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The Holocene vegetation cover of Britain and Ireland: overcoming problems of scale and discerning patterns of openness

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ABSTRACT

The vegetation of Europe has undergone substantial changes during the course of the Holocene epoch, resulting from range expansion of plants following climate amelioration, competition between taxa and disturbance through anthropogenic activities. Much of the detail of this pattern is understood from decades of pollen analytical work across Europe, and this understanding has been used to address questions relating to vegetation-climate feedback, biogeography and human impact. Recent advances in modelling the relationship between pollen and vegetation now make it possible to transform pollen proportions into estimates of vegetation cover at both regional and local spatial scales, using the Landscape Reconstruction Algorithm (LRA), i.e. the REVEALS (Regional Estimates of VEgetation Abundance from Large Sites) and the LOVE (LOcal VEgetation) models. This paper presents the compilation and analysis of 73 pollen stratigraphies from the British Isles, to assess the application of the LRA and describe the pattern of landscape/woodland openness (i.e. the cover of low herb and bushy vegetation) through the Holocene. The results show that multiple small sites can be used as an effective replacement for a single large site for the reconstruction of regional vegetation cover. The REVEALS vegetation estimates imply that the British Isles had a greater degree of landscape/woodland openness at the regional scale than areas on the European mainland. There is considerable spatial bias in the British Isles dataset towards wetland areas and uplands, which may explain higher estimates of landscape openness compared with Europe. Where multiple estimates of regional vegetation are available from within the same region inter-regional differences are greater than intra-regional differences, supporting the use of the REVEALS model to the estimation of regional vegetation from pollen data.

1. Introduction

The vegetation of Europe has undergone substantial changes during the course of the Holocene epoch. This has resulted from range expansion of plants following climate amelioration and

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competition between taxa during the earlier Holocene (e.g. Birks, 1989) and disturbance through anthropogenic activities during the later Holocene. These changes have culminated in the present-day cultural landscapes. Through the development and widespread application of pollen-analytical techniques, much is understood concerning the processes that have driven regional-scale vegetation change, both through examination of individual pollen stratigraphies and synthesis of large numbers of pollen datasets (e.g. Huntley and Birks, 1983; Giesecke et al., 2011). Pollen stratigraphies are biased, however, owing to differential pollen production and dispersal mechanisms, meaning that the pollen percentages used within such studies do not always relate well to the abundance of plant and vegetation types in the past. For example, the relationship between the arboreal/non-arboreal pollen ratio and vegetation openness is non-linear (Sugita et al., 1999; Hellman et al., 2009a), making the ratio an inadequate proxy for landscape/woodland openness. McLauchlan et al. (2007) define landscape openness as the proportional cover of forest and grassland vegetation; here the term landscape/woodland openness is taken as the cover of low herb and bushy vegetation, which can be measured at various spatial scales.

There remains a strong need for systematic data on regional changes in past land/vegetation cover across a broad spectrum of consumers of pollen data, including natural and cultural heritage managers, palaeo-climatologists and archaeologists. Archaeologists frequently draw on pollen-analytical data to provide the context for their sites, to assess resource availability and to determine the scale of human landscape transformation (Evans, 2003). Archaeological applications require fine-grained reconstructions of vegetation for most questions (e.g. visibility analysis; Cummings and Whittle, 2003), but regionalised vegetation cover can provide an important overview of landscape character and human impact (e.g. Kreuz, 2008; Woodbridge et al., 2013). Better estimates of vegetation cover can also provide improved understanding of land cover-climate feedbacks at the regional and global scale and a means to evaluate other regional/global reconstructions of past anthropogenic land cover (e.g. Kaplan et al., 2009; Goldewijk et al., 2010) and simulations of past vegetation using dynamic vegetation models (Gaillard et al., 2010).

