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Pollen production estimates (PPEs) and fall speeds for major tree taxa and relevant source areas of pollen (RSAP) in Changbai Mountain, northeastern China

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ABSTRACT

For model-based quantitative reconstructions of past vegetation cover on the scale of landscapes, pollen productivity estimates (PPEs) are key input parameters. In this study, we employed a random sampling strategy to collect moss polsters at 20 sites in Changbai Mountain, northeastern China. A detailed vegetation survey within 1000-m radius around each sampling point was carried out and digitized vegetation maps were used for vegetation data compilation. A forest map at the scale of 1:25,000 was used to extract information about vegetation for the area between 1000 and 5000 m from each sampling point. Using the ERV (Extended R-Value) model, pollen productivity was estimated for *Larix*, *Pinus*, *Juglans*, *Ulmus*, *Tilia*, *Betula* and *Fraxinus* relative to *Quercus*. Estimates of pollen fall speeds for the eight taxa as well as the relevant source area of pollen (RSAP) were also obtained. Three different ERV sub-models were tested against the data. The sub-model 3 produced the best goodness of fit and the PPE values calculated with this sub-model show that *Betula* (5.04), *Pinus* (3.11), *Juglans* (1.94) and *Ulmus* (1.40) are high pollen producers with higher PPEs than *Quercus* while *Fraxinus* (0.76), *Larix* (0.30), *Tilia* (0.16) are low pollen producers compared to *Quercus*. The high pollen producers are all anemophilous species, while low pollen producing plants include both entomophilous, such as *Fraxinus*, *Tilia* and anemophilous species such as *Larix*. The estimated RSAP for the eight tree pollen taxa is about 2000–2500 m.

1. Introduction

Pollen records are among the most important proxies for reconstructing past vegetation and climate. However the pollen–vegetation relationships are nonlinear and affected by several factors in various ways, making vegetation reconstruction difficult. Over the last few decades the advances in the theory of pollen analysis (Prentice, 1985; Sugita, 1994) have demonstrated that there are several critical factors for the pollen–vegetation relationships, and thus for reliable reconstruction of vegetation; those include intertaxonomic differences in pollen productivity and dispersal, spatial distribution of source plants, and differences in size and type of sedimentary basins from where pollen samples are obtained. When biases caused by those factors are properly corrected, quantitative reconstruction of vegetation would become more realistic and objective (Sugita, 2007a, 2007b; Sugita et al., 2010).

Over the last decade, the number of studies which estimate pollen productivity of major plant taxa has been increased in Europe and South Africa, using training datasets of surface pollen and vegetation abundance surrounding pollen sites (Sugita et al., 1999; Broström et al., 2004; Bunting et al., 2005; Räsänen et al., 2007; Soepboer et al., 2007, 2008; Duffin and Bunting, 2008; Filipova-Marinova et al., 2010; Poska et al., 2011; Abraham and Kozakova, 2012; Hjelle and Sugita, 2012). In theory, when vegetation abundance is properly evaluated by considering inter-taxonomic differences in pollen dispersal and basin size and type, pollen loadings of individual taxa on similarly-sized sites are linearly related to the plant abundances of those taxa surrounding study sites; the slope of the relationship represents the pollen productivity estimates (PPEs) for individual taxa (Sugita, 1994). Although the relationship between pollen percentages and plant abundance is nonlinear, PPEs can be obtained even if only pollen percentage data, not pollen loading, are available, by applying the ERV (Extended R-Value) model (Parsons and Prentice, 1981; Sugita, 1994).

In some areas of China, the PPEs for a number of pollen taxa have been calculated using similar methods to those used in Europe (Li et al., 2011; Wang and Herzschuh, 2011). However, these studies were focused mainly on herbaceous taxa in arid or semi-arid desert regions. Moreover, the resolution of vegetation surveys in these studies was relatively low, which may affect the precision of the estimates.

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Reliable PPEs for many more taxa, including major tree taxa, are urgently needed for quantitative reconstruction of past vegetation in different climate regions of China. This study uses surface pollen–vegetation datasets from Changbai Mountain, northeastern China to obtain PPEs of major tree taxa, such as *Pinus*, *Quercus*, *Betula*, *Juglans*, *Tilia*, *Ulmus*, *Larix* and *Fraxinus*; those types are also common in other temperate and cool-temperate regions of China, thus our results are useful for quantitative reconstruction of vegetation not only at Changbai Mountain but also in other forested regions of northern China.

2. Study area

Northern China refers to the vast region to the north of Qinling Mountain Range and Huaihe River. Temperate mixed coniferous and broad-leaved forests and temperate deciduous broad-leaved forests dominate in the region. Changbai Mountain is one of the major forested regions in northern China. There are a series of moderate to low hills with altitudes ~500–1200 m aligned in a southwest–northeast direction. Due to the effect of moisture from oceanic air masses, a temperate wet monsoon climate with abundant precipitation characterizes the region. The annual average temperature is 2–6 °C, annual precipitation is above 600–800 mm, evaporation is below 1200 mm, and the mean annual wind speed is 2.2–3.4 m/s.

