Association between local airborne tree pollen composition and surrounding land cover across different spatial scales in Northern Belgium

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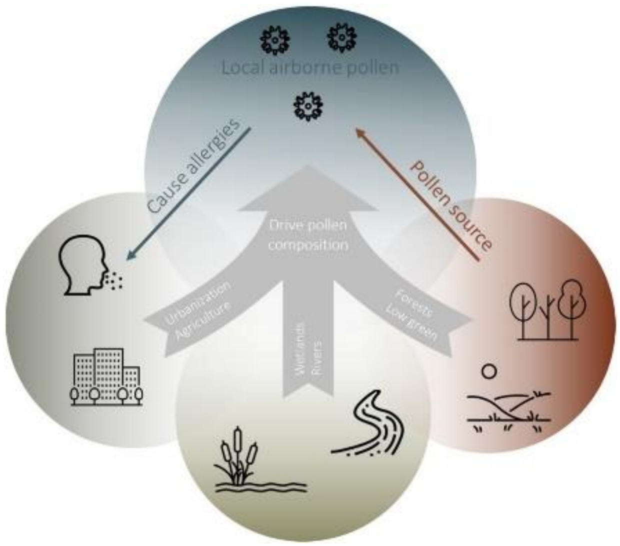

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Title

Association between local airborne tree pollen composition and surrounding land cover across different spatial scales in northern Belgium

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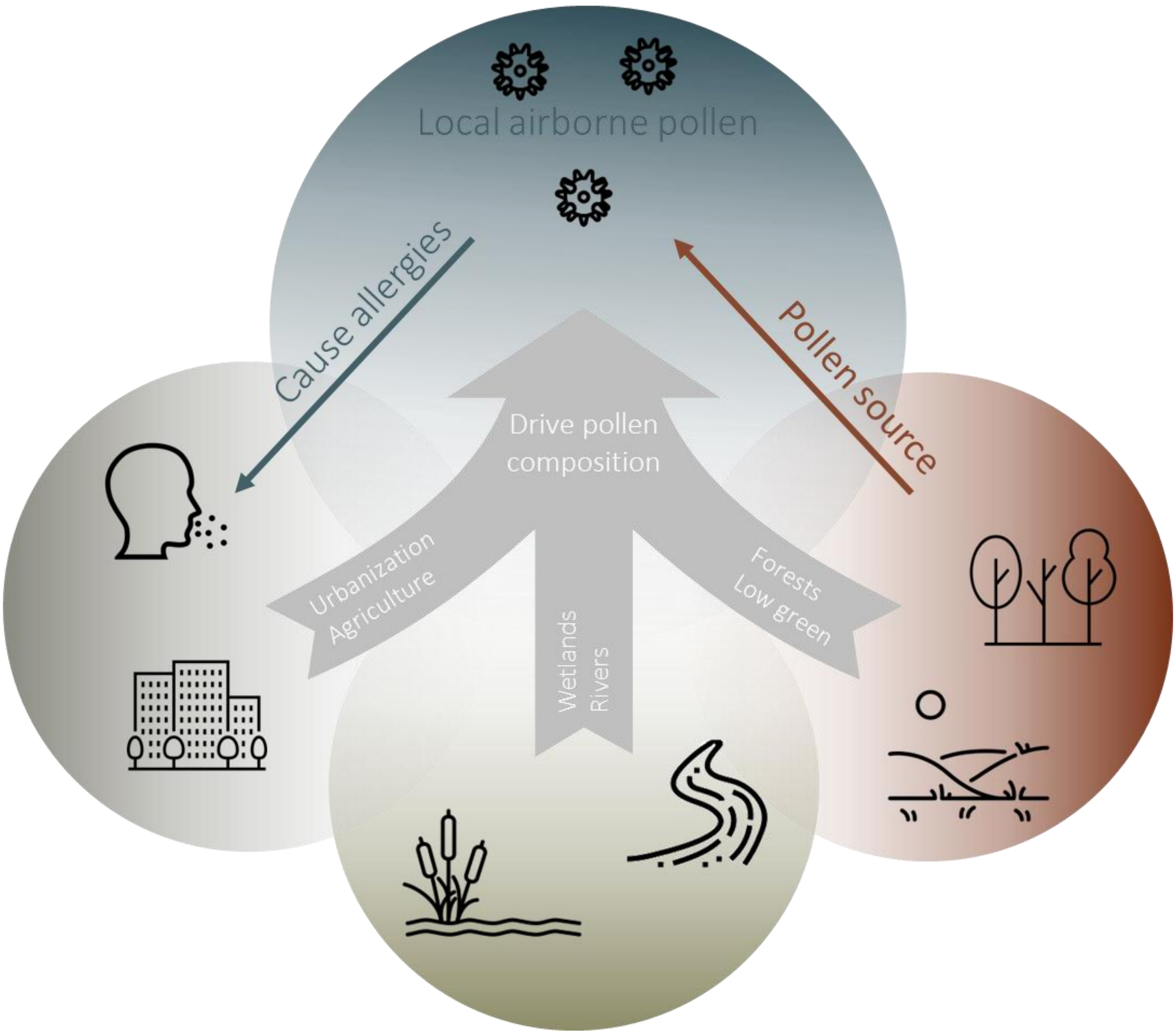
Graphical Abstract



Highlights

- Local airborne pollen composition was assessed with passive sampling
- Different land cover types were marked by different airborne pollen taxa
- Local airborne pollen composition associated to land cover at meso-scale (1-5km)

Abstract

Airborne pollen are important aeroallergens affecting human health. Local airborne pollen compositions can pose health-risks for the sensitized population, but at present little is known about fine-scale pollen composition patterns.

