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Mapping allergenic pollen vegetation in UK to study environmental exposure and human health

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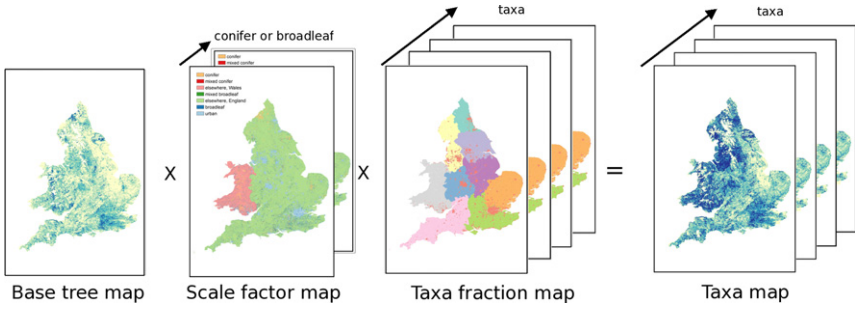
HIGHLIGHTS

- 12 key allergenic vegetation types mapped across the UK at 1 km resolution
- Method combines data from the atmosphere, biosphere, and anthroposphere.
- Different geographical distributions of 12 trees, weeds and grass
- Maps can be used to study UK plants associated with allergy and allergic asthma.
- London results show local level detail around the city, relevant for human exposure.

GRAPHICAL ABSTRACT



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ABSTRACT

Allergenic pollen is produced by the flowers of a number of trees, grasses and weeds found throughout the UK. Exposure to such pollen grains can exacerbate pollen-related asthma and allergenic conditions such as allergic rhinitis (hay fever). Maps showing the location of these allergenic taxa have many applications: they can be used to provide advice on risk assessments; combined with health data to inform research on health impacts such as respiratory hospital admissions; combined with weather data to improve pollen forecasting systems; or as inputs to pollen emission models. In this study we present 1 km resolution maps of 12 taxa of trees, grass and weeds found in the UK. We have selected the main species recorded by the UK pollen network. The taxa mapped in this study were: *Alnus* (alder), *Fraxinus* (ash), *Betula* (birch), *Corylus* (hazel), *Quercus* (oak), *Pinus* (pine) and *Salix* (willow), *Poaceae* (grass), *Artemisia* (mugwort), *Plantago* (plantain), *Rumex* (dock, sorrels) and *Urtica* (nettle). We also focus on one high population centre and present maps showing local level detail around the city of London. Our results show the different geographical

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allergy and allergic asthma. These maps have been produced in order to study environmental exposure and human health, although there are many possible applications. This novel method not only provides maps of many different plant types, but also at high resolution across regions of the UK, and we uniquely present 12 key plant taxa using a consistent methodology. To consider the impact on human health due to exposure of the pollen grains, it is important to consider the timing of pollen release, and its dispersal, as well as the effect on air quality, which is also discussed here.

1. Introduction

Allergenic pollen is produced by a number of trees, grasses and weeds found throughout the United Kingdom (UK). Exposure to such pollen grains can result in exacerbation of pollen-related asthma and allergenic conditions such as allergic rhinitis (pollenosis or hay fever) (Greiner et al., 2012). With the total effect of future environmental changes on pollen production and spread being highly uncertain (Osborne and Eggen, 2014), there is a need for detailed and robust pollen-related health impact information. Highly detailed maps of locations of allergenic plants in the UK, as presented here, are an important part of this as they provide the spatial detail required for impact assessments. Such maps will be highly useful for the next generation co-exposure modelling system currently under development for the UK area. This system is based on an extension of WRF-Chem model (e.g. Grell et al., 2011) and is designed for handling both chemical air pollutants (e.g. Werner et al., 2016, 2017) and bioaerosols (e.g. pollen and spores) at the species level (Skjøth et al., 2015a) where both chemical air pollutants and bioaerosols directly interact with and feedbacks to atmospheric physics.

The UK has one of the highest prevalence of doctor diagnosed asthma affecting around 10% of the adult population (Netuveli et al., 2005). Approximately 80% of people with asthma also have a pollen allergy (Asthma UK, 2017). The NHS Choice website states that over 10 million people have hay fever in England (NHS Choices, 2017). Physician-based diagnosis of allergic rhinitis was 13.2% (95% CI 11.6–14.9) in the UK in 2001 (Bauchau and Durham, 2004).

