Forest Policy and Economics xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Forest Policy and Economics

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

Participatory and multi-criteria analysis for forest (ecosystem) management: A case study of Pohorje, Slovenia☆

Petra Grošelj [a,]*, Donald G. Hodges [b], Lidija Zadnik Stirn [a]

[a] University of Ljubljana, Biotechnical Faculty, Ljubljana, Slovenia
[b] University of Tennessee, Knoxville, TN, USA

ARTICLE INFO

Article history:
Received 19 December 2014
Received in revised form 21 April 2015
Accepted 20 May 2015
Available online xxxx

Keywords:
Forest management
Stakeholders
Slovenia
SWOT analysis
Analytic network process
Group decision making
Fuzzy logic

ABSTRACT

The primary aims of forest management are to rank and evaluate the effects of forest management scenarios on human communities, landscapes, and the development of forest services, and to achieve a balance between the economic, environmental, social, and cultural uses of forests. Multi-criteria decision methodology offers an effective alternative to address such forest management issues, particularly if they involve multiple stakeholders – including local communities, public representatives, and environmentalists – each of which possess different knowledge, experiences, and prospects. Group methods, based on participatory planning, can be applied to integrate such different interests into an optimal, joint decision. It is for this reason that a new decision model based on a group fuzzy analytic network process was designed. In a case study of the forest area at Pohorje, Slovenia, alternative development scenarios were evaluated by means of the generated model. Six possible management scenarios defined by sustainability indicators were identified. The scenarios were compared and assessed by several stakeholders according to the results of a SWOT analysis. The results reveal that most attention should be devoted to preserved nature, cultural heritage, and local tradition.

1. Introduction

Forest management, with its strategic as well as tactical and operational planning, is a very demanding undertaking. In addition to traditional forest management that emphasizes optimizing timber production and the associated financial returns, the natural, cultural, ecological, and social values of forests recently have been incorporated into the broader realm of natural resource management planning. As a consequence, sustainable approaches that protect environmental values and incorporate all forest functions in management decisions are put forward as a multiple criteria decision dilemma (Grošelj and Zadnik Stirn, 2013). Further, stakeholders are now involved in decision making for many forest management situations (Ananda and Herath, 2008). Alternative views, interests, and preferences are included by stakeholders such as forest owners, governmental institutions, non-governmental organizations, and local communities. Thus, the combination of participatory processes and multi criteria decision methods has been demonstrated as an effective tool to rank and evaluate the effects of resource management scenarios on sustainable economic, environmental, social, and cultural uses (Mendoza and Prabhu, 2005; Nordström et al., 2010; Saarikoski et al., 2013).

Strategic planning for natural resource management is based on adjusting to changes in the operational environment, subject to the goals for the use and development of resources. SWOT analysis, a structured method to evaluate the strengths, weaknesses, opportunities, and threats of the problem, is a common tool for evaluating environmental issues and forest ecosystems (Marino et al., 2014; Rauch, 2007). It offers a systematic approach, supports decision making, and allows stakeholder inclusion. It can serve as a solid basis for environmental analysis. Because of the complexity of forest management problems, however, this approach is not adequate in many cases. SWOT analysis provides only a qualitative analysis of the internal and external factors and also fails to evaluate possible decisions according to these factors (Kajanus et al., 2004). As a result, many researchers have attempted to improve and upgrade SWOT analysis, including developing a hybrid method, A'WOT, that integrates an analytic hierarchy process (AHP) and SWOT analysis (Gallego-Ayala and Juízo, 2011; Kajanus et al., 2012; Kangas et al., 2003; Kurttila et al., 2000; Leskinen et al., 2006; Margles et al., 2010; Masozera et al., 2006; Pesonen et al., 2001; Shinno et al., 2006), and combining SWOT and analytic network project (ANP) (Catron et al., 2013; Kazemi et al., 2009; Wei et al., 2011). In other research fields, SWOT analysis has been integrated with many other multi criteria decision making methods (MCDM), including fuzzy AHP (Kahraman et al., 2008; Lee et al., 2009c; Zadnik Stirn, 2006; Zavadskas et al., 2011), fuzzy ANP (Amin et al., 2011; Chen et al., 2010; Lee et al., 2009b; Sevkli et al., 2012; Shakoor Shahabi et al., 2014; Yüksel and Dağdeviren, 2007), TOPSIS and fuzzy TOPSIS (Azimi

☆ This article belongs to special issue: Ecosystem Services & SFM.