The overall objective of this study is to determine local variations in tree pollen composition with passive samplers and to identify the surrounding landscape characteristics that drive them. In February–May 2017, during the tree pollen season, airborne tree pollen were measured by passive sampling at 2 m height above ground-level in 14 sites in the Flanders and Brussels-Capital region (Belgium). Non-metric multidimensional scaling was used to investigate environmental gradients that determine the pollen composition and amounts. Land cover types were identified across spatial scales ranging between 20 m and 5 km.

The passive samplers detected the same pollen taxa during the same time windows as the validated volumetric Burkard samplers. Using passive samplers, we were able to measure local airborne pollen compositions. *Corylus* and *Platanus* pollen were associated to urban areas; *Populus*, *Juglans* and *Fraxinus* pollen to agricultural areas; forests and wetlands were sources of *Alnus* and *Quercus* pollen. *Salix*, *Populus* and *Betula* pollen were also mainly associated to wetlands. The landscape context drives the airborne tree pollen composition at a meso-scale (1-5 km) rather than at finer scale (20-500 m). Thus, land cover types (e.g. forest, bush land, agricultural lands and wetlands) surrounding urban areas may increase exposure to allergenic pollen in the urban area, potentially affecting the health of a large proportion of the population.

Keywords: aerobiology; passive sampling; NMDS; allergy; urban green areas

1. Introduction

Nature and urban green spaces provide ecosystem services associated with numerous health benefits (Twohig-Bennett and Jones, 2018). In urban areas, people have a reduced exposure to nature (Cox *et al.*, 2018) and experience increased symptoms of asthma and allergies (von Hertzen and Haahtela, 2006). Therefore, urban green spaces are of utmost importance for improving physical (Braubach *et al.*, 2017) and mental health (Barton and Rogerson, 2017; Bratman *et al.*, 2019). However, nature and green spaces can also be a source of aeroallergens, especially when allergenic pollen producing tree species are present (Pecero-Casimiro *et al.*, 2019).

Airborne pollen from many wind-pollinated plant species have allergenic potential. Worldwide allergenic pollen exacerbate allergies in up to 25 % of the population (Passali et al., 2018). It is estimated that 100 million Europeans suffer from allergic rhinitis, yet 45% of this group remains undiagnosed (The European Academy of Allergy and Clinical Immunology (EAACI), 2016). Several factors such as meteorological conditions (e.g. wind speed and direction, humidity and precipitation) (Borycka and Kasprzyk, 2018), presence and type of landscape elements and infrastructure may influence the pollen dispersal and persistence in the atmosphere (Rojo *et al.*, 2015). Long term measurements in Brussels, the capital city of Belgium, show increasing trends in pollen concentrations associated with increasing temperature and radiation and inverse associations with relative humidity and rainfall (Bruffaerts *et al.*, 2018).

In European aerobiological networks, airborne pollen concentrations are monitored by the Hirst method at building roof-level, i.e. 10-20 meters above ground (Galán et al., 2014), optimal for homogeneous measurements representative for an approximate 25 km radius area (Oteros et al., 2019; Rojo et al., 2019). Depending on the local landscape, topography and climate, the measured pollen composition can even be relevant for a 50 km radius area (Gehrig, 2019). Pollen can be transported over long distances, contributing to an extension of the pollen season (Bogawski et al., 2019a). Short-distance transport, however, contributes to the most important pollen peaks (Rojo and Pérez-Badia, 2015). Nevertheless, standardized measurements are not taken at ground level, and as such outside the regular human breathing zone, potential local variations in pollen composition at lower height are poorly taken into account (Hjort *et al.*, 2016; Rojo *et al.*, 2019; Werchan *et al.*, 2017). Peel *et al.* (2013) have shown that the actual pollen-dose can differ strongly from the measured regional pollen concentration.

State of the art birch pollen dispersion models still have difficulty taking into account fine-scale patterns of birch habitation (Kurganskiy et al., 2020). Local tree composition is expected to have an effect on the local pollen exposure (Weinberger *et al.*, 2016) and to be a risk factor for tree pollen allergic sensitization (Lovasi *et al.*, 2013). A better understanding of the drivers of local pollen composition could lead to improved urban green management and better health outcomes (Weinberger *et al.*, 2016). While in palynology the link between regional vegetation and pollen has been widely studied (Fletcher and Thomas, 2007), we aim to contribute to the understanding of current health risks of poorly measured and modeled local pollen compositions.

The overall objective of this study is to measure local variations in airborne tree pollen composition by passive sampling at 2 m height above ground-level. We study how the passive measurements correspond to standardized sampling measurements regarding airborne pollen composition as well as timing of detection during the season. Then we want to identify the environmental factors of the surrounding landscape that drive the local airborne pollen composition. In addition, we test multiple spatial scales to find at which spatial scales the environment affects the local airborne tree pollen composition the most and are thus of relevance for exposure studies.