Detailed maps of allergenic pollen producing taxa, in combination with pollen forecasts and calendars, can help sufferers to manage their condition by reducing their exposure. Asthma and allergic rhinitis significantly reduce quality of life and have a large economic impact (Bousquet et al., 2001). As such, it is a significant environmental health issue.

Our method is novel as it not only provides maps of many different plant types, but also at high resolution across regions of the UK. These maps fill a need for detailed vegetation mapping of allergenic plant species across a whole country, to improve understanding of relationships between allergenic pollen exposure and human health outcomes. With an initial assessment of data availability and expertise on plant types and land cover, the method presented here could be duplicated for other locations around the world.

In this paper we present detailed maps of location of different taxa monitored by the UK pollen network that are associated with allergy and allergic asthma. These have been made to study environmental exposure and human health, although these new vegetation maps have many possible applications as outlined in the following section.

1.1. Purpose of this work and wider context

Vegetation maps have many applications worldwide: they can be used to provide advice on risk assessments, e.g. on invasive species (for example Csornai et al., 2011); combined with health data to inform research on health impacts such as respiratory hospital admissions caused by exposure of environmental aeroallergens (Bousquet et al., 2007; Newson et al., 2014); combined with weather data to improve pollen forecasting systems (e.g. Zink et al., 2012); or as inputs to dedicated pollen emission models (Zink et al., 2013).

The vegetation maps presented here have been developed to study human exposure to allergenic pollen, and the effect on human health. They can be combined with hospital admissions data for asthma to study the impact of different allergenic taxa in the UK. By producing detailed maps of the location of allergenic pollen producing plants for the UK it may be possible to identify the taxa that increase risk of higher hospital admissions for asthma in that particular region. This level of detail could help with the accurate measurement of health impacts as well as monitoring for climate impacts through changes in vegetation distribution, and changes to pollen allergenicity.

Vegetation mapping of plants with allergenic pollen may also help affected individuals with self-management of their allergy or asthma. Once linked with health effects, another application of these maps will be to provide advice for vegetation management practices. These practices can include the choice of tree species, sex of tree for planting, and grass cutting regimes to limit exposure to the most allergenic pollen.

Detailed maps of the location of pollen producing plants are also key to a future pollen forecasting system. Maps can be coupled with key weather variables such as wind direction and speed, precipitation, humidity and temperature, and both phenological and dispersion models, to predict the emission timing, amount (Skjøth et al., 2012) and dispersion of pollen grains, to provide more spatially and temporally resolved pollen forecasts for the UK, compared to the existing regression based approaches for trees (Adams-Groom et al., 2002), grasses (e.g. Smith and Emberlin, 2005, 2006) and weeds.

1.2. Health impacts of allergenic pollen

Exposure to allergenic pollen from certain trees, grasses and weeds is associated with a range of health effects, including allergic rhinitis (hay fever), exacerbation of asthma in susceptible individuals, and atopic dermatitis (eczema) (Cecchi, 2012). These pollen grains are produced in the flowers of angiosperm plants (e.g. most deciduous trees, weeds and grasses), and in the pollen cones of gymnosperm plants (e.g. conifer trees), and the timing of their release varies depending on the species and environmental conditions. Susceptible individuals can be sensitive to pollen from one or more different type of trees, grasses or weeds. Estimates of the levels of allergies towards environmental aeroallergens (pollen, spores and cat/dog/house dust mites) among patients range typically from up to 30%−50% in Europe (Newson et al., 2014), where the largest fractions of sensitisations towards specific pollen typically are against grasses and trees of the *Betulaceae* family with clinically relevant sensitisation rates for grasses exceeding 50% for both UK and Denmark (e.g. Burbach et al., 2009).

1.3. Background to allergenic vegetation mapping

Here we outline methods used in the literature to produce spatial maps detailing the location of vegetation that emits allergenic pollen, often referred to as pollen source maps, or inventories (Skjøth et al., 2012). 'Bottom up' and 'top down' approaches to creating pollen source location maps are outlined in Skjøth et al. (2012). 'Bottom