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# Land ownership drives stand structure and carbon storage of deciduous temperate forests

Harald Schaich [a,*], Tobias Plieninger [b,c]

[a] Chair for Landscape Management, Institute of Earth and Environmental Sciences, Faculty of Environment and Natural Resources, University of Freiburg, Tennenbacher Str. 4, 79106 Freiburg, Germany
[b] Ecosystem Services Research Group, Berlin-Brandenburg Academy of Sciences and Humanities, 10117 Berlin, Germany
[c] Department of Geosciences and Natural Resource Management, University of Copenhagen, Rolighedsvej 23, 1958 Frederiksberg C, Denmark

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ABSTRACT

In European cultural landscapes, forest area is subdivided into a mosaic of stands of different ownership types and sizes. Differences in ownership and different goals of the owners have a potentially decisive influence on the provision of forest ecosystem services and the implementation of instruments for the conservation of biodiversity. This study hypothesizes that forest ownership is an indirect determinant of forest management approaches and is thereby relevant for biodiversity conservation and carbon sequestration. We compared structure and species composition of forest stands in clusters of different ownership types, namely state-owned, municipal and small-scale private forests, in southwestern Germany. Although close-to-nature management has been practiced in public forests for some time, our study demonstrates that tree species diversity does not vary significantly between ownership types but is correlated with biogeographical factors. However, small-scale private forests comprise significantly higher levels of structural diversity, more dead wood and greater carbon storage capacity than both categories of public forests. This is contrary to other studies, where publicly owned lands were found to host higher biodiversity, and differs from the global trend, where continued fragmentation of private lands threatens forest sustainability. The importance of small-scale private forests, e.g. for the conservation of old-growth and dead wood dependent species, seems due to less intensive and more diverse forest management. The role of such forests for biodiversity conservation and carbon regulation may be jeopardized through forest conversion and wood mobilization initiatives accompanying rising natural resource prices. To safeguard forest biodiversity and ecosystem services, ownership-specific incentive schemes should be coordinated and refined. In public forests, close-to-nature management approaches should be complemented with binding goals aimed at promoting old-growth forest attributes and allowing site-specific variation in management practices. To conserve diversity in small-scale private forests, financial incentives and remuneration schemes for the provisioning of forest biodiversity and ecosystem services should be developed. Moreover, consulting and the provision of information on sustainable forest and conservation management should be intensified.



## 1. Introduction

Forest management worldwide is a critical determinant of forest biodiversity and ecosystem services and is therefore relevant for society and human well-being (Millennium Ecosystem Assessment, 2005). Globally, the loss of primeval forest through clearing and transformation to agricultural uses or for mining activities is one of the most pressing challenges in terms of halting habitat loss, forest species extinction and the decline of forest ecosystem services (FAO, 2011). In highly human-influenced forest ecosystems, the form and intensity of forest management is, in addition to site conditions (Kuuluvainen, 2002), natural disturbances (von Oheimb et al., 2005), habitat continuity (Wulf, 2003) and land use legacies (Bürgi et al., 2010; Plieninger et al., 2011), the prime influencing factor for conserving forest habitats and species as well as for the level of ecosystem services provision (Brunet et al., 2010; Lonsdale et al., 2008).

According to the framework of the Millennium Ecosystem Assessment (2005), forest management can be considered as a direct driver affecting forest ecosystems and biodiversity, which is in turn influenced by indirect drivers such as biophysical, demographic, economic and institutional factors. Forest ownership, together with related institutional arrangements and specific rules-in-use, affects site-specific forest management via the varying objectives, attitudes and knowledge of different owners. In this

* Corresponding author. Tel.: +49 761 203 3644; fax: +49 761 203 3638.
*E-mail address:* harald.schaich@landespflege.uni-freiburg.de (H. Schaich).

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way, it is a strong indirect driver for the provisioning of forest biodiversity and ecosystem services. Additionally, forest ownership is also an illustrative proxy of forest management in the past and resulting biotope traditions. It therefore needs to be taken into consideration when establishing sustainable forest management practices and strategies for the conservation of forest biodiversity (Tucker and Ostrom, 2005).