2. Materials and Methods

2.1 Study Area

The study was conducted in Flanders, the northernmost of the three administrative regions of Belgium, as well as in the Brussels-Capital Region, which is geographically enclosed within the Flanders region. Flanders has an area of 13,522 km² and a population density of 482 inhabitants per km². The Brussels-Capital Region has an area of 162 km² and a population density of 7,442 inhabitants per km². The climate according to Köppen is a maritime temperate climate (Cfb) (Peel *et al.*, 2007).

2.2 Airborne Pollen Sampling

2.2.1 Passive Samplers

The design of the passive samplers that were used in this study was inspired by the Durham pollen trap for gravitational sampling (Durham, 1946). Such Durham-type passive samplers have already been used by Katz and Carey (2014) to measure local pollen amounts. Passive sampling of airborne pollen relies on gravity and intake flow is not controlled. Two parallel panels spaced 30 cm apart were mounted at 2 m height above the ground (Figure 1a). On the bottom panel a glass slide with a tape covered with an adhesive (Vaseline) was placed, similar to the construction of the drum in the Hirst volumetric spore trap. The sticky surface of 10 mm x 45 mm was capable of trapping airborne pollen (Figure 1b). The top plane served to protect the glass from rain and potential debris. The trap was encapsulated by a medium-sized mesh to exclude birds. After two weeks of exposure, samples were collected to avoid oversaturation of particles on the capture surface, and replaced by unexposed glass slides. The exposed samples were then sealed on microscopy glass slides (Figure

1c) with mounting medium (500mL glycerol, 50g gelatin, 5g phenol diluted in 500mL distilled water) according to Galán et al. (2014).

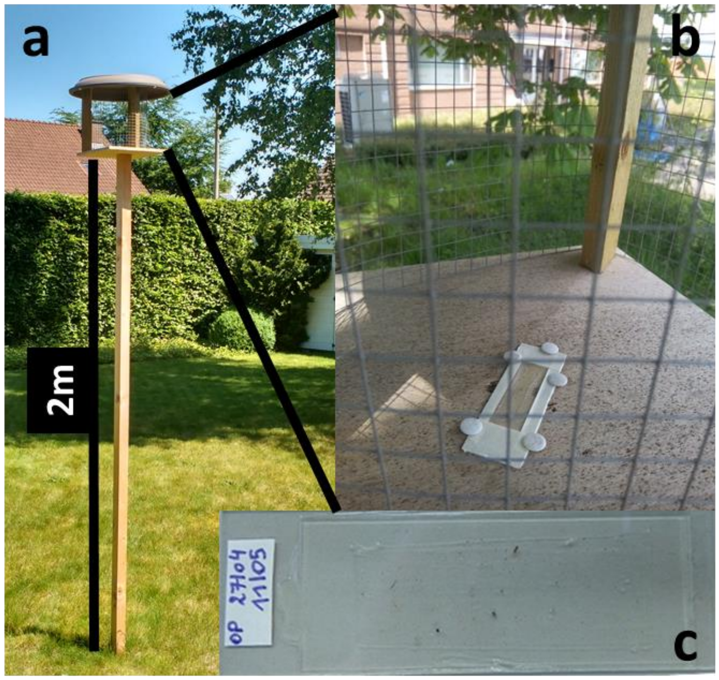


Figure 1: (a) Durham-type passive pollen sampling construction, mounted at 2 m height above ground level. (b) Sticky tapes were placed in the sampler for successive periods of two weeks per tape (c) The samples were mounted on glass slides and labeled before proceeding to pollen identification and counting by light microscopy.

2.2.2 Sampling Sites

Passive sampling was performed during the main tree pollen season of 2017, starting from February 2nd until May 25th. One pollen season generally suffices to obtain insights in the drivers of pollen composition as shown in previous studies (Hugg et al., 2017; Weinberger et al., 2016; Werchan et al., 2017). During this period 8 glass slides with a sticky surface were consecutively exposed at 14 sampling sites. Passive pollen samplers were placed on 14 sites in Flanders and the

Brussels-Capital Region (Figure 2) to monitor the local abundance of pollen of 12 wind pollinated tree taxa: horse chestnut (*Aesculus hippocastanum*), walnut (*Juglans* spp.), beech (*Fagus sylvatica)*, oak (*Quercus* spp.), alder (*Alnus* spp.*)*, hazel (*Corylus avellana*), hornbeam (*Carpinus betulus*), birch (*Betula* spp.), poplar (*Populus* spp.*)*, willow (*Salix* spp.), ash (*Fraxinus excelsior*) and plane (*Platanus* spp.). The authors selected these taxa in consultation with the Belgian Aerobiological Surveillance Network. Not all the taxa listed are strictly wind-pollinated, pollen from *Salix* and *Aesculus hippocastanum* can also be transported by insects.

Two of the fourteen passive pollen samplers were placed close to the reference stations in Brussels (10 m) and Genk (300 m). The reference stations are part of the Belgian Aerobiological Surveillance Network (Sciensano, www.airallergy.be) and monitor average daily pollen concentrations (grains/m³) on building rooftops at about 15 meters above ground level, with Hirst-type 7-day volumetric spore traps (Burkard Manufacturing co., U.K.). Three passive samplers were placed within a 30 km buffer around each of the two reference stations (namely in Mechelen, Kessel Lo, Roosdaal, Heusden-Zolder, Hasselt and Sint-Truiden), and six other samplers were placed outside each of the two 30 km buffers (namely in Gent, Hoboken, Bornem, Aarschot, Oplinter and Neerpelt) (Figure 2). No data were collected in the most Western province of the region because of the coastal climate and divergent landscape.

