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Quercus long-term pollen season trends in the southwest of the Iberian Peninsula

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ABSTRACT

It is widely accepted the influence of meteorology to airborne pollen distribution, this concern is clearly affected by the issue of climate change. In the SW of Iberian Peninsula pollen from *Quercus* species is often the most abundant in the air and their flowering phenology show changes in seasonal pollination affected by meteorological parameters. This study aims to investigate airborne pollen data of *Quercus* from a city on the SW Iberian Peninsula over a 20 year period and to analyse the trends in these data and their relationship with meteorological parameters using time series analysis and propose a predictable model to forecast their concentration. Aerobiological sampling was conducted from 1994 to 2013 in Badajoz (SW Spain) using a 7-day Burkard spore trap. The main pollen season for *Quercus* pollen lasted, on average, 59 days, ranging from 31 to 80 days, from 28th March to 27th May. The model proposed to forecast the airborne pollen concentration is described by Eq. (1). This expression is composed of two terms: the first term represents the resilience of the pollen concentration trend in the air according to the average concentration of the previous 10 days; the second term is obtained from considerations of the actual pollen concentration value, which is calculated based on the most representative climatic variables multiplied by a fitting coefficient. In order to obtain the best fit the model was developed in four partial time series of 5 years, each of one with a high level of accuracy, although a general model was calculated.

1. Introduction

The IPCC report (2013) indicated a rise of the global average temperature between 1880 and 2012 and it is anticipated that this trend will continue in the following years. The change of global warming has been studied (Root et al., 2003, 2005), being the phenology one of the most relevant aspects (Schwartz, 2003). Plants respond complexly to temperature changes, with the interaction of a wide range of local factors such as meteorological parameters (precipitation and wind mainly), photoperiod, diseases, soil factors, etc. (Ibáñez et al., 2010; Jato et al., 2014; Wielgolaski, 2001). Furthermore, the

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distribution of allergenic pollen in relation to climate change has been previously analysed in Europe taking into account meteorological parameters (Zhang et al., 2013, 2014). The relation between *Quercus* pollen with to the climate change has been studied taking into account phenological trends in the Peninsula Iberian (García-Mozo et al., 2008) and with a statistical approach to bioclimatic trend detection (Fernández-Llamazares et al., 2014). The flowering phenophase (Tormo et al., 2011) found for two species of *Quercus* differences of 20–30 days in the southwest of Iberian Peninsula. The most frequent natural vegetation in Extremadura is the Mediterranean forest handling called as 'dehesas', being *Quercus* the main tree genera. Furthermore of their ecological importance, the acorn production of southern Mediterranean oak ecosystems is of vital economic importance, since acorns are a major component in the feeding systems of high-quality Iberian domestic pigs (Hernández-Ceballos et al., 2011b). *Quercus* pollen is an anemophilous genus producing high quantities of pollen (Tormo-Molina et al., 1996) and suitable for the atmospheric dispersion (Hernández-Ceballos et al., 2011a). In Extremadura five species are the most representative: *Quercus ilex* subsp. *ballota*, *Q. suber*, *Q. pyrenaica*, *Q. coccifera* and *Q. faginea*. Occasionally other species are planted as ornamentals, for instance *Q. robur*. Some papers about floral phenology of *Quercus* spp. have been published in Spain (García-Mozo et al., 2008; Jato et al., 2014). The temporal distribution of the *Quercus* pollen has been studied throughout the day (Hernández-Ceballos et al., 2014), the year (Pérez-Badia et al., 2013), comparatively in height (Charalampopoulos et al., 2013; Fernández-Rodríguez et al., 2014b) and distance (Fernández-Rodríguez et al., 2014a). Furthermore, meteorological parameters influence their presence (Grewling et al., 2014; Jung and Choi, 2013; Kasprzyk et al., 2014). The variations of *Quercus* pollen from local and faraway have been analysed with back-trajectory as tools to study the origin of airborne biological particles registered at a sampling station in Spain (Hernández-Ceballos et al., 2011b).

