Ecological Indicators 79 (2017) 391–409

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Review

Management of ecosystem services in mountain forests: Review of indicators and value functions for model based multi-criteria decision analysis

Clemens Blattert[a,*], Renato Lemm[a], Oliver Thees[a], Manfred J. Lexer[b], Marc Hanewinkel[c]

[a] Forest Resources and Management Unit, Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zuercherstrasse 111, 8903, Birmensdorf, Switzerland
[b] Institute of Silviculture, University of Natural Resources and Life Sciences, Vienna, Peter-Jordan-Strasse 82, 1190, Vienna, Austria
[c] Department of Forestry Economics and Forest Planning, University of Freiburg, Tennenbacher Str. 4, 79106, Freiburg, Germany

ARTICLE INFO

Keywords:
Forest management
Forest planning
Multi-functional forestry
Indicator
Forest model
Decision support

ABSTRACT

The main ecosystem services (ES) central European mountain forests provide are: protection against gravitational hazards, timber production, recreation, biodiversity conservation and carbon storage, which are all in high demand. These demands make managing mountain forests a challenging task, involving manifold synergies and conflicts between the different ES. There is therefore an urgent need for appropriate concepts and tools for support decisions in forest management and planning (FMP) to take into consideration all ES and to manage the wide variety of information types, parameters and uncertainties involved in assessing the sustainability of ES. Multi-criteria decision analysis (MCDA) provides a suitable set of methods for sustainability evaluations. In this study sustainability means the persistent fulfilment of the required ES. To address all the phases of the FMP process, MCDA and forest models should be applied together, with indicators providing the main interfaces to combine them. This paper aims to: i) review assessment approaches in order to select appropriate and widely accepted indicators for measuring and assessing the effects of different silvicultural management alternatives on forest ES, and ii) present additional standardisation approaches (value functions) for each indicator. Standardisations are necessary to make the different ES comparable and to study synergies and trade-offs between different management objectives in MCDA. The main ES in central European mountain regions are considered, with a clear focus on those indicators that are directly derivable from forest model outputs and that can refer to sustainable forest management practices. The scales considered are that of the single forest stand and of the larger forest management unit. A holistic indicator-based analysis framework for FMP in mountain forests can be built using the indicators and value functions described. The influence of different management alternatives on ES can then be evaluated, taking into consideration the instruments and information on forest management (forest models, inventory) available. All indicators are selected according to existing and approved approaches that only require data that is normally available in operational forest management. The framework can thus be an important element in developing a decision support system for FMP in mountain forests.

1. Introduction

Managing mountain forests is a challenging task. It needs to ensure not only that the forests main ecosystem services (ES) can be performed, e.g.: timber production, recreation, biodiversity conservation and carbon storage, but also the regulating service protection against gravitational hazards. This is very important for society generally and especially for communities in densely populated mountain regions (Brang, 2001; Dorren et al., 2004; Frehner et al., 2007). Wrong management decisions can have huge consequences, ranging from ecological and social losses to destruction of expensive infrastructure or even loss of human lives. Management has become more complicated with increasing public interest and requires more transparency and participation (Vacik and Lexer, 2014). Climate change has additionally exacerbated the problems (Elkin et al., 2013).

Appropriate concepts and tools for decision support are thus urgently needed to consider all ES and to help forest managers find an optimal management alternative to fulfil these diverse societal and political demands (Muys et al., 2010; Vacik and Lexer, 2014). A comprehensive approach, with a special focus on economic aspects, is required to analyse possible conflicts, synergies and trade-offs between different ES. The concept of ES has been increasingly used to support management decisions regarding natural resources as it helps to link human welfare and the natural environment and to explain the value of

* Corresponding author at: Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Zuercherstrasse 111, CH-8903, Birmensdorf, Switzerland.
E-mail address: clemens.blattert@wsl.ch (C. Blattert).

http://dx.doi.org/10.1016/j.ecolind.2017.04.025
Received 11 July 2016; Received in revised form 17 February 2017; Accepted 11 April 2017
Available online 03 May 2017
1470-160X/

