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Research Paper

Analyzing uncertainties and estimating priorities of landscape sensitivity based on expert opinions

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HIGHLIGHTS

- A method for expert modelling with various uncertainty assessments.
- A high variation between the landscape preferences of the experts noticed.
- Visibility, potential users, and attractiveness have similar importance in determining landscape sensitivity.
- The most sensitive areas were located in high places with intensive use pressure.

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ABSTRACT

The aim of this paper was to present an approach to estimate the priorities of landscape sensitivity criteria and to study uncertainties compounding that process. The data are based on expert judgment priorities of visual landscape sensitivity. The uncertainty model utilized was a Bayesian multi-criteria decision analysis (MCDA) model. The sources of uncertainty were classified into two categories: uncertainty caused by inconsistency of judge-specific assessments, and differences between judges in elicited priorities. In particular, we estimated the relative magnitude of different sources of uncertainty and considered the overall reliability of landscape sensitivity modelling. The results showed that the uncertainties in estimation of landscape sensitivity criteria are large. Further analysis of the two uncertainty sources implied that the number of pairwise comparisons used to assess the landscape sensitivity criteria can be reduced to simplify the assessment task. This was the case since the assessment task involved multiple respondents. However, if there would be only one respondent, the inconsistency of the pairwise comparisons can be an important measure of uncertainty that would help decision makers to avoid over interpretation of the reliability of the priority estimates of the landscape sensitivity estimates.

1. Introduction

Landscape sensitivity is the tolerance of landscape to change, which affects visibility, recreation and ecological sustainability (Lucas, 1991). Visual landscape sensitivity is a combination of several factors. There are two typical ways of approaching visual landscape sensitivity (Bell & Apostol, 2008). The first has traditionally been used in forest and landscape planning, and considers landscape quality, visibility and the number of people who see the landscape (particularly residents and tourist/recreational visitors). The second uses visibility, numbers of people, the nature of viewing experience (whether static, moving, as a tourist or resident, etc.) and landscape value as the factors. Landscape sensitivity varies both spatially and temporally.

The visibility of the landscape depends mainly on the topography, the presence of elements that block or screen views, and the amount of the landscape accessible to potential viewers (Bell & Apostol, 2008). The number of people seeing the forest can be inferred from information on population and from observation of the study area, the strength of the settlement pattern of towns and villages, and the number and importance of roads and places used for recreation in a given area. Furthermore, the nature of the viewing experience will have an effect, since local people are likely to be more sensitive to notify changes easier than travellers who are just passing through (Bell & Apostol, 2008). On the other hand, local

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people may have become accustomed to changes. Visitors can also pay more attention to changes if they occur while they are staying in the area. Landscape quality is the most subjective of all the factors to be assessed. At its most basic it can encompass those landscapes designated in some way for their scenic value, such as national parks. In their absence an expert approach using characteristics known from landscape preference research can be adopted. However, when landscape quality has been compromisingly specified, it can be then objectively measured and the measurement is fairly reliable (Palmer & Hoffman, 2001).

Forest management is one of the most important factors which affects to the quality of visual landscape in Finland. One of the problems with forest landscape is that people do not generally like to see landscape change. In practice, changes concerning an area of high visual sensitivity will probably induce more negative reactions than one of low visual sensitivity. When landscape sensitivity is considered in forest management planning, it must somehow be qualified or even quantified. Visual landscape sensitivity is normally based on raw classification (e.g. County. . ., 2009). However, forest management planning in particular uses numerical methods such as computer simulation and optimisation. Highly automated systems and sometimes very large amount of planning data require that after the generation of alternative management plans, the landscape sensitivity can be quantified for the comparison of these plans. Otherwise, it could be difficult to consider landscape sensitivity in an objective manner.

Landscape factors affecting landscape sensitivity, i.e. landscape sensitivity criteria, are not usually of equal importance. Their importance can be measured by weights. To produce these weights, expert knowledge modelling has been utilized especially in situations in which objective information and applicable models have not been available or sufficient, or the miscellaneous decision criteria coming from many sources and with incommensurable units of measure have been observed to be difficult to value (e.g. Kangas & Leskinen, 2005; Store & Antikainen, 2010; Store & Kangas, 2001).

In expert knowledge modelling, the weights can be produced by an aid of pairwise priority comparisons of the criteria. The advantage of the pairwise comparison technique is that the respondent needs to assess the relative performance of only two items at a time, instead of the holistic evaluation of multiple items. In addition, the pairwise comparison technique enables indirect estimation of judgemental uncertainty in the form of potential inconsistency of the pairwise comparisons.

