



When beech strikes back: How strict nature conservation reduces herb-layer diversity and productivity in Central European deciduous forests



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ABSTRACT

Current nature conservation policy is going to alter the tree-layer composition of many Central European deciduous forests. As a consequence of ceasing silvicultural management, the competitive ecosystem engineer European beech (*Fagus sylvatica* L.) will spread and the proportion of secondary tree species will considerably decrease. Thus, changes can also be expected in herb-layer diversity, productivity and composition. To predict these changes, we analysed relationships between tree- and herb-layer diversity and composition along tree-diversity gradients in the Central German woodland areas of the Hainich National Park (unmanaged) and the Göttinger Wald (managed by close-to-nature forestry).

The flora of both study areas was dominated by typical forest species. In the Hainich, the herb-layer vegetation in beech-dominated stands was less diverse compared to stands richer in canopy species. Herb-layer productivity was also lower in beech-dominated stands. In the Göttinger Wald, herb-layer diversity and productivity were not related to tree-layer diversity and beech proportion, instead to the light transmissibility of the canopy layer. The different results can be explained by logging effects in the Göttinger Wald, which promoted the light factor as significant for herb-layer diversity and productivity. In the consistently darker stands of the Hainich, soil variables, particularly influenced by the ecosystem engineer beech, were decisive. Areas of high canopy diversity in the Hainich result from former management practices and can, in the future, be expected to decrease with the spread of beech.

We conclude that forest management cessation will result in decreasing herb-layer diversity and productivity in many Central European deciduous woodlands, especially in landscapes where historical management practices led to unnaturally low proportions of beech. The short-term consequence of management cessation is a loss of herb-layer diversity due to reduced light availability; in the long-term, herb-layer diversity is expected to decrease due to the expansion of beech.

If the key aim of nature conservation policy is to preserve and develop the typical diversity of near-natural beech forests, then a complete cessation of forest management can be advised. However, if the typical forest herb diversity of the semi-natural, century-old cultural landscape is to be maintained, close-to-nature forestry management is necessary.

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1. Introduction

Diversity relationships and interactions between forest strata are currently an important research topic (Leuschner et al., 2009; Nadrowski et al., 2010; Both et al., 2011; Martin et al., 2011; Bartels and Chen, 2013). It is particularly crucial to study the effects of tree-layer composition variations on herb-layer vegetation,

since herb-layer vegetation contributes significantly to the ecosystem functioning and biodiversity in forests (Augusto et al., 2003; Gilliam, 2007; McEwan and Muller, 2011). Productive and species-rich herb-layer vegetation can contain significant amounts of aboveground biomass and nutrients (Yarie, 1980; Schulze et al., 2009); during periods of high potential leaching, the temporary storage of elements by ground-layer herbs reduces nutrient losses into surface water (Mabry et al., 2008). Furthermore, many forest plant species are specially protected and high valued in nature conservation (Hermý et al., 1999; Jolls, 2003).

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In Central European forests, the tree layer composition is heavily influenced by forestry. Without human activity, European beech (*Fagus sylvatica*) would be the dominating tree species, but silviculture also promotes a great number of other tree species (Heiri et al., 2009; Ellenberg and Leuschner, 2010). In deciduous forests on fertile soils this frequently led to the development of mixed stands, consisting of beech and economically more valuable broad-leaved tree species (e.g., *Acer pseudoplatanus*, *Fraxinus excelsior*, and *Prunus avium*), instead of pure beech stands (Spiecker et al., 2009). Also, historical woodland management practices, such as coppicing and coppicing with standards, altered the tree layer composition (Albert and Ammer, 2012; Altman et al., 2013). Due to the different traits of the canopy trees, the composition and diversity of the herb layer can be expected to change if *F. sylvatica* becomes more dominant in comparison to other deciduous tree species (Barbier et al., 2008). Presently in Germany, 16% of the woodland area consists of beech-dominated stands (BMEL, 2014).

In general, the tree-layer composition has an effect on ground vegetation due to its influence on various ecosystem processes, e.g. nutrient cycles, light transmittance, and soil water supply (Augusto et al., 2003; Barbier et al., 2008; Chávez and Macdonald, 2010a; McEwan and Muller, 2011). The chemical composition of tree leaf litter was particularly found to be a major factor influencing soil acidity and thereby nutrient stocks (Augusto et al., 2003; Langenbruch et al., 2012). Besides altered soil conditions, the light transmissibility of the canopy stratum was found to be another key factor affecting herb-layer diversity (Härdtle et al., 2003; Barbier et al., 2008) and productivity (Axmanová et al., 2012). Diffuse light is transmitted differently depending on the tree species, e.g., beech crowns transmit only a small proportion of daylight to the forest floor (Hagemeier, 2002).

