment analysis in measuring the efficiency of forest management. J Environ Mngt 38: 73-83.

Karppinen, H., Hänninen, H. and Ripatti, P. 2002. Suomalainen metsänomistaja 2000 [Finnish family forest owner 2000]. Finnish Forest Research Institute. Research Papers 852. 83 p (in Finnish).

Klamroth, K. and Miettinen, K. 2008. Integrating Approximation and Interactive Decision Making in Multicriteria Optimization. Operations Research. 56(1):222-234.

Kolb, D.A. 1984. Experiential Learning: experience as the source of learning and development New Jersey: Prentice-Hall. 3

Lahdelma, R., Hokkanen, J. and Salminen, P. 1998. SMAA - Stochastic multiobjective acceptability analysis. European Journal of Operational Research, 106 (1): 137-143.

Lappi, J. 2004. J-users' guide. Version 0. 9.4. Finnish Forest Research Institute, Suonenjoki Research Station 102 pp.

Leskinen, P., Hujala, T., Tikkanen, J., Kainulainen, T., Kangas, A., Kurttila, M., Pykäläinen, J. and Leskinen, L.A. 2009a. Adaptive decision analysis in forest management planning. Forest Science 55(2): 95–108.

—, Pykäläinen, J. and Haara, A. 2009b. Incorporation of preferential uncertainty into interval-scale priority functions – a case of multicriteria forestry decision making. Can. J. For. Res. **16**(2): 1498-1506. doi:10.1139/X09-055.

Liesiö, J., Mild, P. and Salo, A. 2007. Preference programming for robust portfolio modeling and project selection. European Journal of Operational Research. 181:1488-1505.

—, Mild, P. and Salo, A. 2008. Robust portfolio modeling with incomplete cost information and project interdependencies. European Journal of Operational Research. 190:679-695.

Mahmood, M.A., Burn, J.M., Gemoets, L.A. and Jacquez, C. 2000. Variables affecting information technology and end-user satisfaction: a meta-analysis of the empirical literature. International Journal of Human-Computer Studies 52, 751-771.

March, J.G. 1994. A Primer on Decision Making: How Decisions Happen. The Free Press. New York, NY.

Maule, J. and Villejoubert, G. 2007. What lies beneath: Reframing framing effects. Thinking & Reasoning 13(1): 25–44.

Metsähallitus. 2005. Stakeholder Governance in Metsähallitus' Planning Processes. Metsähallitus. Available from: http://www.metsa.fi/sivustot/metsa/en/NaturalResour ces/Planningmethods/Participation/Documents/binary.pdf [Accessed 13 Dec 2011].

Miettinen, K. 1999. Nonlinear multiobjective optimization. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Niskanen, Y. 2005. Metsäsuunnitelman vaikutus metsänkäyttöpäätökseen, volume 10 of Dissertationes Forestales. Faculty of Forest Sciences, University of Joensuu.

Nordström, E.-M., Romero, C., Eriksson, L.O. and Öhman, K. 2009. Aggregation of preferences in participatory forest planning with multiple criteria: an application to the urban forest in Lycksele, Sweden. Can. J. For. Res. 39(10): 1979–1992.

O'Keefe R.M., Chau, P.Y.K., Massey, A., Montoya-Weiss, M. and Perry, M. 2000. From the user interface to the consumer interface: results from a global experiment. Int J Hum Comput Stud 53:611-628.

Öhman, K., Edenius, L. and Mikusiński, G. 2011. Optimizing spatial habitat suitability and timber revenue in long-term forest planning. Canadian Journal of Forest Research, 2011, 41(3): 543-551, doi:10.1139/X10-232.

Pasanen, K., Kurttila, M., Pykäläinen, J., Kangas, J. and Leskinen, P. 2005. MESTA - Non-industrial private forest owners' decision-support environment for the evaluation of alternative forest plans over the internet. International Journal of Information Technology & Decision Making 4(4): 601–620.

