Science of the Total Environment 442 (2013) 36–47

Contents lists available at SciVerse ScienceDirect

Science of the Total Environment

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

Climate sensitivity of allergenic taxa in Central Europe associated with new climate change related forces

Áron József Deák [a], László Makra [b,*], István Matyasovszky [c], Zoltán Csépe [b], Beáta Muladi [a]

[a] Department of Physical Geography and Geoinformatics, University of Szeged, HU-6701 Szeged, P.O.B. 653, Hungary
[b] Department of Climatology and Landscape Ecology, University of Szeged, HU-6701 Szeged, P.O.B. 653, Hungary
[c] Department of Meteorology, Eötvös Loránd University, HU-1117 Budapest, Pázmány Péter st. 1/A, Hungary

HIGHLIGHTS

► Trend analysis on a daily basis is a new approach providing information on annual cycles of pollen concentration trends.
► A multiple association measure is introduced for quantifying the relationships among the trends of the variables.
► Novel climate change related forces are introduced, namely risk potential and expansion potential due to the climate change.
► A novel procedure separates the effects of the past and current weather conditions in influencing current pollen levels.
► The potential effect of land use changes on pollen release of the taxa is discussed using the CORINE Land Cover Database.

ARTICLE INFO

Article history:
Received 2 July 2012
Received in revised form 16 October 2012
Accepted 16 October 2012
Available online 21 November 2012

Keywords:
Pollen
Pollen season
Trend
Ecological indicator
Climate change
Respiratory allergy

ABSTRACT

The aim of the study was to analyse trends of the pollen season with its duration, start and end dates, as well as trends of the annual total pollen count and annual peak pollen concentration for the Szeged agglomeration in Southern Hungary. The data set covered an 11-year period (1997–2007) that included eight taxa and seven daily climate variables. Trend analysis was performed on both annual and daily bases. Trend analysis on a daily basis is a new approach that provides information on the annual cycles of the trends. To quantify the strength of the relationship between the annual cycle of the slope of a pollen concentration trend and the annual cycles of the slopes of the climate variable trends, an association measure and a multiple association measure are introduced. Individual taxa were sorted into three categories according to their climate sensitivities. These were compared with two novel climate change-related forces, namely risk potential and expansion potential due to the climate change. The total annual pollen counts indicated significant trends for 4 taxa and 3 of these 4 trends increased on a daily basis. At the same time, significant changes were detected for the pollen season characteristics of three taxa. The association measures performed well when compared to the climate change-related forces. Significant changes in pollen season characteristics were also in accordance with the risk potential and expansion potential due to the climate change. A novel procedure was applied to separate the effects of the past and current weather conditions that influence the current *Ambrosia* pollen concentrations. The potential effect of land use changes on pollen release of the given taxa was also discussed using the CORINE Land Cover Database.

1. Introduction

Recently, the earth's ecosystem has been experiencing a global warming. Climate change is responsible for the observed northward and uphill distribution shifts of many European plant species. By the late 21st century, distributions of European plant species are projected to have shifted several hundred kilometres to the north (Emanuel et al., 1985; Pearson, 2006; Parry et al., 2007; Lindner et al., 2010); forests are likely to have contracted in the south (Penuelas and Boada, 2003) and expanded in the north (Leemans et al., 1996; Pearson, 2006; Lindner et al., 2010). The rate of change will exceed the ability of many species to adapt. As for plant phenology, the timing of seasonal events in plants is changing across Europe due to changes in the climate conditions. Between 1971 and 2000, the average advance of spring and summer was 2.5 days per decade. The pollen season starts on average 10 days earlier and is longer than it was 50 years ago (Feehan et al., 2009).

Global warming is associated with changes in the phenological and quantitative parameters of pollen dispersion of different species.

* Corresponding author at: Department of Climatology and Landscape Ecology, University of Szeged, Hungary, PO Box 653, HU-6701 Szeged, Hungary. Tel.: +36 62 544856; fax: +36 62 544624.

E-mail addresses: aron@geo.u-szeged.hu (Á.J. Deák), makra@geo.u-szeged.hu (L. Makra), matya@ludens.elte.hu (I. Matyasovszky), csepzol@geo.u-szeged.hu (Z. Csépe), muladi@geo.u-szeged.hu (B. Muladi).

0048-9697/$ – see front matter
http://dx.doi.org/10.1016/j.scitotenv.2012.10.067

An analysis of a continental-scale pollen data set reveals an increasing trend in the yearly amount of airborne pollen for many taxa in Europe, which is more pronounced in urban areas than in semi-rural areas or rural areas (Ziello et al., 2012). Namely, trends for 896 phenological time series in Switzerland for the period 1951–1998 indicated earlier appearance dates in the spring and a weak tendency towards later appearance dates in the autumn (Defila and Clot, 2001). In Austria, the flowering period of six taxa starts earlier, and lasts longer; furthermore, their total pollen production and peak values are increasing (Bortenschlager and Bortenschlager, 2005). In the Mediterranean, the flowering of olive trees (*Olea europaea* L.) starts earlier due to the increased spring temperature (García-Mozo et al., 2009; Orlandi et al., 2010), and the warming climate substantially influences both the quantity and quality of olive production (Orlandi et al., 2012). In addition, the pollen season as well as the flowering period of olive trees in Italy are both expected to lengthen in the twenty-first century (Avolio et al., 2012).

The accumulation of anthropogenic gases, especially CO_2, is likely to have two fundamental effects on plants, namely (1) an indirect effect through increasing global average surface temperatures with subsequent effects on the climate, and (2) a direct effect caused by the CO_2-induced stimulation of photosynthesis and plant growth. Both effects substantially influence human health as well including allergic respiratory conditions (Ziska and Beggs, 2012).

