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Airborne castanea pollen forecasting model for ecological and allergological implementation

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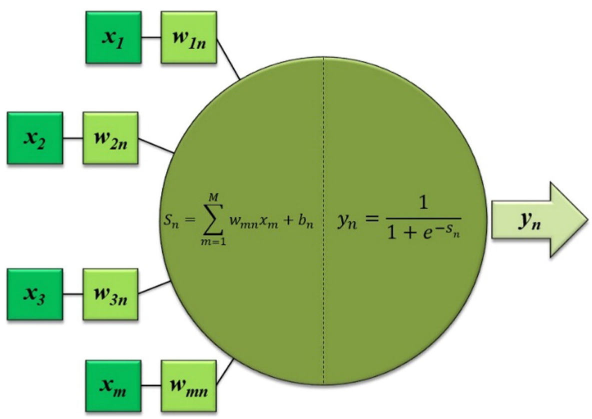
HIGHLIGHTS

- It was detected an increasing trend of total annual *Castanea* pollen concentrations.
- *Castanea* pollen relationships with precipitation and temperature were investigated.
- A strong relationship between pollen and precipitation, and temperature were found.
- The implemented models are based on artificial neural networks (ANN).
- The results show that ANNs are a valid tool to predict *Castanea* pollen.

GRAPHICAL ABSTRACT



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ABSTRACT

Castanea sativa Miller belongs to the natural vegetation of many European deciduous forests prompting impacts in the forestry, ecology, allergological and chestnut food industry fields. The study of the *Castanea* flowering represents an important tool for evaluating the ecological conservation of North-Western Spain woodland and the possible changes in the chestnut distribution due to recent climatic change. The *Castanea* pollen production and dispersal capacity may cause hypersensitivity reactions in the sensitive human population due to the relationship between patients with chestnut pollen allergy and a potential cross reactivity risk with other pollens or plant foods. In addition to *Castanea* pollen's importance as a pollinosis agent, its study is also essential in North-Western Spain due to the economic impact of the industry around the chestnut tree cultivation and its beekeeping interest. The aim of this research is to develop an Artificial Neural Networks for predict the *Castanea* pollen concentration in the atmosphere of the North-West Spain area by means a 20 years data set.

It was detected an increasing trend of the total annual *Castanea* pollen concentrations in the atmosphere during the study period. The Artificial Neural Networks (ANNs) implemented in this study show a great ability to predict *Castanea* pollen concentration one, two and three days ahead. The model to predict the *Castanea* pollen concentration one day ahead shows a high linear correlation coefficient of 0.784 (individual ANN) and 0.738 (multiple ANN). The results obtained improved those obtained by the classical methodology used to predict the airborne pollen concentrations such as time series analysis or other models based on the correlation of pollen levels with meteorological variables.

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1. Introduction

Castanea sativa Miller belongs to the natural vegetation of many European deciduous forests. During the summer months, the tree flowers (Rodríguez-Rajo et al., 2005) rising the atmospheric pollen levels as consequence of its mainly anemophilous behaviour (Jäger and Litschaner, 1999). The *Castanea* pollen production is very high, in the order of 1000 to 1500 grains per anther, which results in 10–12 billion grains per tree released during the pollen season (Jato et al., 2001; Rudow and Conedera, 2001). Due to its small size the chestnut pollen is easily transportable by the wind and clearly recognized as an example of medium and long-range pollen transport (Frei, 1997; García-Mozo et al., 2006; Rizzi Longo and Pizzulin Sauli, 2010). Its presence has been verified in areas without any nearby chestnut populations, exceeding a distance of 100 km and 700 m of altitude a.s.l. (Frei, 1997; Peeters and Zoller, 1988). In North-Western Spain, the *Castanea* pollen abundance and high dispersal capacity (Jato et al., 2001; Rodríguez-Rajo et al., 2005) may cause hypersensitivity reactions in the sensitive human population due to its moderate allergenic capacity (Jäger and Litschaner, 1999; Cosmes Martín et al., 2005). Type I allergy to chestnut pollen represents a major cause of pollinosis in sub-Mediterranean areas (Hirschwehr et al., 1993) due to its major allergen Cas a 1 sensitization (Kos et al., 1993). The scientific interest in this taxon augmented during recent years because available clinical data in the NW part of Iberian Peninsula shows an increase in skin reactivity from the 2–8% sensitisation to *Castanea* pollen among pollinosis sufferers during the 1990's (Arenas et al., 1996; Belmonte et al., 1998; Ferreiro et al., 2002) to 17% of sensitivity in the 2000's (Aira et al., 2000). Moreover, recent findings noted the relationship between patients with chestnut pollen allergy and a potential cross reactivity risk with other pollens or plant foods (Sánchez-Monge et al., 2006). The oral allergy syndrome is a distinctive type of allergy to food resulting from direct contact between food and the oral mucosa, normally affecting patients who are allergic to pollens such as chestnut (Antico, 1996). In addition to *Castanea* pollen's importance as a pollinosis agent, its study is also essential in North-Western Spain due to the economic impact of the industry around the chestnut tree cultivation. Its fruit is collected, transformed and exported to different countries for human consumption. The chestnut tree is also of beekeeping interest because it characterizes the most of the important honeys of the area (Seijo et al., 1997). Finally, the study of the *Castanea* flowering represents an important tool for evaluating the ecological conservation of North-Western Spain woodland and the possible changes in the chestnut distribution due to hotter spring–summer temperatures in recent years (Jato et al., 2013).

