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Ragweed (*Ambrosia*) pollen source inventory for Austria

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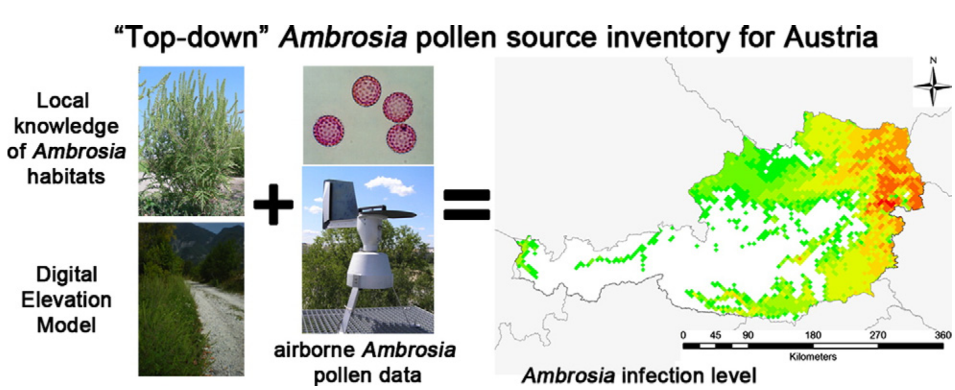
HIGHLIGHTS

- 1st ragweed pollen inventory for Austria, 5 km res
- Using daily pollen data from 19 sites over a ten year period
- Mapping habitats using Corine Land Cover and actual ragweed locations
- Updated methodology compared to previous methods
- Directly comparable with other inventories in Europe

GRAPHICAL ABSTRACT



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ABSTRACT

This study improves the spatial coverage of top-down *Ambrosia* pollen source inventories for Europe by expanding the methodology to Austria, a country that is challenging in terms of topography and the distribution of ragweed plants. The inventory combines annual ragweed pollen counts from 19 pollen-monitoring stations in Austria (2004–2013), 657 geographical observations of *Ambrosia* plants, a Digital Elevation Model (DEM), local knowledge of ragweed ecology and CORINE land cover information from the source area. The highest mean annual ragweed pollen concentrations were generally recorded in the East of Austria where the highest densities of possible growth habitats for *Ambrosia* were situated. Approximately 99% of all observations of *Ambrosia* populations were below 745 m. The European infection level varies from 0.1% at Freistadt in Northern Austria to 12.8% at Rosalia in Eastern Austria. More top-down *Ambrosia* pollen source inventories are required for other parts of Europe.

Capsule abstract: A method for constructing top-down pollen source inventories for invasive ragweed plants in Austria, a country that is challenging in terms of topography and ragweed distribution.

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1. Introduction

Exposure to aeroallergens may cause two principal allergic diseases that are closely related: allergic rhinitis (hay fever) and asthma (Demoly and Bousquet, 2006; Tan and Corren, 2011). Both illnesses significantly reduce quality of life and have a significant economic impact on society (Bousquet et al., 2001). Ragweed (*Ambrosia* spp.) pollen allergens cause symptoms of pollen allergy in late summer and autumn and reportedly induce asthma about twice as often as other pollen types (Dahl et al. (1999) and references therein). Out of five ragweed species present in Europe, only one is native (*Ambrosia maritima* L.) whilst four other ragweed species (*Ambrosia artemisiifolia* L., *Ambrosia trifida* L., *Ambrosia tenuifolia* Spreng. and *Ambrosia psilostachya* DC) have been introduced to Europe from North America (Chauvel et al., 2006; Makra et al., 2005). Of these introduced species, the noxious and invasive *A. artemisiifolia* L. (common ragweed) is by far the most widespread and important in terms of allergy (Smith et al. (2013) and references therein). In Europe, the prevalence of sensitisation to ragweed is increasing and reflects the spread of ragweed plants (Burbach et al., 2009). However, Tosi et al. (2011) showed that the incidence of allergy is delayed during the first years of infestation and so it is not possible to determine the consequences of high *Ambrosia* pollen concentrations over the short-term.

Avoidance of exposure to outdoor allergens is an important part of managing allergy (Peden and Reed, 2010). In the past, forecasts for atmospheric pollen concentrations were usually produced using statistical based receptor-orientated models that are constructed without knowledge of source conditions or calculations of diffusion (Smith et al., 2012). On the other hand, source-orientated models make certain assumptions about the dispersal environment that need to be satisfied before they can be applied and are based on known or estimated emission rates (Seinfeld and Pandis, 2006). The source-orientated models SILAM (e.g., Sofiev et al. (2006)), DEHM (Brandt et al., 2012; Skjøth, 2009), COSMO-Art (Vogel et al., 2008; Zink et al., 2012), METRAS (Schueler and Schlünzen, 2006), ENVIRO-HIRLAM (Kukkonen et al., 2012) and the MACC Ensemble (http://macc-raq.gmes-atmosphere.eu/som_ensemble.php) have currently reported capabilities of modelling pollen transport in Europe. Such forecasts are not just important for allergy sufferers in areas invaded by *Ambrosia*, but forecasters could use the output from these models to warn the public of episodes where *Ambrosia* pollen can be potentially transported into areas where the plant is not considered to be abundant such as parts of Northern Europe (Šikoparija et al., 2013).

