



Methodological and Ideological Options

Comparing land-use alternatives: Using the ecosystem services concept to define a multi-criteria decision analysis



Veronika Fontana^{a,*}, Anna Radtke^{b,1}, Valérie Bossi Fedrigotti^{b,1}, Ulrike Tappeiner^a, Erich Tasser^c, Stefan Zerbe^b, Thomas Buchholz^d

^a Institute of Ecology, Leopold-Franzens University of Innsbruck, Sternwartestraße 15, Austria

^b Faculty of Science and Technology, Free University of Bozen-Bolzano, Piazza Università 5, 39100 Bolzano, Italy

^c Institute for Alpine Environment, European Academy Bolzano, Viale Druso 1, 39100 Bolzano, Italy

^d Gund Institute for Ecological Economics, University of Vermont, 617 Main Street Burlington, VT 05405, USA

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ABSTRACT

In landscape planning, land-use types need to be compared including the ecosystem services they provide. With multi-criteria decision analysis (MCDA), ecological economics offers a useful tool for environmental questions but mostly case-specific criteria are applied. This, however, makes it difficult to compare findings. Therefore, we present a systematic framework that includes the ecosystem services as criteria into MCDA. The ecological quantification of the provided ecosystem services is combined with the assigned importance of the single ecosystem services. In a case study from the central Alps, we compared three land-use alternatives resulting from land-use change caused by socio-economic pressures: traditional larch (*Larix decidua*) meadow, spruce forest (abandonment) and intensive meadow (intensification).

Criteria for the MCDA model were selected by experts, criteria importance was ranked by stakeholders and criteria values were assessed with qualitative and quantitative indicators. Eventually spruce forest was ranked as the best land-use alternative followed by traditional larch meadow and intensive meadow. The combined approach of MCDA using ecosystem services as criteria showed how criteria weightings and criteria indicator values influence land-use alternatives' performance. The MCDA-model visualizes the consequences of land-use change for ecosystem service provision, facilitating landscape planning by structuring environmental problems and providing data for decisions.

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1. Introduction

1.1. The Multi-Criteria Decision Analysis

Multi-criteria analysis is one of the most frequently used methods in ecological economics (Huang et al., 2011). Due to the option to combine economic, ecologic and social criteria it is well suited to address interdisciplinary and complex environmental questions (Khalili and Duecker, 2013; Mendoza and Prabhu, 2003). If a discrete number of alternatives is given, multi-criteria decision analysis (MCDA) is a useful tool to structure the decision-making process (Busch et al., 2011; Hein et al., 2006). Furthermore, MCDA is considered to be one of the most flexible methods since it can be made site as well as time specific, considering qualitative and quantitative attributes simultaneously

* Corresponding author at: Sternwartestrasse 15, 6020 Innsbruck, Austria. Tel.: +43 512 507 5980; fax: +43 512 507 2975.

E-mail addresses: Veronika.Fontana@student.uibk.ac.at (V. Fontana), Anna.Radtke@natec.unibz.it (A. Radtke), Valerie.BossiFedrigotti@natec.unibz.it (V. Bossi Fedrigotti), Ulrike.Tappeiner@uibk.ac.at (U. Tappeiner), erich.tasser@eurac.edu (E. Tasser), Stefan.Zerbe@unibz.it (S. Zerbe), Thomas.Buchholz@uvm.edu (T. Buchholz).

¹ These authors contributed equally to this work.

(Garfi et al., 2011). Up to now, multi-criteria analysis has been mainly applied for case studies with specific focus, e.g. forest management (Ananda and Herath, 2009), river alteration projects (Oikonomou et al., 2011), or bioenergy solutions (Buchholz et al., 2009). Most of those studies apply case-specific criteria, so that the solutions to the environmental problems addressed are hardly comparable or transferable to similar cases. A standardized framework of criteria would help to derive more general solutions for environmental or nature conservation questions. Surprisingly, different land-use options, or land-use changes as omnipresent phenomenon have rarely been the focus of MCDA studies, even if 287 publications in the Web of Science carried 'land use change' in the title only in the year 2012.

1.2. The Ecosystem Service Concept

The ecosystem service concept has become more and more popular since the United Nations' Millennium Ecosystem Assessment 2005 (further referred to as MEA, 2005). It defines ecosystem services as the benefits which humans obtain from ecosystem functions and resources. These benefits can be divided into market and non-market ecosystem goods or services and classified in multiple ways (Costanza

et al., 2008), e.g. provisioning services, regulating services, habitat or supporting services and cultural services (The Economics of Ecosystems and Biodiversity, further referred to as TEEB, 2010). Common frameworks such as TEEB facilitate scientific work when dealing with the complexity of landscapes (de Groot et al., 2010) but so far it is little known and applied by regional, administrative authorities. Likewise, the concept of ecosystem services (TEEB, 2010) could be used as general framework where criteria for multi-criteria analyses are selected from.

Several studies have applied the ecosystem service concept to assess land-use change including its consequences for biodiversity loss and provision of ecosystem services to the society (e.g. Carreno et al., 2012; Hao et al., 2012; Mendoza-Gonzalez et al., 2012). However, the local demand or importance of the single ecosystem services has only recently been included in those studies (Burkhard et al., 2012). Moreover the way in which the changes in ecosystem service provision, caused by land-use change, are summarized differs among these studies or is lacking completely. The MCDA may be an appropriate tool to assess the importance of the ecosystem services and to consequently compare land-use types regarding their ecosystem service provision. In that way, even regional studies could provide generalizable results and solutions by absorbing the established ecosystem service framework (MEA, 2005; TEEB, 2010) on MCDA criteria.