During recent years forecasting airborne pollen concentrations is a hot topic (Aznarte et al., 2007) because the pollen allergy is a very common disease in European and world population. Consequently one of the Aerobiology targets is to obtain predictive models for the airborne pollen concentrations (Sánchez-Mesa et al., 2002). Nowadays, there are advanced techniques such as Artificial Neural Networks (ANN hereafter) or the Support Vector Machines (SVM) that have also been used for forecasting air quality parameters (Csépe et al., 2014). ANNs are a computational method formed by individual cells that perform computational calculations similar to the way the human brain works, learning from training data (Sánchez-Mesa et al., 2002). Multi Layer Perceptron (MLP) Neural Network is a particular case of ANN, the most successful implementation, and it is applied in environmental science to develop predictive models (Csépe et al., 2014). ANNs are used in very different fields such as; i) Engineering, for example to study the solar energy potential in Turkey (Sözen et al., 2005), or to predict the fracture parameters of concrete (Ince, 2004), ii) in Computer Science for estimating the effort required for developing an information system (Heiat, 2002), iii) in Hydrology for predict the river flow forecast in reservoir management (Baratti et al., 2003), or used in hybrid systems model for river flow forecasting (Araujo et al., 2011; Toro et al., 2013), iv) in Medicine for gene expression data analysis (Tan and Pan, 2005) v) in daily life for bus arrival time prediction at bus stop with multiple routes (Yu et al., 2011), vi) to assure the authenticity of food in an important wine Spain's region (Gómez-Meire et al., 2014). In recent years, neural network has been used successfully to forecast different bioaerosol particles such as grass pollen in the Southern part of the Iberian Peninsula (Sánchez-Mesa et al., 2002), *Betula* pollen in different parts of Europe such us in Spain (Castellano-Méndez et al., 2005) or in Poland (Puc, 2012), or even *Alternaria* and *Pleospora* spore airborne concentrations in Central Italy (Tomassetti et al., 2013), etc.… In general, all ANN models present better results than other kinds of models like linear regressions, though the ANNs complexity is greater.

An artificial neural network can model complex and non-linear processes through different layers (input layer, intermediate layers and output layer) trained by back propagation algorithm (Csépe et al., 2014), which is the most used algorithm to relate input variables to output variables (Aznarte et al., 2007). The learning process of neural networks is based on the relationship change between the different neurons in neural network. The parameter that defines this relationship or importance value is called weight. The weight together with the bias associated to each neuron, changes throughout the training process to adjust the outputs of the neural network to the value of the training cases, allowing the neural network learning during the operations in the training phase (Venkatasubramanian et al., 2003). A number of data points is reserved for a validation of the results obtained in the training phase. In this way we can see if the training phase produced a predictive model that is reliable.

The aim of this research is to develop an Artificial Neural Networks for predict the airborne *Castanea* pollen concentration during one, two and three days ahead in the North-West Spain area.

2. Material and methods

2.1. Study area

The study was carried out in Ourense, situated in a depression at 139 m. a.s.l., in Northwestern Spain (42°20′N and 7°52′W). The climate of Ourense is oceanic, with a strong Mediterranean influence. During the last 30 years, the region presents a mean annual temperature of 14.2 °C, a minimum average temperature of 8.2 °C, and a maximum average temperature of 20.2 °C (Jato et al., 2007). Annual rainfall is 794 mm, with very irregular distribution over the year; average summer rainfall is only 21.6 mm (Martínez Cortizas and Pérez-Alberti, 1999). In biogeographic terms, the study area belongs to the Euro-Siberian Region, Atlantic European Province and Cantabrian-Atlantic Subprovince (Rivas-Martínez et al., 2002). The characteristic vegetation is formed by the *Holco mollis–Quercetum pyrenaica* association with the presence of *Q. pyrenaica* Willd., *Q. suber* L. and *Q. robur* L., within the tree stratum, and *C. sativa* as an accompanying species. *Castanea* cultivation is widespread in this region, forming dense forests especially in areas between 600 and 900 m above sea level.

2.2. Aerobiological survey

A Hirst-type LANZONI VPPS 2000 volumetric 7-day recording sampler (Hirst, 1952) was used to collect the airborne pollen from 1993 to 2012. The sampler was situated on the roof of the Sciences Faculty (approximately 20 m above ground level). The sampler is calibrated to handle a flow of 10 l of air per minute, thus matching the human breathing rate. Pollen grains impact on a cylindrical drum covered by Melinex film coated with a 2% silicon solution as trapping surface. The drum was changed weekly, and the Melinex film coated was cut into seven pieces and placed in separate glass slides (Galán et al., 2007). Daily values were expressed as number of pollen grains per cubic metre of air. Pollen grain identification was performed using a microscope equipped with a 40×/0.95 lens. Pollen counts were conducted using the model proposed by the R.E.A., consisting in four continuous longitudinal traverses along