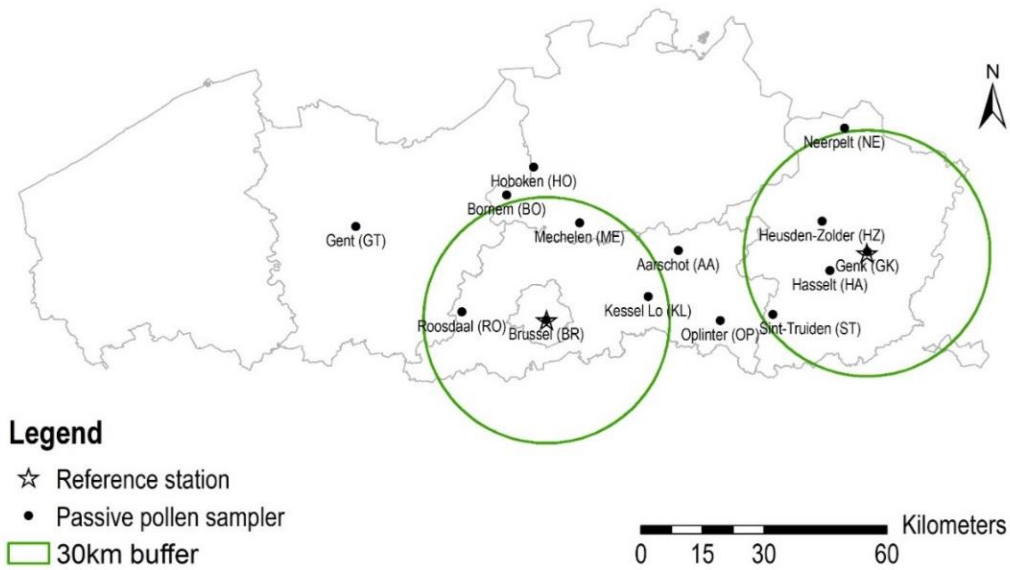


Figure 2: Location of the 14 passive pollen samplers in Flanders and the Brussels-Capital Region (Belgium). The 30 km buffer corresponds to the zone for which the reference stations of Brussels and Genk are representative.

2.2.3 Pollen Identification

Given the taxa selected in this study, Pollen grains were identified by light microscopy (using the Leica optical microscopes with a total magnification of 400 ×; 10 × ocular lens and 40 × objective lens). Two longitudinal swipes were read and counted, each swipe with a length of 45mm and a width of 0.5 mm, corresponding to an area of 45 mm² (10 % of the total sample surface (10 × 45 mm); standard protocol) (Galán et al., 2014). The pollen concentrations obtained through passive sampling should be interpreted as deposition rates: the number of grains that is deposited on a given surface during a certain time, expressed in pollen/cm². The volumetric samplers measure actual pollen concentrations: number of grains present in a given volume of air sampled during a certain time, expressed as pollen/m³. We assumed that higher pollen concentrations lead to higher deposition rates and that therefore the two methods yield pollen data that are correlated. The passive sampling results cover a 14 day period resulting in a biweekly concentration. By dividing the deposition rate by 14, we obtain an average daily deposition rate for each exposure period. For the volumetric samplers at the reference stations daily pollen concentration values were available. These daily values were averaged for the same 14 day exposure periods. The average daily values obtained by the passive and the volumetric samplers were visually compared. Previous studies have shown that passive samplers and volumetric samplers show similar temporal variation and peak periods (Piotrowska and Weryszko-Chmielewska, 2003; Teranishi et al., 2006).

2.3 Pollen composition

To characterize the local airborne pollen composition at each site, the total pollen count (per taxa) from passive sampling was divided by the number of sampling days and multiplied by 30 to obtain estimates of monthly pollen loads. The monthly average pollen taxa data were then log-transformed.

Ordination of the sampling sites based on pollen taxa composition was obtained by non-metric multidimensional scaling (NMDS). An initial exploratory run, testing one- to four-dimensional ordination, showed that a two-dimensional ordination resulted in an acceptable stress score of < 0.1 (Kenkel and Orloci, 1986). NMDS presents the sampling sites in two-dimensional space and based on Bray-Curtis distances a stress level is determined. The stress level quantifies the compositional dissimilarity between the original and current position of the sampling sites. The iterative process (set to a maximum of 100 iterations) aims to minimize the stress value (Clarke, 1993). Ordination was performed using the *vegan* package (Oksanen *et al.*, 2019) for R software (R Core Team, 2017).

2.4 Land cover composition

2.4.1 Land cover data

The surrounding environment was characterized from two land cover data sources available for Flanders. The ECOPLAN dataset (Ecoplan, 2014) is a gridded land cover dataset with a spatial resolution of 5×5 m. The Biological Valuation Map (BVM) (Vriens *et al.*, 2011) is a vector-based dataset (cartographic scale 1:10,000) of habitats with information on the type and ecological value of the habitats. Polygon sizes range between 4 m² and 3236 ha. The mapped polygons are visited by experts in the field to survey the vegetation present to determine specific habitat types. In addition, the presence of remarkable species can be reported as high ecological value. The area fractions (%) of the land cover classes were calculated within six radii (20 m, 200 m, 500 m, 1000 m, 2000 m, 5000 m) around the sampling site using ArcGIS 10.5.1 software (ESRI, 2011). The radii we studied correspond to the meso-gamma scale as proposed by Orlanski (1975), atmospheric processes relevant for pollen transport are studied at this scale (Romero-Morte *et al.*, 2018).