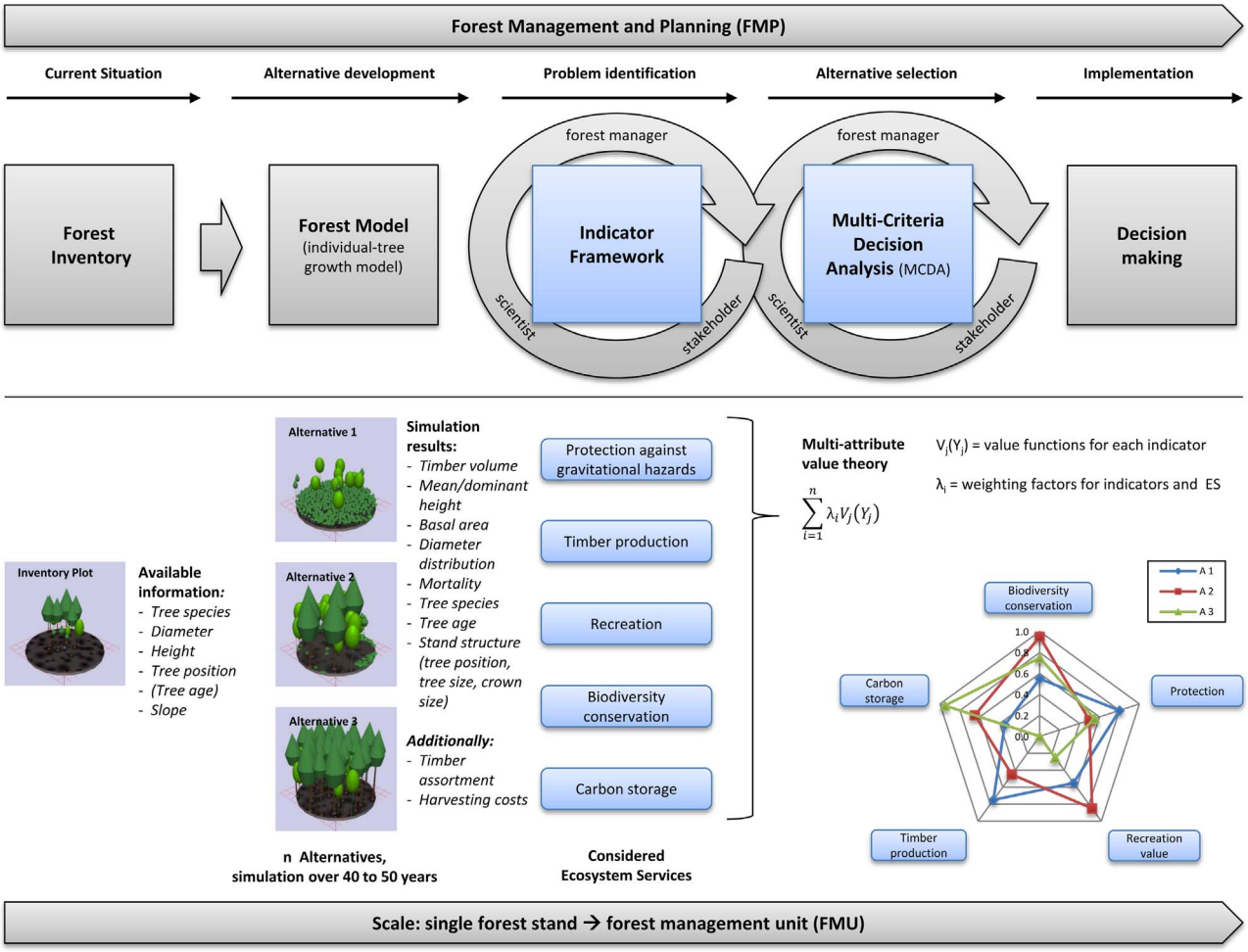

Fig. 1. Integral diagram showing the important phases of the FMP process and the methods that can be used to support them. The focus of this paper is on developing a holistic indicator-based decision framework as well as value functions for MCDA.

particular ecosystems to stakeholders (Grêt-Regamey et al., 2013). Assessing the sustainability of ES requires the management of a wide variety of information types, parameters and uncertainties, for which the method of multi-criteria decision analysis (MCDA) seems to be well suited (Cinelli et al., 2014; Huang et al., 2011). In this study sustainability means the persistent fulfilment of the required ES.

The joint application of MCDA and forest models allows ES to be assessed for decision-making and addresses all the phases of the forest management and planning (FMP) process (Wolfslehner and Seidl, 2010): i) alternative development, ii) problem identification and iii) alternative selection. The final step is the implementation of the management alternative chosen (Fig. 1) (Rauscher et al., 2000; Rauscher et al., 2005).

i) The main purpose of forest models in the context of FMP is to simulate the future development of forests under different silvicultural management alternatives and climate change. In FMP, individual-tree growth models are useful tools that can be applied to individual stands or to larger forest management units (FMU) (Weiskittel et al., 2011). These models should be able to run with information from forest inventories.
ii) Problem identification requires the design and technical implementation of an indicator-based analysis framework capturing all the important ES and their interactions relevant for the decision process (Wolfslehner and Seidl, 2010). With mountain forests, special attention should be paid to the protection services they provide.
iii) MCDA is used as a decision-making tool to analyse and evaluate the effect of decision alternatives on ES provisioning for synergies and conflicts. The ES and their indicators are structured, the indicator performance estimated relative to its desired condition, and the combined effect or impact of the indicators assessed (Mendoza and Prabhu, 2003).

Indicators serve as a major interface combining forest models and MCDA on an operational basis. They provide a reliable picture of the forest situation and allow a comprehensible and transparent assessment of the objectives of sustainable forest management (SFM) and the extent to which they are achieved (Wolfslehner and Seidl, 2010).

Indicators should be directly derivable from model outputs or through scaling up results to the level of the forest stand (Mäkelä et al., 2012), which represents the smallest spatial planning unit in FMP. Policy-driven indicator frameworks, such as the improved Pan-European indicators for sustainable forest management (FOREST EUROPE et al., 2011), are less suitable for decisions at the level of the forest stand as many of the criteria involve national scale issues, and are thus not relevant for FMP at the operational scale of a FMU. Moreover, they do not include the protection service of forests (Brändli and Duc, 2009).

ES management studies in mountain regions tend to focus on the landscape scale (Grêt-Regamey et al., 2013) and include aspects of agricultural land use (Briner et al., 2013). Most of the related indicators are unsuitable for FMP because the scale and the models applied for the simulations are not appropriate. More recent studies that focus on the FMU level often assess only two or three of the main ES at the same time (Lafond et al., 2015; Maroschek et al., 2015; Pardos et al., 2016; Vacchiano et al., 2015). Exceptions are the more holistic studies of