In the future, nature conservation measures in Central Europe are expected to alter the tree-layer composition in many regions. In Germany, during the last two decades, the national parks of Hainich, Eifel and Kellerwald-Edersee have been established in landscapes with deciduous forests (Job, 2010). Additionally, there is a countrywide network of strict forest nature reserves (BLE, 2013). In the near future, there is expected to be an increasing amount of unmanaged forest stands, since the Federal Government of Germany has decided to ensure natural development on 5% of German woodland by 2020 (Küchler-Krischun and Walter, 2007). Currently, 1.9% of the German woodland area is designated to ensure long-term natural development (Wildmann et al., 2014). Following the cessation of silvicultural management, the competitive beech is expected to spread in many areas and to a great extent the proportions of secondary tree species will decrease (Heiri et al., 2009). As a consequence, the composition and diversity of the herb-layer vegetation can also be expected to change (Schmidt, 2005).

In order to predict these herb-layer vegetation changes, we analysed the herb-layer diversity, productivity and composition along a gradient from stands rich in canopy tree species down to pure beech stands (space-for-time substitution; Pickett, 1989) in two study areas with similar forest types and site conditions. Thereby, we investigated whether herb-layer diversity and productivity was related to canopy-layer diversity, with the aim of ascertaining possible causal mechanisms. Since it is important to know if varying (former) management practices result in different relationships between the canopy and the herb layer (Barbier et al., 2008; Durak, 2012), we studied unmanaged stands in the Hainich National Park on the one hand and multifunctional stands with a long tradition of close-to-nature forestry in the Göttinger Wald on the other. In addition, we analysed a 20-year time series on permanent plots from a strict forest nature reserve in the Göttinger Wald with regard to diversity changes in the tree- and in the herb-layer. To interpret the results with regard to conservation issues, the floristic composition of the study areas was also compared, since a

close-to-nature composition of the herb layer is more important than maximum species richness, which may include many generalists (Hermy et al., 1999; Schmidt, 2009; Paillet et al., 2010; Boch et al., 2013).

Our research seeks to answer three main questions. When comparing deciduous stands in a national park without silvicultural management and in a multifunctional forest with a long tradition of close-to-nature forestry,

- Are there comparable relationships between tree-layer diversity and herb-layer diversity and productivity?
- Are there differences regarding the floristic composition and occurrence of forest plant species?
- Which biological, environmental, and anthropogenic factors and mechanisms can be held responsible for the observed relationships and differences?

2. Material and methods

2.1. Tree-layer diversity gradients

2.1.1. Study areas and research site selection

The two study areas, Hainich National Park and Göttinger Wald, are located close to the centre of Germany (Fig. 1). They are about 65 km apart from one another. In each study area, 21 research sites represented a gradient from pure beech stands to mixed stands with the highest tree species richness occurring regularly in the region. The sites were selected by expert opinion after detailed preliminary studies and we sought to ensure that edaphic and climatic conditions were as comparable as possible among the sites of each gradient. This is very important, since sufficiently homogenous climate and soil conditions are crucial for the unbiased analysis of

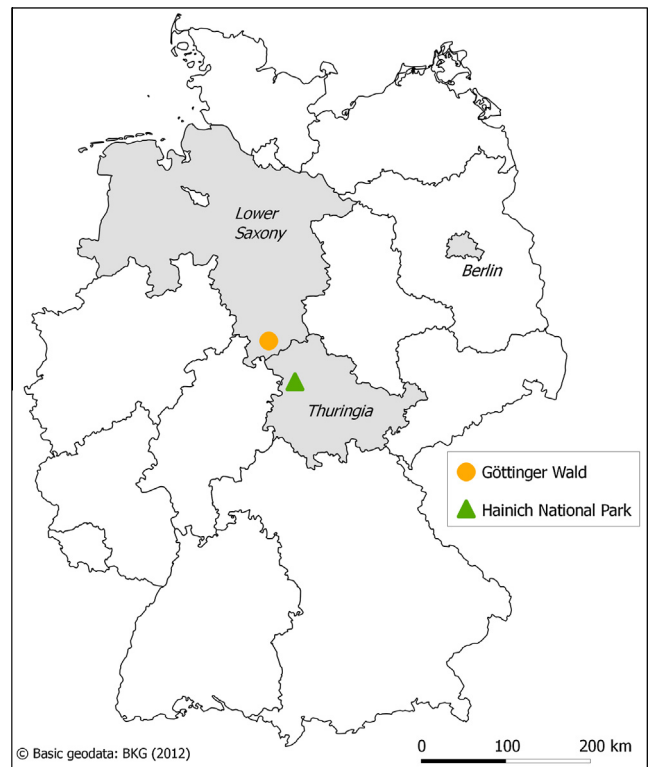


Fig. 1. Location of the study areas Hainich National Park and Göttinger Wald in the German federal states of Lower Saxony and Thuringia.

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