2.4.2 Indirect gradient analysis

For the indirect gradient analysis the site of Brussels was not included, because detailed land cover data was not available for the Brussels-Capital Region. The gradients in the environment are unknown and inferred from the pollen compositions, i.e. an indirect gradient analysis. We used the *envfit* function of the *vegan* package (Oksanen *et al.*, 2019) in the R software (R Core Team, 2017) to correlate (r^2) the area fractions with the ordination of the sampling sites.

3. Results

3.1 Pollen measurements

Pollen of the 12 target tree genera were detected and quantified in concentrations ranging between ~1 to >1000 grains cm^{-2} $month^{-1}$ during the study period (Figure 3). *Quercus* and *Betula* were measured at all sites in the highest quantities (130 – 1324 pollen cm^{-2} month $^{-1}$). *Platanus* (13 sites out of 14), *Aesculus* (2 sites) and *Fagus* (6 sites) pollen were the only taxa that were not recorded at all sampling sites.

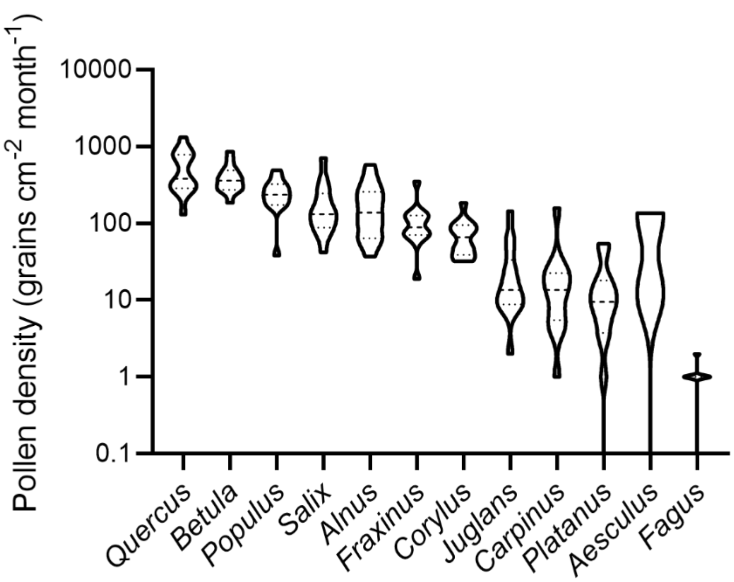


Figure 1: Pollen deposition rates (pollen/cm²/month) of 12 tree taxa measured using Durham-type passive pollen samplers during the 2017 pollen season, at 14 sampling sites in Belgium. Violin plots show the distribution of observations; the y-axis uses a logarithmic scale; horizontal lines represent quantiles.

3.2 Comparison of the Passive Pollen Samplers with the Reference Stations

The passive sampling measurements (lower panels in Figures 4-6) showed that, for each taxon, pollen peaks appeared during the same biweekly periods as in the reference stations with volumetric samplers (upper panels). Results for *Alnus*, *Betula* and *Corylus* are shown as these taxa are considered the most allergenic in the northern hemisphere's temperate zone (Biedermann et al., 2019; D'Amato et al., 2007; Nowosad, 2016). The passive samplers showed variations in pollen density between sampling sites. During the two week peak periods airborne pollen deposition rates varied: 4–113 pollen/cm²/day for *Alnus*, 28–178 pollen/cm²/day for *Betula* and 5–17 pollen/cm²/day for *Corylus*.

