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Segregated versus integrated biodiversity conservation: Value-based ecosystem service assessment under varying forest management strategies in a Swiss case study

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ABSTRACT

There is an ongoing debate regarding segregated and integrated approaches to biodiversity conservation in Central European forests. The ecosystem services provisioning of timber, recreation and carbon sequestration are, however, also of great importance. The existence of manifold objectives makes it difficult to find an appropriate strategy in forest management, especially for practitioners at the management unit level. We simulated forest development over 50 years under five management strategies in a Swiss forest enterprise: business as usual (BAU), segregated (BC-seg) and integrated (BC-int) biodiversity conservation, intensive management (INTENS) and no management (NO). INTENS and BAU were used as benchmark strategies. The available forest inventory data was used as input for the growth simulator WaldPlaner. Management strategies were analysed over time with a value-based multi-criteria approach based on 21 indicators regarding the provisioning of biodiversity and ecosystem services (BES) as well as their synergies and conflicts.

The analysis yielded the best overall BES values for the strategies INTENS, BAU and BC-seg. However, INTENS and BAU were not envisaged as alternatives for biodiversity conservation because they lack essential late successional forest elements. Strategy NO had the lowest BES values, despite the good biodiversity results of the climax states (micro-habitat bearing large deadwood and large old living trees). Of the two intended conservation strategies integration and segregation, the latter had higher values. Segregation therefore offers a compromise by combining the positive aspects of both conservation and management-oriented strategies. With regard to the case study area, we thus conclude that a small-scale segregation of the forest into zones with multiple management strategies is best for achieving structural biodiversity aspects in multiple-objective forest management.

1. Introduction

The conservation of forests biodiversity has received increasing attention in forest management (Forst Europe et al., 2011; Kraus and Krumm, 2013). Forests in late successional development stages are considered especially important, as they contain a rich diversity of niches and species (Lassauce et al., 2013; Moning and Müller, 2009). However, commercial forests are grown for distinctly shorter periods until economic maturity, when harvested timber volumes and revenues are highest (Chang, 1998). The provisioning of timber is a very important Ecosystem Service in Central Europe (Forst Europe et al., 2011). Additionally, forest biomass plays an important role in the future energy system (Burg et al., 2018; Thees et al., 2017) and forest management and the usage of wood can realise carbon mitigation efficiency, which contributes to a climate smart forestry (Yousefpour and Hanewinkel, 2009). Harvest reductions associated with conservation efforts may not only have negative impacts on the whole forest-wood sector (Schwarzbauer and Martin, 2017) but could also increase timber imports from foreign countries, which in turn may increase the ecological footprint (Schulze et al., 2016). Consequently, there is an inherent conflict between biodiversity conservation and the provisioning service timber production.

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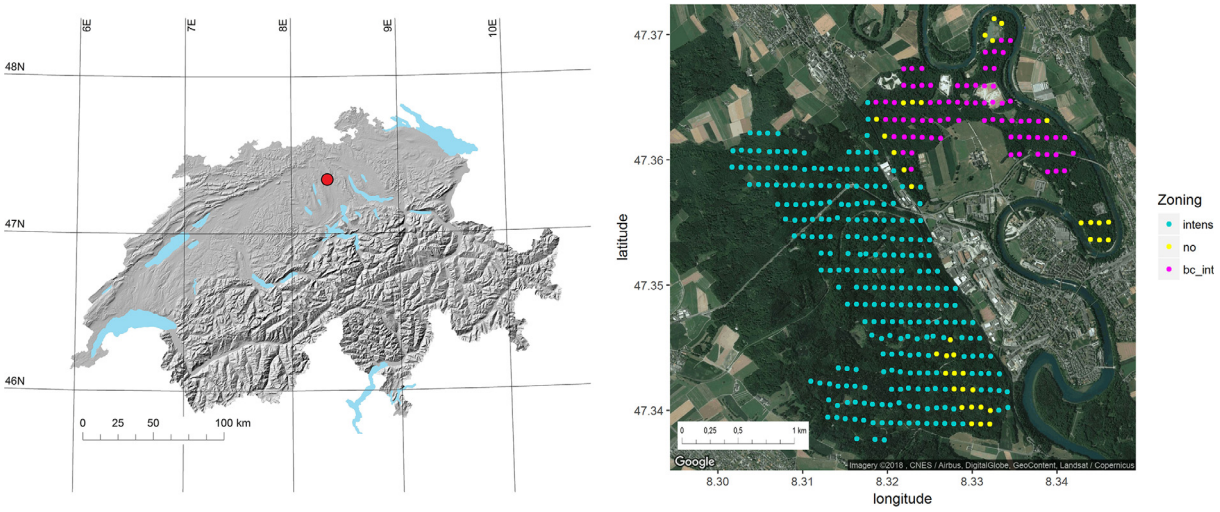

Fig. 1. Location of the case study area in Switzerland (left) and its 366 inventory plots (right) with the small-scale zoning for the segregated biodiversity conservation strategy BC-seg; 37 plots (10%) serve as natural forest reserve or deadwood islands (strategy NO), 73 plots (20%) are managed extensively as a special forest reserve (strategy BC-int) and 256 plots are managed for timber production (strategy INTENS).