Airborne pollen have previously been published as air pollutant in papers related with the air quality (Cuinica et al., 2014; Mimura et al., 2014; Motreff et al., 2014). *Quercus* pollen is considered a moderate cause of pollinosis in different countries of Europe (Egger et al., 2008; Jato et al., 2014) and India (Bist et al., 2005). In EEUU have been confirmed the contribution to asthma morbidity (Darrow et al., 2012). In the north of Extremadura, 21% of patients studied with suspected respiratory allergy were sensitised to *Quercus* pollen. The authors believe that this figure is low, considering the large amount of *Quercus* pollen collected. This finding and the absence of monosensitized patients, supports the idea that *Quercus* pollen is little allergenic and rarely causes symptoms (Prados et al., 1995).

The acorn production forecast from airborne pollen data has been analysed in Spain (García-Mozo et al., 2007, 2012). For *Quercus* pollen the statistical tools used to analyse pollen season trends were correlation and regression analyses (Fernández-Llamazares et al., 2014; Jato et al., 2014; Myszkowska et al., 2011), linear regression equations forced through the origin and their root mean square error (RMSE) (García-Mozo et al., 2002) and multiple regression analysis (García-Mozo et al., 2012). A growing degree hour (GDH) model has been applied to establish a relationship between start/end dates and differential temperature sums using observed hourly temperatures from surrounding meteorology stations (Zhang et al., 2014). Phenological models were based in order to fit parameters to both start and peak dates (García-Mozo et al., 2008). Other tools as HYSPLIT model were employed to analysis cluster with aerobiological data (Hernández-Ceballos et al., 2014). Spatial interpolation using ordinary kriging and longitudinal regression analysis with the purpose to estimate pollen concentration in places without pollen data were examined, this method incorporates weather and landcover characteristics that may provided reliable estimates of pollen concentration (Della Valle et al., 2012).

The aim of the present work is to model the *Quercus* pollen concentration in relation with the temporal distribution of five different meteorological variables for 20 years of continuous recording to model the *Quercus* pollen concentration by proposing a mathematical model calibrated with the Shuffle Complex Evolution Metropolis Algorithm (SCEM-UA) as optimisation tool.

2. Materials and methods

2.1. *Sampling site*

Aerobiological samples were collected from 1994 to 2013 in Badajoz (SW Spain) using a 7-day Burkard spore trap with an intake hole located 1.5 m above ground on an open terrace situated 6 m above ground at the Agricultural Engineering School of the University of Extremadura (38°53′45″ N, 6°58′07″ W). Petrolatum White (CAS number 8009-03-8) was used as adhesive. Standardised data management procedures were used as described by the Spanish Aerobiology Network (REA) (Galán et al., 2007). The main pollen season (MPS) was determined using the 5–95% range of the data (Nilsson and Persson, 1981), the number of days is defined as intensity. Seasonal pollen index (SPI) was calculated as the sum of the daily average pollen counts recorded in each MPS for *Quercus* pollen. *Quercus* trees and shrubs from an area of approximately 500 m around the spore trap location were counted and mapped.

2.2. *Climate data and statistical analysis*

Badajoz has a Mediterranean climate with the maximum rainfall in autumn (195 mm) (AEMET, 2015). The highest temperatures are recorded during the summer dry period. On average, the annual rainfall is 463 mm, and the annual temperature is 16.6 °C (1971–2000 mean). Climate data were obtained from Badajoz Airport (38°53′ N, 6°49′ W). The normal distribution of the data was tested using the Kolmogorov–Smirnov and Shapiro–Wilk tests. These tests showed that the daily data did not follow a normal distribution. The tests also showed that the log 10-transformed data also did not follow a normal distribution. A Spearman correlation test was used to analyse associations between selected variables. The statistical analysis included the entire daily data set and was performed with the SPSS 15.0 statistical package. Quercus index (QI) is defined as the daily pollen concentration of this pollen type. The use of meteorological information to predict QI was evaluated with a mathematical model. The model was calibrated using the Shuffled Complex Evolution Metropolis Algorithm (SCEM-UA) with the root-mean-square error (RMSE) as the optimisation function. The suitability of the SCEM-UA has been previously verified in other areas of science, such as hydrodynamics (Efstratiadis and Koutsoyiannis, 2010; Vrugt et al., 2003). This algorithm is based on an automatic search of the feasible parameter space and starts by generating random samples of unknown calibration parameters. From this search, the set of solutions that optimises the goodness-of-fit