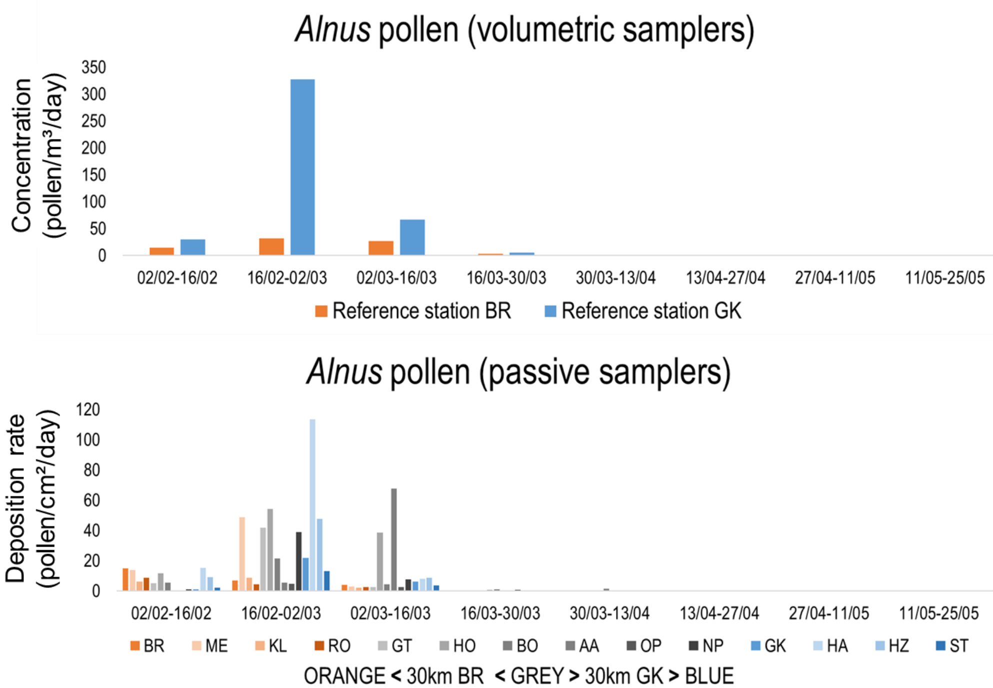


Figure 2: Daily average Airborne *Alnus* pollen concentrations measured by volumetric sampling (pollen/m³/day) at the reference stations Brussels (BR) and Genk (GK) in the upper panel and daily average pollen deposition rates measured by passive sampling (pollen/cm²/day) in the lower panel. Sampling sites within 30 km of Brussels (BR) are shown in shades of orange, within 30 km of Genk (GK) in shades of blue. Sampling sites outside the two 30 km buffers are displayed in shades of grey.

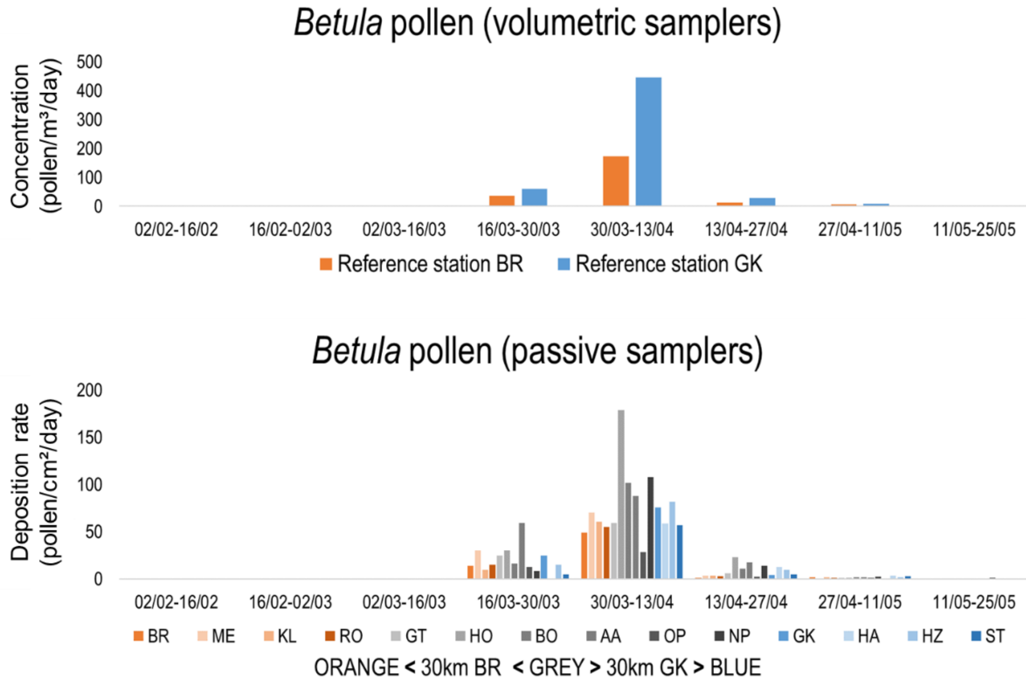


Figure 3: Daily average airborne *Betula* pollen concentrations measured by volumetric sampling (pollen/m³/day) at the reference stations Brussels (BR) and Genk (GK) in the upper panel and daily average pollen deposition rates measured by passive sampling (pollen/cm²/day) in the lower panel. Sampling sites within 30 km of Brussels (BR) are shown in shades of orange, within 30 km of Genk (GK) in shades of blue. Sampling sites outside the two 30 km buffers are displayed in shades of grey.