Under such climatic conditions, there are a wide range of forest communities (Fig. 1): mixed coniferous-broad-leaved forests (CBS-3, CBS-13 and CBS-15, characterized by *Pinus koraiensis*), broad-leaved mixed forests (CBS-1, CBS-5, CBS-11 and CBS-14; dominated by *Quercus mongolica*, *Juglans mandshurica*, *Tilia mandshurica*, *Acer mono*, *Ulmus laciniata*, and *Ulmus japonica*), *Quercus* forests (CBS-6, CBS-10, and CBS-17), *Betula* forests (CBS-20), *Ulmus* forests (CBS-19), *Acer* forest (CBS-8), *Fraxinus* forest (CBS-4), *Tilia* forest (CBS-12), *Pinus sylvestris* forest (CBS-2), *Pinus koraiensis* forest (CBS-16), *Larix* forest (CBS-18), *Larix*, *Pinus* forest (CBS-9) and *Abies* forest (CBS-7). These vegetation communities have a long history in the region (Jiang et al., 2008). Important tree species in the region include *P. koraiensis*, *P. sylvestris*, *Larix olgensis*, *Larix gmelinii*, *Q. mongolica*, *Betula platyphylla*, *Betula ovalifolia*, *J. mandshurica*, *Juglans regia*, *Tilia amurensis*, *T. mandshurica*, *U. laciniata*, *Ulmus davidiana*, *Ulmus macrocarpa*, *Fraxinus mandshurica*, *Fraxinus rhynchophylla*, *Fraxinus chinensis*, *Acer mono*, *Chosenia arbutifolia*. Table 1 lists characteristic tree species in each forest community and vegetation type.

3. Methods

3.1. Vegetation survey and pollen sampling

Changbai Mountain is an important forestry base in China where a detailed forest inventory is documented by a forest map on a scale of 1:25,000. Information about the distribution and proportion of different dominant plant taxa is therefore available. We selected 20 sites for pollen sampling and vegetation surveys within an area of 52 km × 47 km (125°55.541′–126°34.427′E, 42°03.788′–42°29.033′E) (Fig. 1). The location and plant communities, in which these 20 moss sample sites are located, are listed in Table 1.

The locations of the sampling sites were randomly selected within the study area, but with the proviso that different types of plant community were sampled, that the 1:25,000 scale forest map of the area covers a minimum radius of 5 km around each sampling site, and that the minimum distance between sites was 3000 m. The Morans I index is less than 0.01, indicating that these sites have no spatial autocorrelation.

At each site, we chose a place that was relatively open, about 100 m across, and where mosses were present for pollen sampling. We used a GPS to record the longitude and latitude of each sampling site and used

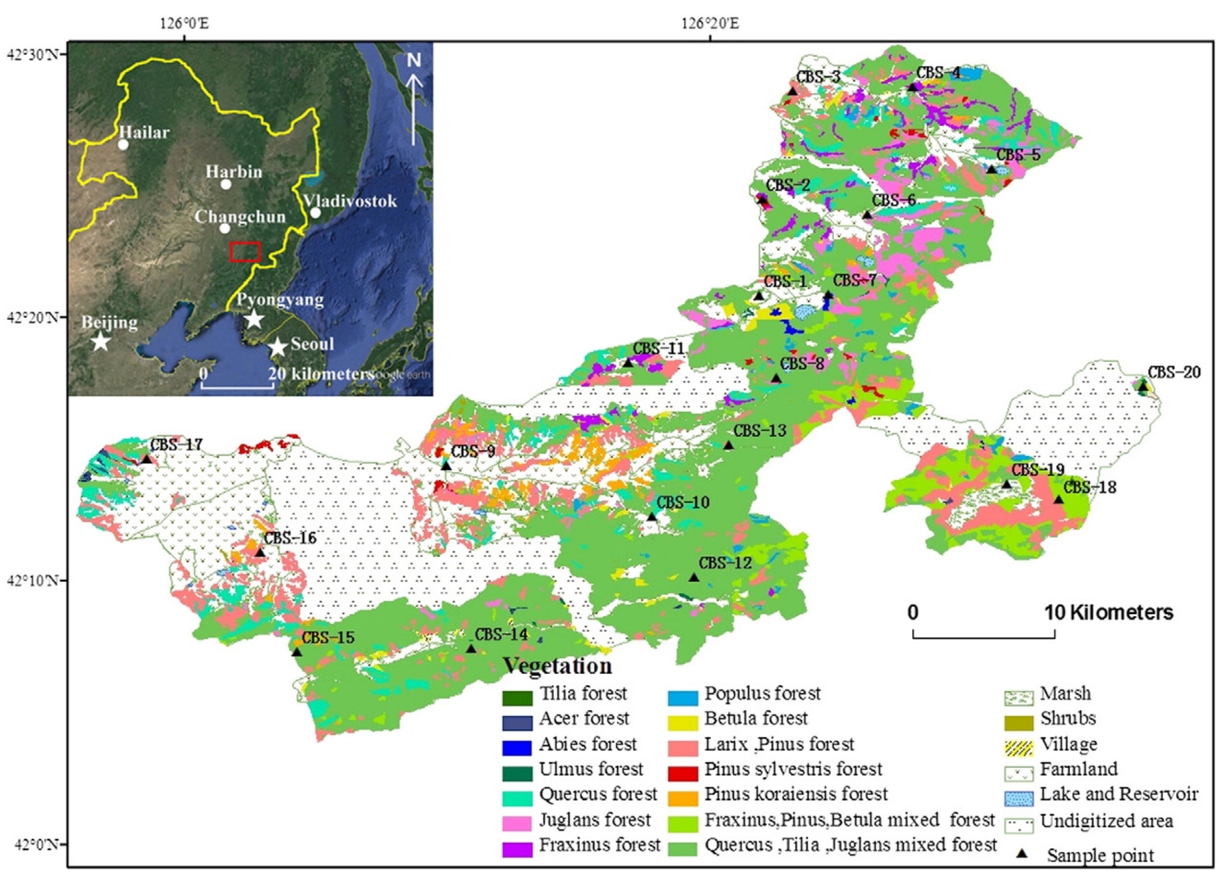

Fig. 1. Study area location and the distribution of sample sites on a vegetation map based on the digitized forest map.