Agricultural and Forest Meteorology 221 (2016) 94–110

Contents lists available at ScienceDirect

Agricultural and Forest Meteorology

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

Biogeographical estimates of allergenic pollen transport over regional scales: Common ragweed and Szeged, Hungary as a test case

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ARTICLE INFO

Article history:
Received 26 March 2015
Received in revised form 26 October 2015
Accepted 6 February 2016
Available online 21 February 2016

ABSTRACT

Long-distance pollen transport can substantially raise local pollen levels, but their relative contribution has not yet been quantified temporally or spatially in ragweed infested regions. Using common ragweed (*Ambrosia artemisiifolia*) pollen accumulation at a ragweed infested area, Szeged, Hungary as a test case, this study attempted to: (1) identify, using cluster analysis, biogeographical regions that contribute to long-range transport of ragweed pollen to Szeged; (2) quantify the relative

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http://dx.doi.org/10.1016/j.agrformet.2016.02.006
0168-1923/

Keywords:
Ambrosia pollen transport
Backward trajectories
Cluster analysis
Mahalanobis distance
Separation of medium- and long-range transport

contribution of ragweed pollen from these regions; (3) determine the relative contribution of "local" and "transported" pollen for Szeged. Using the HYSPLIT model, three-dimensional backward trajectories were produced daily over a 5-year period, 2009–2013 for ragweed pollen accumulation at Szeged. A *k*-means clustering algorithm using the Mahalanobis distance was applied in order to develop trajectory types. Nine back-trajectory clusters were identified. Cluster 1 (direction: from the Channel area south of Great Britain) and cluster 5 (direction: from Northern Mediterranean) were found the most relevant potential long-distance sources for *Ambrosia* pollen transport to Szeged. Potential source contribution function (*PSCF*) and concentration weighted trajectory (*CWT*) values indicated additional potential source areas including the central and eastern part of France, the northern part of Italy and the Carpathian Basin. For Szeged on non-rainy days, medium-range transport is important, while on rainy days the two transport ranges have equal weights. Based on the Granger causality, annual pollen amount transported by the atmospheric circulation is 27.8% of the annual total pollen at Szeged. From this quantity, 7.5% is added to (due to transport), while 20.3% is subtracted from (e.g. because of wash-out by frontal rainfalls going towards Szeged) local sources.

1. Introduction

1.1. Ambrosia *pollen in Europe*

Among the most important invasive plants introduced to Europe, *Ambrosia artemisiifolia*, or common ragweed involves the highest environmental threat through its impact on yield losses, pollen allergy and other direct and indirect social and economic injuries (Makra et al., 2005; Bullock et al., 2010; Vinogradova et al., 2010). The genus of ragweed (*Ambrosia spp.*) comprising 42 species is widely acknowledged as a global source of allergenic pollen and a significant cause of seasonal allergic rhinitis (Béres et al., 2005). Allergic disorders are a widespread recognised chronic disease, those economic and health costs can run into billions of Euros (Bullock et al., 2010).

The spread of *A. artemisiifolia* across Europe from pre 1900 to 2011, regarding four time periods (up to 1900, up to 1960, up to 1990 and up to 2011), shows an accelerated increasing expansion reaching even until the East European Plain in Russia in east and even until the mid-northern areas of Sweden and Finland in north (Bullock et al., 2010; Cunze et al., 2013; Prank et al., 2013; Chapman et al., 2014; Storkey et al., 2014).

The most important habitat areas of common ragweed in Europe, in decreasing order, are as follows. (1) The Ukraine (Rodinkova et al., 2012; Rodinkova, 2014) and the southern part of the European Russia, particularly the latter area, could be a substantial, if not the most important source of ragweed pollen in Europe (Reznik, 2009). Note that ragweed pollen measurements over the most extended habitat areas of *Ambrosia* in the Ukraine (Victoria Rodinkova, personal communication) and the European Russia (Elena Severova, personal communication) have only started at the very end of the 2000s and even the data are rather incomplete. Accordingly, no reliably long data sets are available for quantitatively evaluating *Ambrosia* pollen abundance over these areas compared to well-known pollen sources in Europe. (2) The Pannonian Plain, especially its part, the Hungarian Great Plain including major area of Hungary and Serbia; furthermore, extended regions of Croatia, Slovenia, Slovakia and Romania within the Carpathian Basin (Kiss and Béres, 2006; Makra et al., 2005) are the largest areas of ragweed population in the European Union. (3) The Po River valley with special attention to Western Lombardy in Italy (Bonini et al., 2012), and (4) the Rhône-Alpes region and the central areas in France (Chauvel et al., 2006; Gladieux et al., 2011; Thibaudon et al., 2014) are the most extended habitat areas in Western Europe.

Because of its importance in public health (Cecchi et al., 2006; D'Amato et al., 2007), biogeographical information on the sources and movement of ragweed pollen can be an effective tool in its mitigation and control. Although the establishment of common ragweed has long been recognised in European habitats, current and potential transport of its pollen has not been well quantified. Long-distance pollen transport may substantially raise local pollen levels. Main aspects of this issue are summarised as follows.

1.2. *Long-distance transport of* Ambrosia *pollen*

Since the settling velocity of a ragweed pollen grain is 1 cm s^{-1}, it would take about 1 day for the p EEA Technical ollen to fall 1000 m through the atmosphere. Considering the average wind speed in Europe (EEA Technical Report, 2009), this involves well over 100 km travel for the pollen without falling out, being the lower threshold of the long-distance transport (OECD, 2008; WMO, 2008).

Several authors detected source areas of ragweed pollen arriving at the target area through long-distance transport (Table 1). It was found that ragweed pollen arrived at Poland through long-range transport from Czech, Slovakia and Hungary (Smith et al., 2008; Kasprzyk et al., 2011), as well as from the Ukraine (Kasprzyk et al., 2011). A major long-range source area of *Ambrosia* pollen for Szeged (Hungary) was found the Pannonian Plain in the Carpathian Basin (Makra et al., 2010). Ragweed pollen peaks were recorded in Florence and in Pistoia (both in Italy) when north-north-east winds were observed. Due to back-trajectory analysis, southern Hungary was found as a possible source area of *Ambrosia* pollen over these cities through long-distance transport (Cecchi et al., 2006). Zemmer et al. (2012) detected that transported ragweed pollen arrived at the atmosphere of Istanbul from Bulgaria (a regional source area), furthermore from Moldova, the Ukraine and the Russian coastal region of the Black Sea (long-distance sources). Šikoparija et al. (2009) found the southern part of the Pannonian Plain around Novi Sad and Ruma as a potential source region for *Ambrosia* pollen recorded at Niš and Skopje in the Balkans (Šikoparija et al., 2009). In addition, some authors (Šikoparija et al., 2009; Zink et al., 2012) concluded that long-distance transport should not be neglected when predicting ragweed pollen concentrations over a target area. Peak *Ambrosia* pollen counts in Szczecin (Poland) in 2002 (Puc, 2004) and 2003 (Puc, 2006) are also associated with long-range airflows from south and south-east. In Sweden, occurrences of *Ambrosia* spp. were rare formerly. In recent years, however, long-range pollen transport has been detected in South Sweden (Šikoparija et al., 2013) that is likely to be increasingly more common as ragweed is rapidly spreading in Europe (Dahl et al., 1999; Bullock et al., 2010; Cunze et al., 2013; Prank et al., 2013; Smith et al., 2013; Chapman et al., 2014; Storkey et al., 2014) (Table 1).