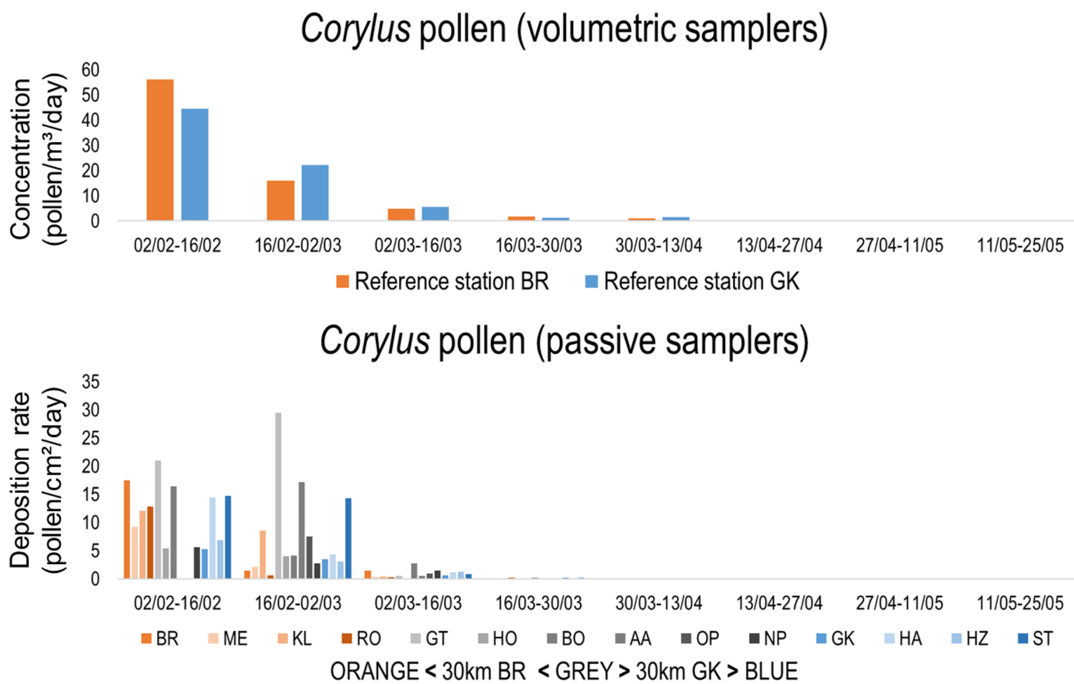


Figure 4: Daily average airborne *Corylus* pollen concentration measured by volumetric sampling (pollen/m³/day) at the reference stations Brussels (BR) and Genk (GK) in the upper panel and daily average pollen deposition rates measured by passive sampling (pollen/cm²/day) in the lower panel. Sampling sites within 30 km of Brussels (BR) are shown in shades of orange, within 30 km of Genk (GK) in shades of blue. Sampling sites outside the two 30 km buffers are displayed in shades of grey.

3.3 Drivers of the airborne pollen taxa composition

The NMDS ordination result is shown in Figure 7. The two-dimensional ordination had a low stress-value of 0.11. The airborne pollen composition at each site is presented as a pie chart, showing a large variation among sites and highest abundance of *Quercus* and *Betula* in correspondence with Figure 3. The pollen taxa that drive the ordination are presented as arrows in Figure 7. The composition of the landscape around the measuring sites at all the radii (20-5000 m) are given in the supplementary tables S1 (habitats), S2 (habitat value) and S3 (land cover). The most common land cover types are urban land covers and grasslands. Certain less-urbanized sites have more agricultural land cover. The Ecoplan land cover map (Table S3) shows that high green and low green sites are very common. By definition green spaces are classified as high green when the vegetation is taller than 3 m (groups of trees) and low green when the vegetation is shorter than 3 m (grass fields and bush lands, often including *Corylus*) (ECOPLAN, 2014). the BVM habitat map (Table S1) shows high area fractions of small landscape elements (e.g. hedgerows or road verges). Most of the vegetation in Flanders is less-valuable according to the Biological Valuation map, yet several of the sites have high area fractions of valuable and very-valuable habitat (Table S2).

To enhance clarity of the ordination figures (Figure 7-9) only correlations with a p-value < 0.1 are shown. Airborne pollen amounts of *Aesculus*, *Fagus* and *Carpinus* did not contribute to the two-dimensional NMDS ordination of sampling sites (Figure 7). The other nine taxa were associated with the ordination (p-value < 0.1). The airborne pollen composition varied along an urbanization gradient (urban–rural; NMDS axis 1) and a soil moisture gradient (dry–wet; NMDS axis 2) (Figure 8 and Figure 9). Associations with the habitat types also revealed an ecological value gradient (ecologically valuable–complexes of mixed value) (Figure 9). Low green and deciduous forests are associated with ecologically valuable habitats. Agricultural fields are associated with ecological complexes of mixed value.

We found no associations for the 20 m buffer zone with a p-value smaller than 0.1 (Figure 8 and Figure 9). For the 200 m and 500 m zones some associations had a p-value < 0.1. Most of the associations with a p-value < 0.1 were found for the 1 km to 5 km buffer zones (Figure 8 and 9).