### 1.1. Evidence on the links between forest ownership and stand structures

Empirical evidence shows that land ownership is decisive for biodiversity conservation outcomes and has an impact on landscape structure, for example on the size of habitat patches and fragmentation on a landscape scale (Lovett-Doust et al., 2003). The type of ownership and the motives of different owners have been shown to be relevant for the form and intensity of land use as well as for the reception of management- and conservation-related information and policy programs (Hilty and Merenlender, 2003; Huntsinger et al., 1997). Links between forest ownership and stand structure or habitat diversity have rarely been studied in European forest ecosystems, but have been found in temperate, boreal and mountain forest ecosystems of Northern America and Asia. For example, differences in stand structure, composition and carbon storage have been detected between private and public ownership in California and Oregon (Hudiburg et al., 2009) and relationships between ownership and reforestation practices as well as intensity of forest management were established in Canada (Rotherham, 2003; Zhang and Pearse, 1997). In Nepal, significant differences in forest structure and biodiversity accompanied the conversion of state to community forests (Nagendra, 2002). Forest ownership in Europe – according to a recent study that considered 23 countries excluding Russia, Belarus and Ukraine – is divided into 50.1% publicly (states, municipalities or other public bodies) owned and 49.6% privately owned forest lands; however, there are large differences between countries, as well as regionally within countries (Schmithüsen and Hirsch, 2010). In Germany, roughly 47% of forest area is private, 20% state owned and 33% owned by municipalities or other public bodies (such as public trusts or churches). Most private forests are small in size, with 57% of all private forest lands being smaller than 20 ha (Depenheuer and Möhring, 2010).

### 1.2. Management goals of privately owned forests

Management motives of private forest owners frequently vary according to the size of their lands, e.g. in the case of California's hardwood rangelands (Huntsinger et al., 2010). Often, owners of large (>1.000 ha) to medium scale (200–1000 ha) private forest enterprises are motivated by economic considerations and they prioritize timber production (Pickenpack, 2004). In contrast, the motivations and goals of small-scale forest owners (>200 ha) are different and typically more diverse than those of owners of larger properties (Bieling, 2004; Dominguez and Shannon, 2011; Huntsinger et al., 1997). In a study on the interests of small-scale forest owners in the federal state of Baden-Württemberg in southern Germany, Härdter (2004) found that – while economic gains and savings are strong motives – nature conservation and recreation are becoming more important motivators for owning forest land. Economic reasons for owning small-scale forest lands were more often expressed by farmers, while non-farming forest owners more frequently cited conservation and recreation as being important. Although farmers as forest owners play a substantial role in rural areas, a growing share of small-scale forest owners today lives – due to increased mobility – in cities and is engaged in urban lifestyles (Ziegenspeck et al., 2004). Those so-called urban forest owners are often using their forests very extensively for firewood cuttings or walking activities or else they do not manage their forest at all (Bieling, 2004). While farmers and rural populations are often consulted by forest extension services and farmer unions on forest management, urban forest owners are poorly accessible through classical consulting activities (Bieling, 2004; Schraml, 2006).

### 1.3. Management goals of publicly owned forests

All forest owners have to comply with the established legal standards for forest management; but in Germany and other European countries public forests have additionally been declared a good of common welfare. Thus they have to be managed in line with a multitude of societal interests and serve as models for the multifunctional provision of conservation of biodiversity and ecosystem services (Ruppert-Winkel and Winkel, 2011; Schaich, 2013). However, despite these aims toward multifunctionality, timber production has played a predominant role in on-the-ground management of public forests for centuries (Pistorius et al., 2012). Close-to-nature approaches to forest management emerged in some European public forests in the second half of the 20th century (Schütz, 1999) as a response to the ecological problems that the prevailing even-aged, relatively young forest stands with few tree species in Europe at that time were believed to create. State forests in Germany have been imprinted by refined concepts of close-to-nature forest management since the 1980s. The vision of close-to-nature forestry is to enhance continuous forest cover, mixed stands, uneven-aged stand structures, selective harvest and the use of natural tree regeneration (Larsen and Nielsen, 2007). The management concept comprises selective cuttings, shelterwood cuttings to foster natural regeneration and site-adapted tree species choices (MLR, 1993).

### 1.4. Objective

The varying motives and interests of different forest owners and ownership groups may translate into different forms and intensities of forest management and finally result in variations with regard to stand structures and tree diversity (Moser et al., 2009). Such knowledge concerning different forest ownership regimes is needed to guide forest and environmental policies, in particular those related to halting biodiversity loss and fostering the provision of ecosystem services (Landell-Mills and Porras, 2002; Meyerhoff et al., 2009). However, the influence of different ownership categories and their inherent management practices on forest ecosystems have been poorly studied so far. Biodiversity and conservation-orientated knowledge for private lands in general (Hilty and Merenlender, 2003) and especially detailed information on stand structure and diversity of small-scale private forest is largely missing (Gamborg and Larsen, 2003).

In this study, we investigated adjacent forest stands under state, municipal and small-scale private (<200 ha) ownership in the Swabian Alb area in southwestern Germany. Our major objective was to analyze differences in tree species composition, stand structure and carbon sequestration in biomass between stands under different ownership in this area, taking into account mediating environmental factors. Based on the assumptions made in previous, non-empirical studies, we hypothesized that the diversity in objectives and management intensities of small-scale private forest owners triggered a higher structural variability (hypothesis 1) and a higher amount of carbon stored biomass (hypothesis 2) in comparison to state and municipal forests. In contrast, we expected that close-to-nature management approaches in state and municipal forests lead to a higher number of old-growth features like dead wood (hypothesis 3) as well as a more mixed and