* Corresponding author.
E-mail addresses: petra.groselj@bf.uni-lj.si (P. Grošelj), dhodges2@utk.edu (D.G. Hodges), lidija.zadnik@bf.uni-lj.si (L. Zadnik Stirn).

http://dx.doi.org/10.1016/j.forpol.2015.05.006
1389-9341/

et al., 2011; Bas, 2013), and fuzzy quality function deployment (Manteghi and Zohrabi, 2011; Pur and Tabriz, 2012).

The aim of this paper is to offer a new approach for handling complex, vague forest management problems with many parameters and variables that also allows for evaluating potential scenarios, while accounting for the opinions of multiple stakeholders. We propose a two-step approach based on SWOT analysis and group AHP. A fuzzy concept is included in the approach as well to enable a convenient environment for including stakeholder opinions, and a new group aggregation method in AHP is proposed to incorporate stakeholder opinions into one group opinion. The model then is applied to a case study of a forest ecosystem management problem at Pohorje, Slovenia. Section 2 presents the new approach, followed by a revision of the AHP, fuzzy AHP, and ANP methods, and a presentation of the new group fuzzy AHP. Section 3 describes the case study for Pohorje; Section 4 discusses the implications of the results and Section 5 presents the main conclusions.

2. Methods

2.1. Two-step evaluation framework

MCDM is widely used for solving complex problems with various supplementary, often conflicting criteria. It offers a powerful tool by enabling a formal structuring of the problem and providing instruments for analyzing and interpreting the results (Mendoza and Prabhu, 2005). To meet the main objective of this paper, that is, to rank and/or evaluate management scenarios with respect to the criteria from a SWOT analysis, we developed a two-step evaluation procedure consisting of:

Step 1: SWOT analysis and evaluation of SWOT groups through applying fuzzy group AHP.

Step 2: Evaluation of scenarios regarding the SWOT groups using AHP or its upgraded procedure, assigned as an ANP approach.

2.1.1. Step 1

The objective of the process must be clearly defined by a leader or a group of decision makers at the beginning of the decision making process. Next, potential stakeholders are identified and invited to take part in the decision process. In order to perform the SWOT analysis, significant factors in the external and internal environments must be identified. The SWOT analysis is completed as a part of a participatory process in which stakeholders participate in meetings, workshops, or through a web platform. The stakeholders identify and rank the SWOT factors, after which the highest ranked factor is chosen to represent the SWOT group (Pesonen et al., 2001). A group of carefully selected stakeholders who are experts in their fields is invited to the next phase where the SWOT groups are ranked using AHP. In this phase each stakeholder compares the SWOT groups regarding the objective in a pairwise fashion. A new fuzzy aggregation approach is proposed to incorporate individual judgments into the group judgment.

2.1.2. Step 2

In the second step, all possible scenarios are identified with the support of stakeholders. Next, a hierarchy or network for the main goal, SWOT groups, and scenarios are created and all pairwise comparisons used in the AHP procedure are obtained by the stakeholders. The final result is a vector of weights, and on this basis, the discussed scenarios are ranked.

The AHP and its varieties are presented in the following subsections.

2.2. Analytic hierarchy process

AHP (Saaty, 1980) is a well-known subjective weighting approach for assessing the priorities of the criteria. The AHP procedure is composed of three stages: 1) construction of the hierarchical structure of the problem; 2) pairwise comparisons of factors (criteria, alternatives) on the same level of hierarchy and derivation of weights for each level; and 3) synthesis of weights to gain global weights. This tool uses Saaty's 9-point scale to express the relative preference of one factor over another in stage two. The eigenvector method (Saaty, 1980) can be applied to derive a vector of weights from the comparison matrix. The consistency of comparisons is measured by the consistency ratio:

$$CR = \frac{CI}{RI}, \quad CI = \frac{\lambda_{\max} - n}{n-1}, \tag{1}$$

where $\lambda_{\max}$ denotes the maximal eigenvalue of $n \times n$ comparison matrix and RI denotes a random index. According to Saaty (2005), $CR < 0.1$ is considered acceptable.