Currently, two main approaches exist for the implementation of nature conservation in forest management, the segregated and the integrated approach (Bollmann and Braunisch, 2013; Boncina, 2011; Suda and Pukall, 2014). Under the segregated approach, the forest is divided into zones with different management strategies, each zone with a dominant management objective. With the integrated approach, the forest is managed using a single strategy, usually one that is more extensive and conservation oriented. According to Boncina (2011), the aim of the integrated approach is to combine several management objectives in the same forest area instead of focusing on a single objective.

The distinction between segregation and integration is a matter of scale and national legislation (Bollmann and Braunisch, 2013). In vast forested regions, large segregated forest reserves that contribute considerably to nature conservation can be established. In densely populated regions like in Central Europe, however, the designation of strictly segregated large forest reserves or national parks is limited (Boncina, 2011). Additionally, forests in most Central European countries are usually managed within a near-nature silvicultural system and without clear cutting (Röhrig et al., 2006). Hence, there is a trend towards small-scale segregation or even the integrated model for multiple-objective forest management (Borrass et al., 2017; Kraus and Krumm, 2013).

For forest management in Central Europe, management objectives other than biodiversity conservation and timber provisioning are also of great importance, such as recreation and mitigation of climate change (Forst Europe et al., 2011). The existence of manifold objectives makes it difficult to find an appropriate management strategy, especially for practitioners at the management unit level.

Complex decision-making can be supported by the joint application of forest simulation models and multi-criteria decision analysis (MCDA). This enables the assessment of multiple objectives and addresses all the main phases of the decision-making process: problem identification, development of management alternatives and selection of an appropriate alternative (Wolfslehner and Seidl, 2010). A widely used MCDA method for decision-making in forest management is the multi-attribute value theory (MAVT) (c.f. Ananda and Herath, 2009; Uhde et al., 2015). Based on this method, Blattert et al. (2017) recently developed a value-based indicator framework that captures biodiversity and key ecosystem services in central European forests and their interactions relevant for the decision-making process.

In this study, we apply this indicator framework together with a previously evaluated forest growth simulator (Blattert et al., 2016, 2015). In particular, we want to address the question of whether a segregated approach with multiple management strategies or an integrated management approach is more suitable for biodiversity conservation within multiple-objective forest management. Such a value-based assessment approach has rarely been used to address this question (Carpentier et al., 2016). Furthermore, to our knowledge, no previous MAVT-studies have involved the investigation of a whole management unit and its realistic decision-making context (Briceño-Elizondo et al., 2008; Diaz-Balteiro et al., 2017; Langner et al., 2017; Schwenk et al., 2012).

The goal of this study was to evaluate forest management strategies regarding the provisioning of multiple-objectives at the forest enterprise level. In particular, we aimed to determine whether segregation or integration is the better approach for nature conservation within a small-scaled forest landscape. The evaluation is based on the joint application of a forest growth simulator and a previously developed indicator-based analysis framework. The analysis covers biodiversity and key ecosystem services (abbreviated BES) in forest management: timber production, recreation and carbon sequestration. BES are assessed based on forest structural attributes simulated by the growth simulator. A forest enterprise in the Swiss Plateau was selected as a case study to represent multiple-objective forest management in a densely populated region.

2. Materials and methods

2.1. Study area

The study area is situated in the central part of the Swiss Plateau (canton Aargau) and has a size of 440 ha (Fig. 1). It is part of the forest enterprise Wagenrain (960 ha), which is owned by five communities of citizens. The elevation of the area ranges from 360 to 470 m a.s.l. The mean annual temperature is approximately 9.5 °C and the annual precipitation is 850 mm. Site quality in Wagenrain ranges from fertile to very fertile stands. The current mean productivity is approximately 10 $m^3 ha^{-1} year^{-1}$ according to the last inventory in 2011. The mean growing stock is about 270 $m^3 ha^{-1}$.

The main tree species are Norway spruce (*Picea abies*; 44%), European beech (*Fagus sylvatica*; 13%), birch (*Betula pubescens*; 10%), maple species (*Acer pseudoplatanus*, *A. platanoides*; 9%), oak species (*Quercus robur*, *Q. petraea*; 6%) and European ash (*Fraxinus excelsior*; 6%). Other coniferous tree species occurring in the study area are silver fir (*Abies alba*), Scots pine (*Pinus sylvestris*), European larch (*Larix decidua*) and Douglas fir (*Pseudosuga menziesii*). Other broadleaf species