A variety of approaches have been developed to interpret pollen data in terms of vegetation change, including indicator species approaches (Behre, 1986), modern analogue and multivariate methods (e.g. Gaillard et al., 1994), and assignment of pollen taxa to plant functional types to reconstruct biomes (Prentice et al., 1996) or land cover classes (Fyfe et al., 2010). However, none of these methods are capable of quantifying vegetation cover (a measure of the relative proportion of different plant taxa). During the course of the past decade, advances in the application of the extended R-value models and mechanistic pollen dispersal-deposition models developed in the 1980s (Parsons and Prentice, 1981; Prentice and Parsons, 1983; Prentice, 1985) have led to the development of model-based reconstructions of land cover – first with the POLLSCAPE programmes (Sugita, 1994) and subsequently with the establishment of the Landscape Reconstruction Algorithm (LRA: Sugita, 2007a, b). The LRA, a framework for quantification of local vegetation cover (described below), represents an important advance in quantification of past regional and local land cover through the application of the REVEALS (Regional Estimates of Vegetation Abundance from Large Sites) and LOVE (Local Vegetation Estimates) models on pollen records from large and small sites (lakes or bogs), drawing on estimates of the relative pollen productivity and fall speed of pollen (m/s) of key taxa to transform pollen proportions into estimates of vegetation cover. The REVEALS model has been successfully tested against modern and recent vegetation cover using pollen from lake sediments in Europe (Hellman et al., 2008a; Nielsen and Odgaard, 2010; Soepboer et al., 2010) and in northern America (Michigan and Wisconsin; Sugita et al., 2010). The entire LRA approach, implying the application of both the REVEALS and LOVE models, has been tested and evaluated thus far in northern America (Sugita et al., 2010), Denmark (Nielsen and Odgaard, 2010; Overballe-Petersen et al., 2012), and southern Sweden (Fredh, 2012; Cui et al., 2013).

The aim of this paper is to present regionalised former vegetation cover of the British Isles based on the application of the REVEALS model on a large number of sites. The British Isles are of particular interest, as unlike other parts of Europe, it has been suggested that its landscapes may have been substantially cleared of woodland by the historic period. Rackham (1986) argues that by 2500 cal BP the British Isles had only 50% woodland cover, which was reduced to 15% by 900 cal BP and reached levels of 5% at the start of the twentieth century. We therefore seek to determine whether the British Isles had different levels of landscape/woodland openness from mainland Europe earlier in the Holocene. This study is part of the LANDCLIM (LAND cover – CLIMate interactions in NW Europe during the Holocene) project, the major objective of which is to quantify human-induced changes in regional vegetation/land-cover in northwestern Europe during the Holocene with the purpose to assess the possible effects on the climate of two historical processes (compared with a baseline of present-day land cover): (i) climate-driven changes in vegetation, and (ii) human-induced changes in land cover (Gaillard et al., 2010). The full methodological protocol used for the REVEALS application in LANDCLIM is described in Mazier et al. (2012), and the REVEALS reconstructions for the whole study region are presented in Trondman et al. (submitted).

Previous studies from mainland Europe have successfully applied the REVEALS model using pollen records from large lakes (Sugita et al., 2008 (southern Sweden); Soepboer et al., 2010 (Swiss Plateau)), and from multiple large and small sites (lakes and bogs) (Nielsen et al., 2012) (Denmark and northern Germany). The latter study is also part of the LANDCLIM project and use the same methodological protocol. The particular aims of the British Isles study are (i) to assess the application of the REVEALS model to regions for which data are not readily available from the ideal site types (large lakes); (ii) to assess how open the landscape/woodlands of the British Isles was during the Holocene at the regional scale; and (iii) to assess the degree of regional vegetation heterogeneity through time. The approach taken is to produce regional vegetation cover for groups of taxa in 500 year time slices from 10,200 cal BP to the present day for Britain and Ireland.

2. The Landscape Reconstruction Algorithm

This paper attempts to estimate past regional vegetation composition based on pollen count data from the British Isles using the first step of the LRA. The LRA is a framework for the estimation of vegetation abundance within the relevant source area of sedimentary basins based on pollen count data (Sugita, 2007a, b). The LRA has two steps: estimation of regional vegetation using the REVEALS (Regional Estimates of VEgetation Abundance from Large Sites) model (Sugita, 2007a), and estimation of vegetation from within the relevant source area of pollen (RSAP) of target, smaller sites using the LOVE (LOcal Vegetation Estimates) model (Sugita, 2007b). Full details of the LRA can be found in Sugita (2007a, b) and Sugita et al. (2010). The REVEALS model is a generalised form of the R-value model (Davis, 1963) which estimates regional vegetation abundance of a taxon at a given depositional basin using (i) pollen count data from the site; (ii) an estimate of the relative pollen productivity of the taxon (PPE); (iii) an estimate of the fall