1.3. Study Case Larch Meadows

To test the integration of the ecosystem service concept into multi-criteria decision making on the example of a land-use change question, we used a traditional land-use system of the central Alps, which is currently under pressure by two contrasting trends: intensification and abandonment. So-called larch meadows are semi-open grasslands that are mown or pastured and scattered with larch trees (*Larix decidua* Mill.). They provide both hay and timber, but mowing around the trees and collecting the fallen branches are awkward and time-consuming. Therefore, they are often either abandoned so that succession into forest begins, or the larches are cut and the ground is leveled so that they can be managed more intensively. These two trends are very typical for extensive land-use systems in Europe (Hunziker, 1995; Tasser et al., 2007), which have co-evolved with human use for hundreds of years (Ellenberg and Leuschner, 2010). In fact, very few European ecosystems can be considered 'natural' today; instead most of them have been altered by humans (Grabherr et al., 1994). Within this cultural landscape, extensive agricultural systems exhibit biodiversity hot spots (European Habitat Directive, 1992; Zerbe and Wiegler, 2009). In particular, traditional wood-pasture systems, which are named differently and made up by different species depending on the geographic region, are of high nature conservation value (Bergmeier et al., 2010). High biodiversity, in turn, is generally connected with many ecosystem services such as climate regulation, water purification, and recreation (MEA, 2005). For that reason, the European Union as well as local authorities are spending a lot of money to support this kind of traditional land-use systems (Institute for European Environmental Policy, 2007; Marini et al., 2011). To test if those subsidies entail a surplus of ecosystem services, we compared three competing land-use types regarding their provision of ecosystem services.

In this case study from the Central Alps, we present a multi-criteria decision analysis which combines normative values with the ecological quantification of ecosystem services. The importance of ecosystem services in the regional landscape is indicated by stakeholder interviews and the provision of those ecosystem services is assessed with qualitative and quantitative indicators. In this way we demonstrated the use of MCDA with an ecosystem service framework and developed four systematic, discrete steps to compare different land-use types regarding their ecosystem service provision. At the end of the paper, the suitability of this method to help the decision-making process in practice is discussed.

2. Methods

2.1. Study Area

South Tyrol is the northern-most province of Italy covering an area of 7400 km² located in the south of the Eastern Alps. According to the definitions of the European Union, 94% of the total area of South Tyrol belongs to mountain territory (Autonome Provinz Bozen-Südtirol, 2009). Larch meadows, the objects of our study, are an ancient man-made land-use system which is found mainly on dry south-exposed slopes around the alpine main ridge at 1000–2000 m a.s.l. Beside South Tyrol, which is one of the main distribution areas of the remaining larch meadows, they are also present in adjacent countries. Results of fossil pollen analysis in nearby Switzerland show a high accumulation of pasture and culture indicator species together with macro-residuals of *L. decidua* between 2100 and 1900 B.C. (Gobet et al., 2004). This warm and dry climate period is known as an intensive culture phase in the Alps (Tinner et al., 2003) where a lot of forests were cleared and the origin of larch meadows is assumed (Ammann, 2001b). Over the centuries, larch meadows were preserved as a double functional land use, and particularly in times of poverty single larches were cut and sold. However, larch meadows need a lot of human care. Depending on weather, fallen branches have to be removed at least once a year, the area around the trees can be mown only by hand and the tree shade increases drying time for the hay. Furthermore the areas are often steep or difficult to reach. Consequently larch meadows lost far more than half of their former areal proportions since the 1980ies and nowadays they play only a small part in South-Tyrolean agriculture. Nevertheless larch meadows are beautiful landscape elements which are used by tourists and locals for recreational activities. Due to this scenic beauty and the high biodiversity they harbor, larch meadows are regarded as an important ecosystem. Therefore they are supported with European and national subsidies.

2.2. Multi-criteria Decision Analysis

Among the different methods of multi-criteria analysis we chose the multi-attribute decision making (MCDA) because a discrete and finite number of alternatives (meadow, larch meadow, and forest) is given. MCDA solutions are more likely to achieve realizable results because of its transparency and traceability (Linkov et al., 2006). The multi-criteria decision analysis to compare the three land-use alternatives regarding their ecosystem service provision entailed four steps (Fig. 1).

2.2.1. Problem Definition

The problem in the study region is that traditional larch meadows are disappearing due to two contrasting trends: abandonment and intensification. Hence three land-use types representing the alternatives required for a MCDA are given (Table 1). The alternative forest is the result of succession taking place on abandoned larch meadows and the alternative meadow follows from removing the larches and converting the area into a permanent meadow often leveling the ground to facilitate machine use. With the changing land use, also the amount of provided ecosystem services can change. To structure this problem we formulated three questions (step 1, Fig. 1). First we asked which alternative provides the most ecosystem services, second we wanted to know which points make larch meadows strong or weak and third we asked if larch meadows can compete with the other two alternatives.

2.2.2. Expert Selection and Criteria Elicitation

To perform a MCDA, a number of five to seven criteria describing the alternatives are ideal (Buchholz et al., 2007). To select criteria for this MCDA from ecosystem goods and services, we hold an expert discussion. Based on their knowledge and familiarity with larch meadows, we invited 30 local private and official experts of agriculture, forestry, nature conservation, research, and tourism. In the end, ten

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