Forest Ecology and Management 330 (2014) 228–239

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Determining ancient woodland indicator plants for practical use: A new approach developed in northwest Germany

Marcus Schmidt [a], Andreas Mölder [a,*], Egbert Schönfelder [a], Falko Engel [a], Inga Schmiedel [b], Heike Culmsee [c]

[a] Northwest German Forest Research Station, Department A (Forest Growth), Section Forest Conservation and Natural Forest Research, Grätzelstraße 2, D-37079 Göttingen, Germany
[b] Georg-August University Göttingen, Albrecht von Haller Institute for Plant Sciences, Department Vegetation and Phytodiversity Analysis, Untere Karspüle 2, D-37073 Göttingen, Germany
[c] DBU Natural Heritage, German Federal Foundation for the Environment, An der Bornau 2, D-49090 Osnabrück, Germany

ARTICLE INFO

Article history:
Received 24 April 2014
Received in revised form 26 June 2014
Accepted 27 June 2014

Keywords:
Floristic datasets
Forest species
Historical maps
Nature conservation
Recent woodland
Habitat continuity

ABSTRACT

Ancient woodlands that have been in continuous existence for hundreds of years have a floristic composition which greatly differs from younger afforestations. The occurrence of certain associated vascular plant species, termed "ancient woodland indicator plants", can be used to recognise the continuity of woodland cover. Ancient woodland habitats frequently contain a typical and rich forest biodiversity and can often be regarded as "biodiversity hotspots". To pinpoint these habitats for nature conservation, there is a need to compile ancient woodland indicator lists with a widespread validity.

In this study, we introduce a new methodical approach that enables the compilation of such lists from the readily available resources of plant species monitoring programs, archive records, and land cover data. Using northwest Germany as a model region, we have developed an ecologically grounded list of 67 ancient woodland indicator plants for this area. In this context, we consider the "ancient woodland indicator plants" as a subset of the larger group of "ancient woodland plants".

The widely applicable ancient woodland indicator plants list presented here may be a useful tool for future forest nature conservation. Potential applications include: (a) the identification of ancient woodlands in areas where historical maps are lacking, (b) the identification of biodiversity hotspots of ancient woodland indicator plants, and (c) locating ancient semi-natural woodlands.

Finally, we highlight the importance of effective conservation management, which should seek to promote the typical plant diversity of ancient semi-natural woodlands. In doing so, conservation management should promote the preservation of remaining ancient deciduous woodlands and inhibit the conversion of ancient woodlands to coniferous or mixed forests.

Additionally, conservation management should strengthen the connections between recent and ancient woodlands through habitat corridors. Furthermore, careful forest management of deciduous ancient woodland sites with high typical woodland plant diversity has to be ensured to avoid soil damage.

1. Introduction

The continuity of woodland cover in time is regarded as a key factor for biodiversity in temperate forest ecosystems (Peterken, 1974; Singleton et al., 2001; Hermy and Verheyen, 2007; Moning and Müller, 2009; Nascimbene et al., 2013). Numerous studies have shown that woodlands in existence for hundreds of years differed greatly from younger afforestations with regard to their floristic composition (Wulf, 2003; Ito et al., 2004; Hermy and Verheyen, 2007; Svenning et al., 2008; Kelemen et al., 2014). This discrepancy is particularly distinctive in regions with a low proportion of woodland cover and a high degree of fragmentation (Ferris and Humphrey, 1999; Hermy et al., 1999; Wulf, 2003). In contrast, the linkage between woodland continuity and the occurrence patterns of woodland plant species is lower in areas where the majority of woodland is ancient and features a smaller degree of ecological isolation (Dzwonko and Gawroński, 1994; Ferris and Humphrey, 1999; Schmidt et al., 2009).

In Great Britain, the term 'ancient woodland' defines land that has been continuously wooded since at least 1600 AD (Spencer and Kirby, 1992; Goldberg et al., 2007; Stone and Williamson, 2013). In our study, with a focus on the highly fragmented ancient

* Corresponding author. Tel.: +49 551 69 401 313; fax: +49 551 69 401 160.
E-mail address: moelder@gmx.de (A. Mölder).

http://dx.doi.org/10.1016/j.foreco.2014.06.043
0378-1127/

woodland of northwest Germany, we refer to ‘ancient woodland’ as land that has been continuously wooded since at least 1800 AD, since only from this point on are area-wide coverage data on historically old woodland sites available (Wulf, 2003; Glaser and Hauke, 2004). Ancient woodlands with a long habitat continuity harbour a high number of rare and threatened species, and are therefore of particular importance for nature conservation (Rose, 1999; Rackham, 2003; Hermy and Verheyen, 2007; Leuschner et al., 2014).

Based on 22 regional studies from northwest and Central Europe, Hermy et al. (1999) compiled a list of 132 vascular plants closely linked to ancient woodland. Verheyen et al. (2003) evaluated 20 field studies from eight European countries and four northeast American states that compared the vegetation of ancient and recent forests. From these they concluded that the response of forest plant species to land use coincided with a clustering of species featuring different ecological characteristics. In regard to this, slowly colonising species, many of which occur in ancient forests, are typically characterised by low dispersibility (Verheyen et al., 2003; Kimberley et al., 2013).

