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Vegetation changes in meso- and eutrophic submontane oak–hornbeam forests under long-term high forest management

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ABSTRACT

In the recent decades considerable changes have occurred in the plant species composition and diversity of mixed deciduous forests in the large areas of western and northern Europe. The changes have been caused by substantial alterations of the forest management in the 20th century (transformation of low forests maintained for centuries into high forests). This paper analyzes changes in the vegetation patterns of mixed deciduous forests in the part of Europe where low forest systems had not been implemented in the past. Two datasets from the Polish Eastern Carpathians collected in the 1970s and 2000s were used to analyze temporal and spatial changes in the species composition of oak–hornbeam forests. Herb species richness and compositional dissimilarity (β diversity) decreased. The observed changes in species composition have resulted from the disappearance of specialist species, including the typical species for oak–hornbeam forests and fertile deciduous forests and a rare group of thermophilous species as well as the spread of species with wider ecological niche and lower trophic requirements, and species typical for beech forests. It is suggested that the preferential forest management might have contributed to these changes through an increased share of beech and oak at the expense of hornbeam. Such changes in the species composition of forest stands promote changes in soil properties determining the structure of the herb vegetation – litter becomes thicker and the topsoil pH, nutrient concentration and moisture decrease. Additionally, the processes occurring in the topsoil are enhanced by the cessation of non-timber forest use. Yet, despite the recorded changes in the vegetation, results suggest that in the conditions of long-term high forest management the studied forests have only slightly changed their species composition and maintained their individual character.

1. Introduction

Mixed deciduous forests have been managed for the longest time and in the most intense fashion among all European forest types. For centuries they were used for pasture, were burned, cut down or used as a source of litter (Gimmi et al., 2008; Kirby and Watkins, 1998; Rackham, 1980). The resultant decrease in forest area and increased demand for wood in the last few hundred years was created by the woodland management methods adopted in former times, like coppice or coppice-with-standards and clear cut. Forests were also plundered for selected types of wood. In the face of the threat of wood shortages a need arose to develop forest management systems designed to ensure increase timber production. As a result of scientific forestry development, improved traditional and new management systems (e.g. clear cut, coppice, seed tree, uniform shelterwood). However, in the majority of cases they only managed to promote unnatural, even-aged stands, which in turn resulted in a decrease in forest diversity. In recent decades, non-timber forest use has gradually disappeared, accompanied by a decrease in the demand for timber (Turnock, 2002). Yet, due to the deterioration of biological conditions of forest ecosystems, a different selection or irregular shelterwood high forest management systems have been widely introduced in order to mimic the patterns and processes of natural disturbances, and thus improve the naturalness of forest ecosystems (O'Hara, 2001; Raymond et al., 2009). These changes in forest management, in combination with changes in the use of non-timber forest products, have induced change in the regime of disturbances which a result in different patterns of change in forest ecosystems (Durak and Holeksa, 2015; Wohlgemuth et al., 2002). More often than not, stands have become more denser resulting in more shaded conditions and increased soil fertility (Keith et al., 2009; Verheyen et al., 2012). Consequently, at the

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landscape level, there has been a directional change in the composition of plant and animal species and functioning of forest ecosystems, accompanied by a decrease in taxonomic diversity (Decocq et al., 2005; Ranius and Jansson, 2000; Spitzer et al., 2008; Strandberg et al., 2005; van Calster et al., 2007).

Most of previous papers have examined changes in the vegetation of mixed deciduous forests in Europe with coppice or coppice-with-standard, as a traditional method of woodland management (Peterken, 1981). In those instances, low forests (also known as coppice forests) are converted into high forests with denser canopies or left to overgrow (Rackham, 2008; van Calster et al., 2008), which results in distinct changes in the ecosystem (Decocq et al., 2005; Spitzer et al., 2008; van Calster et al., 2007). However, little is known about changes in mixed deciduous forests prevailing in East Central Europe where low forest systems had not been implemented in the past. In former times they were managed using the clear cutting system, which was later gradually replaced by more refined shelterwood systems. This present study focuses mainly on the thermophilous oak forests in which the change of management triggers succession towards more compact oak–hornbeam forests (Jakubowska-Gabara, 1996).

Mixed-oak–hornbeam forests next to beech forests are a potentially dominant type of forest vegetation in Central Europe (Bohn et al., 2004). This natural type of East Central Europe mixed deciduous forests occur in lowlands and foothills, and in a wide habitat gradient. Despite the huge area of their potential habitats, deforestation and forest management favouring coniferous species have resulted in a negligible share of the oak–hornbeam forests in the total forest area (Matuszkiewicz, 2001). Hence the high conservation value of well-preserved oak–hornbeam complexes in Europe; one of the best preserved and relatively well known oak–hornbeam complexes in the European lowland area is the Białowieża National Park (north-eastern Poland).