The quality of the emissions data strongly influences the performance of pollen dispersal models (e.g., Sofiev et al. (2006)), which is considered to be one of the largest, or the largest, sources of uncertainty in dispersion modelling. Pollen emission data requires inventories of the pollen producing species, which can be produced by using a bottom-up approach that needs statistical data of pollen releasing species with respect to location and abundance within a given geographical area (e.g., the tree species inventory presented by Skjøth et al. (2008)). The bottom-up approach is not suitable for many important allergenic plants such as herbaceous weed species like *Ambrosia* because of the lack of distribution data with high spatial and temporal resolution at the time. For such species, it is necessary to adopt alternative approaches, such as the top-down method that uses measured quantities of pollen concentrations as a starting point and then employs a backwards calculation method for estimating the geographical distribution of the species of interest, as described for *Ambrosia* for the Pannonian Plain by Skjøth et al. (2010) and France by Thibaudon et al. (2014). This study aims to improve the spatial coverage of top-down *Ambrosia* pollen source inventories for Europe by expanding the methodology to Austria, a country that is challenging in terms of topography and distribution of ragweed plants, as it borders highly infested regions to the South and East (i.e., the Pannonian Plain and the Po Valley), as well as regions with relatively little infestation to the North and West.

2. Methodology

The inventory of ragweed pollen sources is based on a well-documented methodology that has been developed and tested in recent years (e.g., Skjøth et al. (2010) and Thibaudon et al. (2014)). It combines the annual ragweed pollen index from a number of stations (Section 2.1), an understanding of ragweed ecology, local knowledge of ragweed infestation in Austria and detailed land cover information from the source area (Section 2.2).

2.1. Ambrosia pollen data

Annual ragweed pollen indices used in this study were obtained from 19 pollen-monitoring stations (Table 1) distributed throughout Austria (Fig. 1) for the period 2004–13. The annual pollen index is based on daily observations that are extracted from the European Aeroallergen Network (EAN) database. *Ambrosia* pollen data were collected using volumetric spore traps of the Hirst design (Hirst, 1952) and analysed following the standardised methodology presented by Jäger et al. (1995). The sum of ragweed pollen recorded annually is expressed as annual pollen indexes (grains) (Comtois, 1998).

2.2. Determining Ambrosia species distribution

Common ragweed is an expanding alien species that has not yet colonized its full potential range (e.g., Chapman et al. (2014)). The plant tends to grow in suitable habitats if two conditions are fulfilled (Skjøth et al., 2010): (1) available seeds; and (2) soil disturbance. Expansion of its range is occurring into regions where the plant is not yet, or sparsely, present, as well as upwards into mountainous areas (e.g., Thibaudon et al. (2014)). The risk of suitable habitats being infested is determined by their altitudinal position. This upper altitudinal limit of ragweed distribution varies from location to location due to macroclimate differences. Knowledge of local variations in the upper limit of ragweed distribution can be used to construct a digital elevation filter to remove climatically unsuitable habitats above a certain threshold using the method described by Thibaudon et al. (2014).

The digital elevation filter for Austria was calculated based on data from Essl et al. (2009) and F. Essl (unpubl. data) based on 657 ragweed observations (Fig. 2). These data include information on altitude, which is used to construct the elevation filter. Using the same approach as Thibaudon et al. (2014), we have employed a high resolution Digital Elevation Model (http://srtm.csi.cgiar.org.) with 90 m resolution in order to obtain complete spatial coverage for Austria (Fig. 2). All ragweed habitats for Austria are identified in the Corine Land Cover (CLC2000) (EC, 2005) dataset. Areas experiencing frequent and extensive soil disturbance have been extracted from identified CORINE categories. The growth habitats of common ragweed in Austria are identified (Table 2) using local knowledge of actual infestation of different land use categories, and information taken from literature (Chauvel et al., 2006; Essl et al., 2009; Fumanal et al., 2007; Karrer et al., 2011; Makra et al., 2005). There is an East–west gradient in Austria (Fig. 3 a–d) in terms of habitats invaded by ragweed (Table 2, left hand column). A large number of habitats in the Eastern parts, especially those areas being part of the Pannonian Plain, are already invaded (Table 2, middle column), whereas a smaller set of habitats in the West, where the topography is more mountainous, is currently invaded (Table 2, right hand column). We therefore split Austria into two and used somewhat different sets of suitable habitats for ragweed invasion for eastern and western Austria. The full set of habitats from the CLC2000 dataset was then reduced by using the elevation filter (Fig. 2.) that describes the limit of upward expansion of ragweed in Austria. The final set of ragweed habitats was then combined with the stations information data and the pollen index at the stations by using the method from Skjoth et al. (2010).