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Research Paper

Impacts of land clearance by fire on spatial variation of mountain cedar pollen concentrations in Texas

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HIGHLIGHTS

- Airborne *Juniperus* pollen was sampled at burnt vs. control plots.
- We determined diurnal patterns with peak concentrations between 2 and 3 pm.
- Pollen concentrations were on average 15% lower at burnt vs. control plots.
- Plant abundance and prevailing winds affect pollen loads at the local scale.

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ABSTRACT

Austin, Texas, is one of the worst places with respect to allergies. In winter, mountain cedar (*Juniperus ashei*) is producing high pollen amounts exerting the so-called cedar fever in individuals allergic to this pollen species. In this study, we evaluated to which extent the effect of prescribed fires in a semi-arid ecosystem decreases pollen concentrations at the local scale.

The study was performed on patches characterized by human-induced fire disturbances and unmanaged areas (control sites) in the southwest of Austin. Pollen was sampled on four consecutive days in January 2015 using ten pollen traps installed at 1.5 m a.g.l. Microscope slides were inserted every second hour during 8 am and 6 pm. Each station was equipped with meteorological devices to account for influencing factors such as wind speed and direction.

Mean cedar pollen concentrations differed across the studied days and plots and ranged between 633 (16th January) and 126,400 pollen grains/m^3 (17th January). We determined diurnal patterns with peak values between 2 and 3 pm. Pollen concentrations were on average 15% lower at burnt vs. control plots. Comparing pairs of adjacent plots even revealed a reduction of up to 50%.

Therefore, local land management can alter pollen concentrations drastically. A walk across previously burnt areas may trigger less severe symptoms for allergic people during the flowering period of mountain cedar. Our results add to the knowledge about individual cedar pollen exposure in heterogeneous areas and help improving mitigation strategies.

1. Introduction

According to the World Health Organisation 30–40% of the global population suffers from allergies (Pawankar, Canonica, Holgate, & Lockey, 2011). The Asthma and Allergy Foundation of America lists Austin, Texas, among the most challenging places in the US to live for people with spring allergies (AAFA 2015). In winter, mountain cedar (*Juniperus ashei*) produces high pollen amounts exerting the so-called cedar fever in individuals allergic to this pollen species (Levetin & Van de Water, 2001). The pollen production is estimated to more than 400,000 pollen grains per male cone and up to 500 billion pollen for one single tree (Bunderson, Van de Water, & Levetin, 2012; Levetin, Bunderson, Van de Water, & Luvall, 2011).

Facing this situation, it is worth to seek for possible adaptation or mitigation strategies. In terms of adaptation, a number of rules

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related to the avoidance of pollen exposure by individual behaviour such as the timing of outdoor activities or room ventilation are suggested (Enomoto et al., 2004; Menzel, Matiu, Michaelis, & Jochner, 2016; Platts-Mills, 2004). Mitigation strategies mostly focus on land management that reduce or not further increase local allergenic plant abundance. Although several suggestions for landscape planning are proposed (Bergmann, Zuberbier, Augustin, Mück, & Straff, 2012; Cariñanos & Casares-Porcel, 2011; Cariñanos, Casares-Porcel, & Quesada-Rubio, 2014; Cariñanos, Adinolfi, Diaz de la Guardia, De Linares, & Casares-Porcel, 2016; Ogren, 2000), these strategies are hardly implemented.

Populations of mountain cedar in Texas and other south central US states are currently increasing; thus, further sensitization or more severe symptoms are likely (Levetin, Van de Water, & Main, 2000). Case studies have reported a high burden of cedar pollen in Texas, underlining the great population size covering millions of acres in central Texas (Levetin et al., 2000, 2011). Even long-range transport to Tulsa, Oklahoma, which is at a 200 km distance to the nearest mountain cedar population, contributes to daily concentrations exceeding 2000 pollen/m^3 (Levetin & Van de Water, 2001).

Land use changes are considered to have substantial impacts on local as well as on the global scale (e.g., reviewed by Foley et al., 2005). Kalnay and Cai (2003) found that recent temperature increases were substantially influenced by urbanization and other land use changes such as agricultural intensification. In turn, temperature, along with rising CO_2 concentrations, may lead to enhanced biomass growth and pollen production of certain plants such as ambrosia (Ziska et al., 2003). The extensive accretion of built-up areas as a response of population growth and economic development often leads to adverse environmental impacts such as declines in habitat quality (Dewan & Yamaguchi, 2009). Generally, a well-conceived management of ecosystems may result not only in environmental but also in social and economic benefits (Foley et al., 2005).

