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Management driven changes (1967–2005) in soil acidity and the understorey plant community following conversion of a coppice-with-standards forest

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Abstract

Forest management regimes influence plant diversity and soil properties. Many European forests were traditionally managed as coppice-with-standards of which the majority are nowadays being converted to or have been converted to high forest systems. To evaluate the impact of these changes on abiotic and biotic characteristics, long-term data are needed. Here results are presented from the 245 ha Tournibus forest (Belgium) where soil acidity was determined and vegetation records were made in 1967 and 2005 for 246 semi-permanent plots. In 1967 most of the forest was managed as coppice-with-standards, whereas in 2005 stands were managed as high forest (either uneven-aged high forest, even-aged high forest with *Quercus* spp., or even-aged high forest with *Fagus* spp.).

We determined if soil acidity (at 5 and 45 cm depth) and understorey vegetation related characteristics changed between 1967 and 2005 for the whole forest and if conversion types differentially influenced these variables. Each conversion type was also characterised in terms of canopy and forest floor/topsoil derived factors.

Soil acidity at 5 cm depth increased and the magnitude depended on conversion type and initial soil acidity. No soil acidification was observed at 45 cm. Significant overall increases were found for: α-diversity (i.e. plot species richness), the proportion of ruderal species and Ellenberg indicator values for soil moisture, soil reaction and soil nitrogen. On the contrary, β-diversity (i.e. the degree of change in species identities among plots) and the proportion of competitive and stress-tolerant species on average decreased significantly. Moreover, conversion type differentially affected the magnitude of change for all variables, except α-diversity. Conversion to even-aged high forest led to larger departures from the 1967 situation than conversion to uneven-aged high forest. Most changes were interpreted as abiotic or biotic homogenization, which are likely not independent: increased convergence of abiotic factors within a conversion type (mainly even-aged high forest) most likely has led to biotic homogenization.

Keywords: Conversion; Coppice-with-standards; Herb layer; High forest systems; Homogenization; Permanent quadrats; Soil acidification; Species diversity

1. Introduction

Concerns about effects of forest management on species diversity (e.g. Kirby, 1988; Meier et al., 1995; Ramovs and Roberts, 2003; Decocq et al., 2004) and the forest floor and soil (e.g. Worrell and Hampson, 1997; Fischer et al., 2002) have resulted in guidelines for sustainable forest management strategies (e.g. Bengtsson et al., 2000). These strategies often state that harvesting should mimic the natural disturbance regime (e.g. Bengtsson et al., 2000; Roberts, 2004). However, little consideration is given to the long history of former forest management.

The herb layer of temperate forests contributes most to forest plant diversity (Roberts, 2004) and especially ancient forests are characterised by rich herbaceous layers (e.g. Peterken and Game, 1984). Thus, the internal management in long established, ancient forests should minimize the impacts on these important assets of biodiversity. European forests have

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known a long history of traditional management – often coppice or coppice-with-standards (e.g. Peterken, 1981) – and the alteration of such disturbance regimes may have adverse impacts (White and Jentsch, 2001). In coppice-with-standards systems, new shoots grow from the stumps of felled, young trees which are cut on a short-term rotational basis (coppice) and single-stemmed trees are retained for one or more rotations to yield a sparse canopy (standards). Environmental conditions such as light and temperature change fast and cyclically throughout coppice cycles (Ash and Barkham, 1976). This makes them apt to conserve many functionally diverse groups of species such as vernal species (Ash and Barkham, 1976), seed-banking species (e.g. Brown and Warr, 1992), and shade-tolerant species (e.g. de Kroon, 1986).

The change of coppice-with-standards to high forest management affects many components of the forest ecosystem. Apart from changes in intensity, severity, frequency and extent of disturbances that result hereof (e.g. Barkham, 1992), tree species substitution can constitute another aspect of this change (e.g. Ovington, 1955; Fischer et al., 2002). The latter is often a confounding factor in studies of changing management systems (Kirby, 1988). Choice of tree species influences soil chemistry and humus type (e.g. Muys and Lust, 1992; Prescott, 2002; Aubert et al., 2004; Reich et al., 2005) as well as the herb layer (e.g. Sydes and Grime, 1981; van Oijen et al., 2005). No long-term studies have shown effects of changing forest management per se on soil acidity or the herb layer, mostly changes were attributed to atmospheric deposition and/or leaf litter (e.g. Persson, 1980; Hallbäcken and Tamm, 1986; Persson et al., 1987; Thimonier et al., 1994; De Schrijver et al., 2006). Forest management conversions to high forest differ in the length of time of a transitional period and the degree of mixing of tree species and ages. Many alternatives exist ranging from a period of neglect followed by tree-by-tree harvesting to abrupt clearcut followed by artificial implant of (new) tree species (Peterken, 1981).