Payne, J.W., Bettman, J.R. and Schkade, D.A. 1999. Measuring Constructed Preferences: Towards a Building Code. Journal of Risk and Uncertainty 19, 243-270.

Pukkala, T., Lähde, E., Laiho, O., Salo, K. and Hotanen, J.P. 2011. A multifunctional comparison of even-aged and uneven-aged forest management in a boreal region. Can J For Res. 41:851-862.

Pykäläinen, J. 2000. Interactive use of multi-criteria decision analysis in forest planning. Doctoral thesis. University of Joensuu, Faculty of Forestry, 39p.

— and Kurttila, M. 2009. Interactive method for supporting forest owners in biodiversity protection decisions. Small-Scale Forestry 8(3): 337-348.

—, Hiltunen, V. and Leskinen, P. 2007. Complementary use of voting methods and interactive utility analysis in participatory strategic forest planning: experiences gained from western Finland. Canadian Journal of Forest Research 37: 853-865

Rabin, M. 1998, Psychology and economics, Journal of Economic Literature 36:11−46.

Rasinmäki, J., Mäkinen, A., and Kalliovirta, J. 2009. SIMO: an adaptable simulation framework for multiscale forest resource data. Comput. Electron. Agric. 66(1): 76–84. doi:10.1016/j. compag.2008.12.007

Redsven, V., Hirvelä, H., Härkönen, K., Salminen, O. and Siitonen, M. 2011. MELA2009 Reference Manual (2nd edition). The Finnish Forest Research Institute. 662 p. ISBN: 978-951-40-2283-3

Remus, W. 1986. Graduate students as surrogates for managers in experiments on business decision making, Journal of Business Research 14(1): 19–25.

Romero, C. 2001. Extended lexicographic goal programming: A unifying approach. Omega. 29(1): 63-71.

— 2004. A general structure of achievement function for a goal programming model. Eur. J. Oper. Res. 153(3): 675-686.

Rozin, P. 2009. What kind of empirical research should we publish, fund, and reward? A different perspective. Perspectives on Psychological Science 4:435–39.

Saaty, T.L. 1980. The Analytic Hierarchy Process. McGraw-Hill, New York.

Salehirad, N. and Sowlati, T. 2006. Productivity and efficiency assessment of the wood industry : A review with a focus on Canada. Forest products journal, 56(11-12): 4-11.

Simon, H.A. 1955. A behavioral model of rational choice. Quarterly Journal of Economics, 69, 99-118.

— 1965. Rational choice and the structure of the environment. Psychological Review 63, 129-138.

Steuer, R. 1986. Multiple criteria optimization: Theory, Computation, and application. John Wiley & Sons.

Slovic, P., Finucane, M., Peters, E. and MacGregor, D.G. 2007. The affect heuristic. European Journal of Operational Research, 177, 1333-1352.

Tamiz, M. and Jones, D. 1996. Goal programming and Pareto efficiency, Journal of Information and Optimization Sciences, 17, 291-307.

—, Jones, D., and Romero, C. 1998. Goal programming for decision making: an overview of the current state-of-the-art. Eur. J. Oper. Res. 111(3): 569–581. doi:10.1016/S0377-2217(97)00317-2.

Tversky, A. and Kahneman, D. 1974, Judgment under uncertainty: Heuristics and biases, Science, Vol. 185, pp. 1124-1131.

— and Kahneman, D. 1981. The framing of decisions and the psychology of choice. Science 211: 453–458.

Viitala, E.J. and Hänninen, H. 1998. Measuring the efficiency of public forestry organizations. Forest Science 44(2): 298-307.

Vitoriano, B. and Romero, C., 1999. Extended interval goal programming. J. Oper. Res. Soc. 50(12): 1280–1283.

Wiersum, K.F., Elands, B.H.M. and Hoogstra, M.A. 2005. Small-scale forest ownership across Europe: Characteristics and future potential. Small-scale Forestry 4: 1–19.