This paper deals with oak–hornbeam forests located in the Polish part of the Eastern Carpathians. Their representative phytosociological association is *Tilio-Carpinetum* (*Tilio cordate-Carpinetum betuli* Tracz. 1962, Matuszkiewicz, 2001) – a type of natural oak–hornbeam vegetation that occurs in East Central Europe as well as in Eastern Europe. In Poland, it is associated with the moderate continental climate zone and reaches the western limit of its range there. In the Carpathians, this forests reach the upper limit of their range bordered by the lower border of the lower montane forest zone. In the Polish part of the Eastern Carpathians, the lower montane forest zone is dominated by beech forests (Carpathian beech forest, association *Dentario glandulosae-Fagetum*), with a pattern of changes in vegetation determined by the decrease in soil pH (Durak, 2010, 2011). Oak–hornbeam forests cover a narrow strip of the lowermost areas and can rarely be found above 600 m a.s.l. Despite this limited range, they show a large differentiation (Dzwonko, 1977); thermophilous oak–hornbeam forests are particularly valuable.

In the past, the studied forests, as in other mountain ranges, were particularly exposed to human pressure like grazing, litter raking, picking of oak seeds, felling of trees, etc. (Glatzel, 1991; Schramm, 1958). However, as a result of decreased local population levels and social and economic changes, human pressure gradually decreased in recent decades. In former times, East Carpathian oak–hornbeam forests were subjected to large scale clear-cutting (Schramm, 1958). After WWII stands were managed using systems with lower disturbance intensity, that increasingly began to mimic natural disturbance regimes, in order to maintain the natural diversity of the forest (before the 1991 the uniform shelterwood system and from 1990s onwards the irregular shelterwood group system). The recommended composition of oak–hornbeam forests in the submontane Carpathian zone is based on a combination of oak, beech and fir, with an admixture of hornbeam, which is considered to have a low economic value (Anonymous, 2012). Thus promoted tree species composition in the area differed from typical oak–hornbeam forest, based on hornbeam, oak and lime, where beech and fir should constitute a small admixture.

According to the intermediate disturbance hypothesis, species diversity is maximal at intermediate disturbance levels which prevent competitive exclusion (Connell, 1978). One could therefore expect that the decline in the level of disturbance resulting from the gradual disappearance of non-timber use and more sustainable forest management would cause directional changes in forest vegetation resulting in a decrease in the diversity in the late 20th century. Unlike in the European forests managed previously using coppice or coppice with standard, the changes in vegetation of oak–hornbeam Eastern Carpathians forests would not have been influenced by increased shading and fertility of habitats, as is clearly the case in the conversion from low to high forest (Hédl et al., 2010; Keith et al., 2009). Under the lower intensity disturbance conditions, the most likely pattern of change to a large extent, will be determined by the overstory composition. So, we can expect an increase in the role of beech (preferred in submontane forest management) in the shaping of temporal changes in oak–hornbeam forest vegetation. In this case, we expect a decrease in topsoil pH and vegetation variability (Mölder et al., 2008; Jacob et al., 2010).

The aims of this study were: (1) to assess the impact of the changes in forest management practices and cessation of non-timber forest use on compositional changes in high oak–hornbeam forest vegetation, (2) to explore whether changes in the disturbance regime, induced by forestry overstory composition might explain patterns of change observed in herb vegetation, and (3) evaluate the conservation status of oak–hornbeam forests, taking into account thermophilous plant species (rare in other forests of the region), species diagnostic for oak–hornbeam forests and those characteristic for beech forests (preferred in forestry).

2. Material and methods

2.1. Study site

Data used in this study were obtained from an area in the Sanocko-Turczańskie Mountains located in the northern part of the Polish Eastern Carpathians, part of the Natura 2000 network "Słonne Mountains" PLH180013, PLB180003. The study area with a characteristic system of parallel mountain ranges running from SE to NW covers the area of about 46,000 ha with altitudes ranging from about 300 to 672 m a.s.l. The dominant type of soils are brown soils i.e. Eutric Cambisols, created on Carpathian flysch (Dzwonko, 1977; Skiba and Drewnik, 2003). The average annual temperature is 7.3 °C and the annual rainfall is 814 mm (Michna and Paczos, 1972). The study area has a dense forest cover; about 65% of the area is occupied by forests dominated by beech forest in the higher altitudes and oak–hornbeam forests in the lower altitudes (Anonymous, 2007; Dzwonko, 1977). Most of the region is managed by the State Forest administration. Forests of the studied area are characterized by a high average age of 75 years old. Compared with the lowland parts of Poland, this region has a larger percentage of old stands in the renewal class with diverse tree ages and heights (ca. 25%, data for Brzozów, Brzegi Górne and Lesko forest districts, Anonymous, 2007).

Until the end of the sixteenth century, approximately 80–90% of the Polish Eastern Carpathian region was covered by forests. The forests were used by the local population as pasture, were burned in order to create room for interim agricultural crops, cut down or used as a source of litter and seeds for forage (Schramm, 1958). At the end of the eighteenth century, with the rise in demand for wood as fuel and construction, the clearance of large tracts of