Multi-criteria decision analysis (MCDA) techniques consider the evaluation of decision alternatives with respect to several generally conflicting decision criteria (e.g. Keeney & Raiffa, 1993). A typical example is a natural resources management problem, where, the ecological and economic impacts of different management alternatives are evaluated and compared, among other things (e.g. Kangas, Store, Leskinen, & Mehtätalo, 2000; Leskinen & Kangas, 1998, 2005). In addition to natural resources management, MCDA has previously been applied to the strategic management of logistic services (Korpela, Tuominen, & Valoaho, 1998), financial decision-making (Zopounidis & Doumpos, 2002) and industrial competitiveness analysis (Sirikrai & Tang, 2006), and industrial resource assessment (Lähtinen, Haara, Leskinen, & Toppinen, 2008), for example.

The MCDA process can be divided into the following phases: 1. determine the decision problem, 2. determine the decision alternatives, 3. study the consequences of the decision alternatives, 4. determine the objectives of decision-making, 5. compare the decision alternatives with respect to the objectives, and 6. select the optimal decision alternative. The phases of the MCDA process can be carried out in a different order, repeatedly or even simultaneously. It is also possible that only some of the above phases of the decision analysis process are utilized. Likewise in this paper, only the importance of the decision criteria is considered as such without providing actual decision alternatives.

Uncertainty exists in all phases of the decision-making process, and it may have a significant impact on the quality of the process and the optimality of the decisions. In addition, uncertainty can play a very important role, when the subject under assessment is very controversial because of high variation in opinions or difficulties to assess the subject. One solution for measuring and incorporating the uncertainties involved is to utilize statistical modelling techniques developed for modelling subjective priorities and expert views in the context of multi-criteria decision-making (e.g., Alho & Kangas, 1997; Alho, Kangas, & Kolehmainen, 1996; Alho, Kolehmainen, Leskinen, 2001). Statistical modelling is based on well-known estimation techniques and statistical inference, which enable the measurement and illustration of the level of uncertainty in a manner that is understandable to decision-makers (e.g. Kangas & Leskinen, 2005). According to Bayesian statistical analysis (Alho et al., 2001), it is possible to calculate the probabilities for certain decision criteria or decision alternatives as being more important or better than other criteria or alternatives.

In the analysis of scenic values, there are two main sources of uncertainty: the inconsistency of judge-specific evaluations, and the differences between responses of the judges. Leskinen and Kangas (1998) represented a method to analyze the uncertainty of interval judgment data in multiple-criteria evaluation, which is further applied in this study.

The aim of this paper is to present an approach to estimate the priorities of landscape sensitivity criteria and to study uncertainties compounding that process. The data are based on expert judgment priorities of visual landscape sensitivity. The uncertainty model utilized is a Bayesian multi-criteria decision analysis (MCDA) model. Similar to Leskinen and Kangas (1998), the sources of uncertainty are classified into two categories: uncertainty caused by inconsistency of judge-specific assessments, and differences between judges in elicited priorities. In particular, we estimate the relative magnitude of different sources of uncertainty and consider the overall reliability of landscape sensitivity modelling. In addition, we discuss the usability of alternative expert judgment elicitation processes in light of uncertainty measures and reliability that the processes produce. The estimated priorities and uncertainty measures can be further utilized on forest and land management for classification of visual landscapes and assessment of classification results e.g. on GIS-based sensitivity classification tools.

2. Material and methods

A Finnish landscape province, namely the Kainuu and Kuusamo hill region (Maisemanhoito, 1992) in north-east Finland, was chosen as a study area. Landscape provinces are discrete geographical areas of a particular landscape type, and thus form a suitable geographically-specific area for the local expert sensitivity model (Landscape character assessment, 2002). The Kainuu and Kuusamo hill region is a typical Finnish ridge area with varied topography, lots of differently sized watersheds and relatively infertile soil types (Fig. 1).

The calculation process of landscape sensitivity model is illustrated on Fig. 2. The determination of the landscape criteria with respect to landscape sensitivity to be measured with the questionnaire was based on elicitation carried out in consecutive meetings and workshops with a small group of landscape and GIS experts. Criteria choose was started from the main level criteria often used in landscape sensitivity evaluations, namely scenic attractiveness or quality, visibility, and the amount and type of viewers (Bell, 1998; Bell & Apostol, 2008; Visual Landscape Inventory, 1997). The set of criteria was revised and elaborated during the meetings to be