The prevalence of allergic respiratory conditions has increased over the last three decades, especially in industrialised countries (D'Amato, 2002; Asher et al., 2006; ARIA, 2008). This increase may be partly explained by changes in environmental factors. Urbanisation, the ever-increasing automobile traffic with its high levels of vehicle emissions (diesel exhaust can enhance IgE production, Krämer et al., 2000) and changing lifestyles are linked to the rising frequency of respiratory allergic conditions (D'Amato et al., 2005). Furthermore, there is evidence that high levels of traffic-derived air pollutants may interact with pollen and bring about more intense respiratory allergy symptoms (Motta et al., 2006). Hence, due to the rising air pollution, respiratory problems are of major concern worldwide.

A comprehensive spectrum of the regional pollen flora was only analysed in three studies, namely in Clot (2003, 25 plant taxa), Damialis et al. (2007, 16 plant taxa) and Cristofori et al. (2010, 63 plant taxa), respectively. Clot (2003) found that 71% of the dates of the onset or the end of the pollen seasons occurred significantly earlier in the year. For the majority of the pollen types the pollen season was not prolonged, but shifted in time. Both Damialis et al. (2007) and Cristofori et al. (2010) detected significant increasing trends in the pollen levels for the majority of the taxa studied. In all three studies, the pollen production of the arboreal plants indicated more comprehensive and stronger increasing trends compared to the herbaceous species (Clot, 2003; Damialis et al., 2007; Cristofori et al., 2010). Though these studies provided a broad survey and a detailed analysis on the pollen season characteristics and trends of a large number of taxa, they did not take into account the associations between the structure of the annual cycles of trends of the pollen concentrations on one hand and the meteorological elements on the other. Furthermore, they did not examine the climate sensitivity or the potential reactions of the individual taxa on the recent warming or the effect of the temporal distribution of the values of the meteorological parameters on the current pollen levels. An analysis of these aspects seems necessary in order to understand the effect of the recent warming on each taxon.

The main aim of this paper is to study an extended spectrum of airborne pollen characteristics (8 plant taxa) for the Szeged region in Southern Hungary. Trends for both quantity-related and phenological pollen season characteristics have been calculated for each taxon. A multiple association measure (MAM) is introduced that describes how well the annual cycle of the daily slopes of a pollen concentration trend can be represented by a linear combination of the annual cycles of the daily slopes of the climate variable trends. Two novel climate change-related forces, namely risk potential (RP) and expansion potential (EP) due to the climate change have also been introduced and these forces are evaluated for each taxon. In addition, a novel procedure was applied to separate the effects of the past and current weather conditions which influence the current *Ambrosia* pollen concentration. The potential effect of land use change on *Ambrosia* pollen concentration is also discussed using results taken from the CORINE Land Cover Database.

2. Materials and methods

2.1. Location and data

Szeged (46.25°N; 20.10°E), the largest settlement in South-eastern Hungary is located at the confluence of the Rivers Tisza and Maros (Fig. 1). The area is characterised by an extensive flat landscape of the Great Hungarian Plain with an elevation of 79 m above sea level. The city is the centre of the Szeged region with 203,000 inhabitants. The climate of Szeged belongs to Köppen's Ca type (warm temperate climate) with relatively mild and short winters and hot summers (Köppen, 1931).

The pollen content of the air was measured using a 7-day recording Hirst type volumetric spore trap (Hirst, 1952) (Fig. 1). The air sampler is located on top of the building of the Faculty of Arts at the University of Szeged approximately 20 m above the ground surface (Makra et al., 2010). Meteorological variables include daily values of minimum (T_{min}, °C), maximum (T_{max}, °C) and mean temperature (T, °C), total solar radiation (TR, $W \cdot m^{-2}$), relative humidity (RH, %), wind speed (WS, $m \cdot s^{-1}$) and rainfall (R, mm). They were collected in a meteorological station located in the inner city area of Szeged (Fig. 1). The data set consists of daily pollen counts (average daily pollen count per cubic metre of air) of those taxa that have the highest pollen release and their mean total annual pollen counts exceeded 80% of the total pollen dispersion over the period 1997–2007. Hence, 8 taxa were analysed. With their Latin (English) names they are as follows: *Ambrosia* (ragweed), *Artemisia* (mugwort), *Betula* (birch), Chenopodiaceae (goosefoots), *Morus* (mulberry), Poaceae (grasses), *Populus* (poplar) and *Urtica* (nettle). Note that pollen grains of Chenopodiaceae and Amaranthaceae are similar in their shape and appearance. Hence their separation and identification require great skill. However, we carefully separated the pollen grains of these two genera. Taxa with the highest pollen levels include *Ambrosia* (32.3%), Poaceae (10.5%), *Populus* (9.6%) and *Urtica* (9.1%), which together account for 61.5% of the total pollen production.

The pollen season is defined by its start and end dates. For the start (end) of the season we used the first (last) date on which 1 pollen grain m^{-3} of air is recorded and at least 5 consecutive (preceding) days also have 1 or more pollen grains m^{-3} (Galán et al., 2001). For a given pollen type, the longest pollen season during the 11-year period was considered for each year.

2.2. Methods

2.2.1. Trend analysis

A common way of estimating trends in data is via linear trend analysis. The existence of trends is examined generally by the *t*-test based on the estimated slopes and their variances. This test, however, may be used for normally distributed data. Data having probability distributions far from the normal one can be tested against monotone trends by the Mann–Kendall (MK) test (Önöz and Bayazit, 2003). Hence this method is used here, though the slopes have also been calculated (Table 1).

It may happen that some trends might have overly complex forms that cannot be suitably approximated by global linear fits, so nonparametric methods are preferable. Nonparametric methods assume