The example of prescribed fires in central Texas shows how management tools can aggravate or alleviate ecosystem services: In former times, the occurrence of natural wildfires was not suppressed and grassland and savanna ecosystems dominated over vast areas (Smeins & Fuhlendorf, 1997). Owing to the man-made fire depression in recent years, invasions by brush species transformed grassland and savanna ecosystems to dense woody canopy (Fowler & Simmons, 2008). Nowadays, great efforts have been undertaken to maintain or restore the native ecological states of grasslands and savannas (Lady Bird Johnson Wildflower Center, 2010) since these ecosystems were shown to provide larger water quantities and better water quality (Banta & Slattery, 2011). In comparison to native grass species, mountain cedar consumes a far greater amount of water by plant transpiration (Baxter, 2009). Mountain cedar might shade out native grasses implying an overall reduction of herbaceous cover with subsequent increased erosion rates impacting soil stability and water quality (Lady Bird Johnson Wildflower Center, 2010). Therefore, one of the ecological restoration activities in Texas encompasses grass restoration via prescribed fire, especially targeting mountain cedar (Thuesen, 2013). Another co-benefit from land clearance by fire represents the destruction of allergenic tree or shrub species. In this study, we evaluated to which extent the effects of prescribed fire in a semi-arid ecosystem in Austin, Texas, help to decrease pollen concentrations of mountain cedar at the local scale. Investigations on patches characterized by human-induced fire disturbances and unmanaged areas will add to the knowledge about individual pollen exposure in heterogeneous areas and will help to further improve clinical applications as well as mitigation strategies.

2. Methods

2.1. Monitoring sites

The study was performed within the research area of the Lady Bird Johnson Wildflower Center located in the southwest of Austin (30.18°N, 97.87°W, 240 m a.s.l, Fig. 1) where mountain cedar presents the dominant tree species.

We selected five patches characterized by human-induced fire disturbances ("Burn") and five plots characterized by unmanaged forests ("Control") adjacent to them (Fig. 2 and Table 1). Land clearance took place in the previous season (2014) and resulted in a high percentage of cedar mortality associated with a substantial decrease in woody canopy cover.

We calculated the area of each plot and estimated the percentage of trees and shrubs (woody canopy cover) within this polygon and within a radius of 30 m in order to account for plant abundance in the direct vicinity of a pollen trap using Esri ArcGIS 10.3. These values were further used for correlation analyses with pollen indices. For the interpretation of wind rose plots, we also calculated the proportion of woody canopy cover within the four sectors NE, SE, SW, and NW in each 30 m radius.

2.2. Pollen monitoring

Airborne pollen was sampled on four consecutive days in January 2015 (15th to 18th) using ten personal volumetric air samplers (PVAS; Burkard Manufacturing Co. Ltd., UK) based on the Hirst principle (Hirst, 1952). The samplers were mounted on stackable trays at 1.5 m a.g.l. Air was aspirated at 10 l per minute through a vertically oriented orifice and pollen was deposited on microscope slides coated with white pharmaceutic Vaseline. Microscope slides were manually inserted six times a day for one hour during 8 am and 6 pm (8–9 am, 10–11 am, 12 am-1 pm, 2–3 pm, 4–5 pm, and 5–6 pm). Due to a technical failure, the pollen trap at plot 3a only operated on the first day of the campaign. In total, we collected 216 samples that were fixed with cover glasses using a mixture of distilled water, Gelvatol, gelatine and the staining safranin. In the course of shipping from US to Germany, some slides were broken; thus, 194 samples could be further used for analyses. The slides were analyzed under a light microscope at x400 magnification (Zeiss AXIO Lab.A1, Germany) and counts were converted to concentrations in pollen grains per cubic meter of air (pollen grains/m^3) by dividing the number of counted pollen by the volume of air that was sucked in during the measurement period of one hour.

Background pollen concentrations were obtained from a ~23 km distant monitoring site operated by the KVUE television station in Austin (30.37°N, 97.74°W, 220 m, Fig. 1) that started its monitoring in 1999. Here, an Allergenco Air Sampler MK-3 (Environmental Monitoring Systems Inc., Charleston, South Carolina) is used located on the roof in ca. 10 m height which provides mean concentrations for a 24-h period (http://www.kvue.com/weather/allergy-forecast) in pollen grains/m^3. Following the recommendations of the European Aeroallergen Network (EAN, www.ean.polleninfo.eu) the start and the end of the pollen season was defined as the date on which the cumulative sum of daily mean pollen concentration reaches 1 and 95% of the total annual sum, respectively. According to the American Academy of Allergy, Asthma & Immunology and the National Allergy Bureau, a high concentration for cedar pollen is reached when daily station-based concentrations exceed 1500 pollen grains/m^3 (http://www.aaaai.org/global/nab-pollen-counts/reading-the-charts). The seasonal pollen index (SPI) represents the sum of cedar pollen concentrations in one specific pollen season; the daily pollen index (DPI) refers to the sum of our six hourly measurements between 8 am and 6 pm and the