The continuity of woodland cover can be recognised by means of certain associated vascular plant species, known as ‘‘ancient woodland indicator plants’’ (Rose, 1999; Glaves et al., 2009). In Great Britain, several regionalised lists of ancient woodland indicator plants have been compiled over the last 30 years (Rose, 1999; Glaves et al., 2009), initiated by the work of Peterken (1974). In this study, we consider the ‘‘ancient woodland indicator plants’’ as a subset of the larger group of ‘‘ancient woodland vascular plants’’, even though there is no clear differentiation in literature.

Ancient woodland habitats frequently contain a typical and rich forest biodiversity and can often be regarded as ‘‘biodiversity hotspots’’. Ancient woodland indicators are an important tool to determine these valuable habitats (Myers et al., 2000; Hermy and Verheyen, 2007; Meyer et al., 2009; Mölder et al., 2014a). Furthermore, the occurrence of ancient woodland indicator plants can be an indicator for the conservation value of adjacent open areas. In this regard, Diekmann et al. (2008) pointed out that forest and open-habitat specialists respond not only similarly to landscape heterogeneity and environmental gradients, but also to regional patterns of land use and habitat continuity.

According to Hermy et al. (1999), due to the distinct local variation in the ecological behaviour of forest plant species, regional lists of ancient woodland indicator plants are more appropriate than one Pan-European list. This point of view has been supported by numerous other authors (e.g., Rose, 1999; Wulf, 2004; Glaves et al., 2009; Perrin and Daly, 2010). However, for the application of ancient woodland indicator lists (e.g., by nature conservation authorities or woodland surveyors), it is more convenient to cover larger areas at the supra-regional greater landscape level in order to achieve enhanced validity and comparability. Here, we present a new methodological approach for the identification of supra-regionally implementable ancient woodland indicator plants. In contrast to previous studies, we have not adopted our ancient woodland indicator plant list from a number of previous single studies or local observations. Instead, we systematically evaluated plant distribution data of floristic surveys in relation to ancient woodland cover data from state-wide inventories. In doing so, we determined ancient woodland indicators using consistent and repeatable statistical methods. We have used the large area of northwest Germany as a model region. Here, in these Pleistocene lowlands, ancient woodlands are scattered and their extent is relatively low (Glaser and Hauke, 2004). We would therefore expect a strong association of certain woodland plant species with these woodlands. In addition, the study area is covered by a mapping program of the distribution of vascular plants with a resolution of ca. 30 km^2 and so provides a promisingly large data set.

In developing the ancient woodland indicator plant method, we addressed the following questions:

(1) Which forest plant species can be classified as supra-regionally valid ancient woodland plants for the area of northwest Germany?
(2) Are there groups of ancient woodland plants that are related to certain environmental conditions of different woodland types?
(3) Which of the ancient woodland plants are suitable indicators for application in forestry and nature conservation practice?

2. Materials and Methods

2.1. Study area

The study was conducted in northwest Germany and covered the entire federal states of Schleswig–Holstein and Bremen and the lowland parts of the state of Lower Saxony (altogether covering a total area of 53,549 km^2). We delimitated the borderline between the lowland and the upland parts of Lower Saxony by following Garve et al. (2007). Based on the German network of topographical maps (scale 1:25,000), the study area was divided into a grid of 2378 quadrants, of which each grid cell had a resolution of approximately 5.5 $\times$ 5.5 km or 30 km^2 (Fig. 1).

In the Pleistocene lowlands of northwest Germany, natural woodlands would be dominated by deciduous tree species, especially beech (*Fagus sylvatica*). However, as elsewhere in Central Europe, there are no remaining woodlands completely unaffected by long-term human activity (Szabó, 2009; Ellenberg and Leuschner, 2010; Arnold, 2011). The middle of the 18th century saw initial attempts to establish conifer plantations on infertile heathlands; a century later, for the first time, coniferous and mixed forests (consisting of broadleaved and coniferous trees) reached significant proportions (Niemann, 1809; Kremser, 1990; Hase, 1997). Since then, even deciduous stands on ancient woodland sites have been converted to conifer plantations or mixed forests (see Table 1; ‘‘coniferous ancient woodland’’ or ”mixed ancient woodland’’). This is especially true for nutrient-poor sites (Glaser and Hauke, 2004). Currently, 26% of the woodlands in our study area are ancient. The proportion of deciduous ancient woodland amounts to 7%. In contrast to other European regions (e.g., parts of Great Britain), coppicing played only a minor role in northwest German ancient woodlands during the last 200 years (Kremser, 1990; Hase, 1997; Rackham, 2003).

2.2. Data sets

The floristic data for Lower Saxony and Bremen were obtained from the database of the Lower Saxon plant species monitoring program (NLWKN 1982–2003; Garve et al., 2007). For Schleswig–Holstein, floristic data was collected by Raabe (1987) and the AG Geobotanik (2013) from 1961 to 2012. From these data sets, we considered the 452 vascular plant species that are closely bound to forest habitats according to the German Forest Vascular Plant Species List (Schmidt et al., 2011). 164 species belong to category 1.1 (largely restricted to closed forests), 38 species to category 1.2 (preferring forest edges and clearings), and 250 species to category 2.1 (occurring in forests, as well as in open habitats). For each of these plant species, we ascertained the occurrence (presence or absence) in each topographic map quadrant. Nomenclature followed Wisskirchen and Haeupler (1998).

We determined the ancient woodland area (area_aw) and proportion (perc_aw) in each quadrant, distinguishing respectively between ancient woodland sites currently dominated by deciduous tree species (perc_daw), coniferous tree species