2.3. Fuzzy analytic hierarchy process

Fuzzy set theory (Zadeh, 1965) has been used in decision making processes to express uncertain and vague information often gained from decision makers' judgments. In order to enable decision makers to use linguistic expressions rather than numbers and efficiently convey human perceptions, a fuzzy AHP approach was developed (Heo et al., 2012). Among the many fuzzy AHP methods (Buckley, 1985; Deng, 1999; Stam et al., 1996; Van Laarhoven and Pedrycz, 1983) the extent analysis method (Chang, 1996) is the most popular. In this study, a modified extent analysis method (Heo et al., 2010; Heo et al., 2012; Wang and Elhag, 2006; Wang et al., 2008; Zhu et al., 1999) that presents an improved version of Chang's method was applied. It utilizes triangular fuzzy numbers (TFN) $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$ for pairwise comparison scale. Let

$$\tilde{A} = (\tilde{a}_{ij})_{n\times n} = \begin{bmatrix} (1,1,1) & (l_{12}, m_{12}, u_{12}) & \cdots & (l_{1n}, m_{1n}, u_{1n}) \\ (l_{21}, m_{21}, u_{21}) & (1,1,1) & \cdots & (l_{2n}, m_{2n}, u_{2n}) \\ \vdots & \vdots & & \vdots \\ (l_{n1}, m_{n1}, u_{n1}) & (l_{n2}, m_{n2}, u_{n2}) & \cdots & (1,1,1) \end{bmatrix} \tag{2}$$

be a triangular fuzzy comparison matrix where $\tilde{a}_{ij} = \tilde{a}_{ji}^{-1} = (1/u_{ij}, 1/m_{ij}, 1/l_{ij})$ for $i, j = 1,\ldots,n$. To calculate the vector of weights from the triangular fuzzy comparison matrix, first the normalized synthetic extents with respect to the i-th object are defined (Wang et al., 2008) according to Eq. (3).

$$S_i = \left(\frac{\sum_{j=1}^{n} l_{ij}}{\sum_{j=1}^{n} l_{ij} + \sum_{k=1,k\neq i}^{n} \sum_{j=1}^{n} u_{kj}}, \frac{\sum_{j=1}^{n} m_{ij}}{\sum_{k=1}^{n} \sum_{j=1}^{n} m_{kj}}, \frac{\sum_{j=1}^{n} u_{ij}}{\sum_{j=1}^{n} u_{ij} + \sum_{k=1,k\neq i}^{n} \sum_{j=1}^{n} l_{kj}} \right), \quad i = 1,\ldots,n \tag{3}$$

where fuzzy arithmetic operations were considered. Second, the degree of possibility of $S_i = (l_i, m_i, u_i) \geq S_j = (l_j, m_j, u_j)$ is defined by Eq. (4) (Chang, 1996).

$$V(S_i \geq S_j) = \begin{cases} 1, & \text{if } m_i \geq m_j \\ 0, & \text{if } l_j \geq u_i \\ \frac{l_j - u_i}{(m_i - u_i) - (m_j - l_j)}, & \text{otherwise} \end{cases}. \tag{4}$$

Next, for calculating the degree of possibility of a fuzzy number S to be greater than k fuzzy numbers S_i, $i = 1,\ldots,k$ Eq. (5) is used.

$$V(S \geq S_1, S_2, \ldots, S_k) = \min_{i=1,\ldots,k} V(S \geq S_i). \tag{5}$$

Denoting

$$d'(A_i) = \min_{k=1,\ldots,n;k\neq i} V(S_i \geq S_k) \tag{6}$$