Here results are presented from a resurvey of semi-permanent plots in an ancient forest, where two major forest conversion types are present. Almost all plots had a coppice-with-standards structure in 1967. These were converted to high forest by means of either: (i) a combination of abandoning the regular cutting of coppice and promoting coppice shoots and maiden stems to the tree layer, or either (ii) clearcut and replanting with a single tree species. The former gave rise to uneven-aged high forest with mixed tree species, the latter resulted in even-aged high forest monocultures of mainly beech (*Fagus sylvatica*) or oak (*Quercus* spp.). Data on soil acidity and vegetation descriptions were available from a survey by Rogister (1971) and a resurvey of the plots in 2005. Few long-term semi-permanent plot studies at the meso-scale (i.e. forest level) are available that document changes on both biotic and abiotic aspects (but see Persson, 1980; Persson et al., 1987). Furthermore, the 1967 survey is ideal as base-line data to assess effects of forest conversion to high forest.

Therefore, above and beyond exploring how soil acidity and vegetation changed between 1967 and 2005 for the whole forest, the main research questions were: (i) what are the main pathways of forest conversion and to what extent can each conversion type be uniquely characterised by changes in overstorey and forest floor and topsoil attributes, (ii) have different conversion types resulted in different changes in soil acidity, and (iii) which herb layer characteristics are differentially influenced by the different conversion types over time?

2. Material and methods

2.1. Study area

The Tournibus forest is located in the Condroz region in Belgium (Fig. 1) and has an area of 244 ha. This region is characterised by south-west to north-east oriented forested hills and deforested valleys. The geological substrate consists of upper Fammenian sandstone, siltite and shales (Delcambre and Pingot, 2004) and is covered by quaternary eolian loamy deposits of variable depth. This gives rise to two major soil textures: (i) loamy soils and (ii) loamy-gravelly soils (colluvial loamy deposits mixed with >15% small fragments of substrate material). Altitude varies between 218 and 268 m asl. Slopes are gentle and with a south or north aspect, except one slope which faces west. Annual averages for air temperature, amount of precipitation and snow-days are: 8.6 °C, 856 mm and 18.5 days, respectively.

The forest is part of a larger forest complex comprising a total area of 610 ha. Other adjacent land uses include pastures and arable fields (Fig. 1). Tournibus is an ancient forest (i.e. originating before 1775 A.D.), except for a small part (16 ha), which has known a short period (around 1880) of probably arable land use (Institut Cartographique Militaire, 1880, 1/10,000, Feuille LIII, Planchette 1).

In 1967, a cartographical survey of the forest soil, under- and overstorey vegetation was made (Rogister, 1971). The locations of 460 plots of 10 m × 10 m were mapped, and records of at least one of the aforementioned aspects were made. The density of plot locations was adapted to the heterogeneity of soil and vegetation (>1 ha^{-1}). A 1967 map with plot locations at 1/5000 scale and occasional plot field descriptions were used to relocate – with the aid of a GPS (Trimble, Geo-Explorer series, GeoXT, ±1 m accuracy) – 246 semi-permanent plots before leaf-out in 2005. Excluded plot locations were non-forest plots (e.g. forest dwellings, new rides), coniferous plantations, plots located at the intersection of different stand types or nearby large clearings, and plots where no record for the herb layer was available. Coniferous plantations were excluded because they generally did not contain understorey vegetation and our prime interest was in more subtle effects of altered disturbance regimes.

Two hundred and thirty-eight of 246 relocated plots in the study area were converted from coppice-with-standards (CWS) to either: uneven-aged high forest (UAHF; $n = 187$; most frequent tree species: *Quercus robur*, *Acer pseudoplatanus* and *Betula pendula* + *alba*) and even-aged high forest with oak (EAHF-*Quercus*; $n = 27$; age = 28 ± 7 (mean ± standard deviation)) or beech (EAHF-*Fagus*; $n = 24$; age = 36 ± 3 (mean ± standard deviation)).