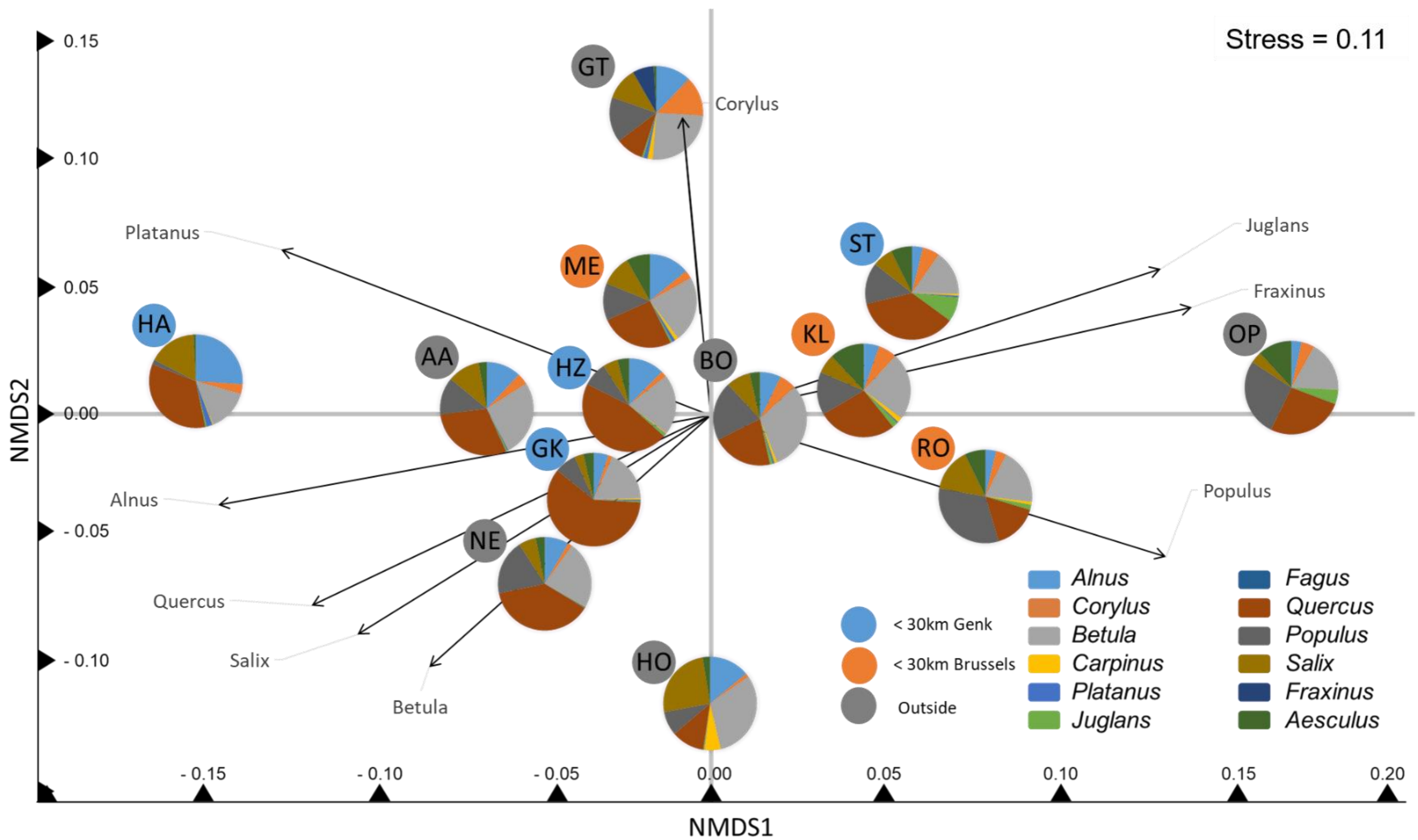
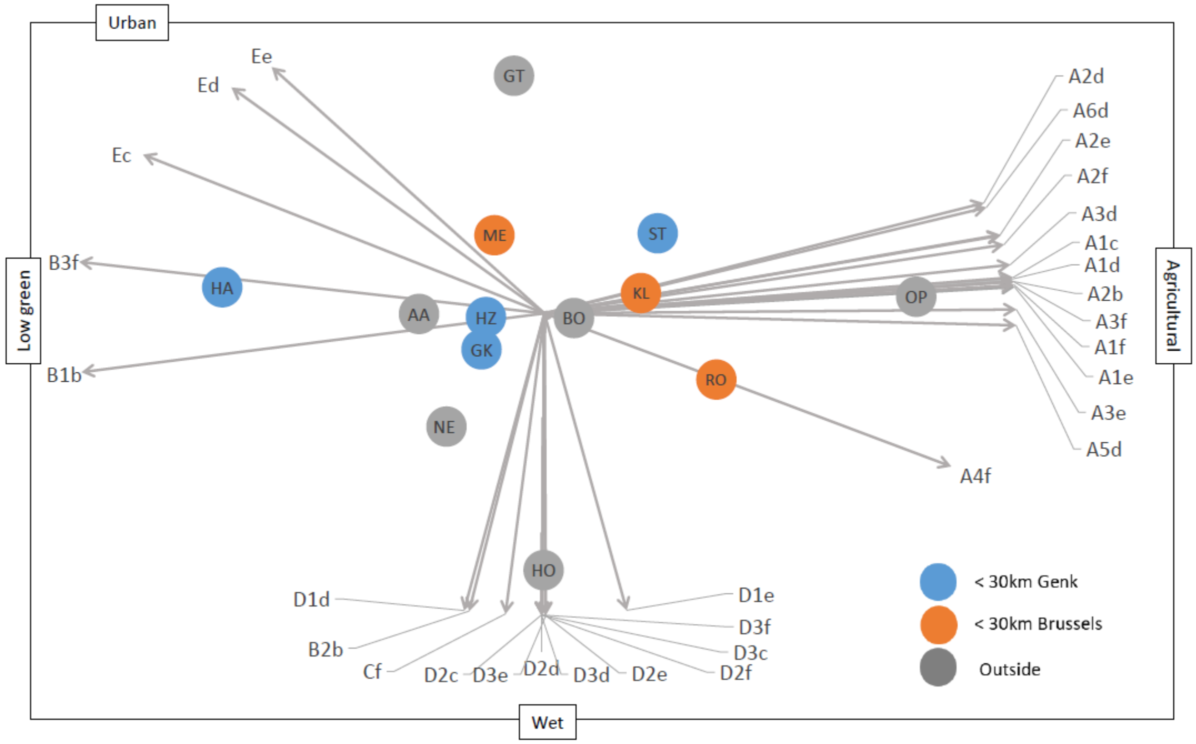
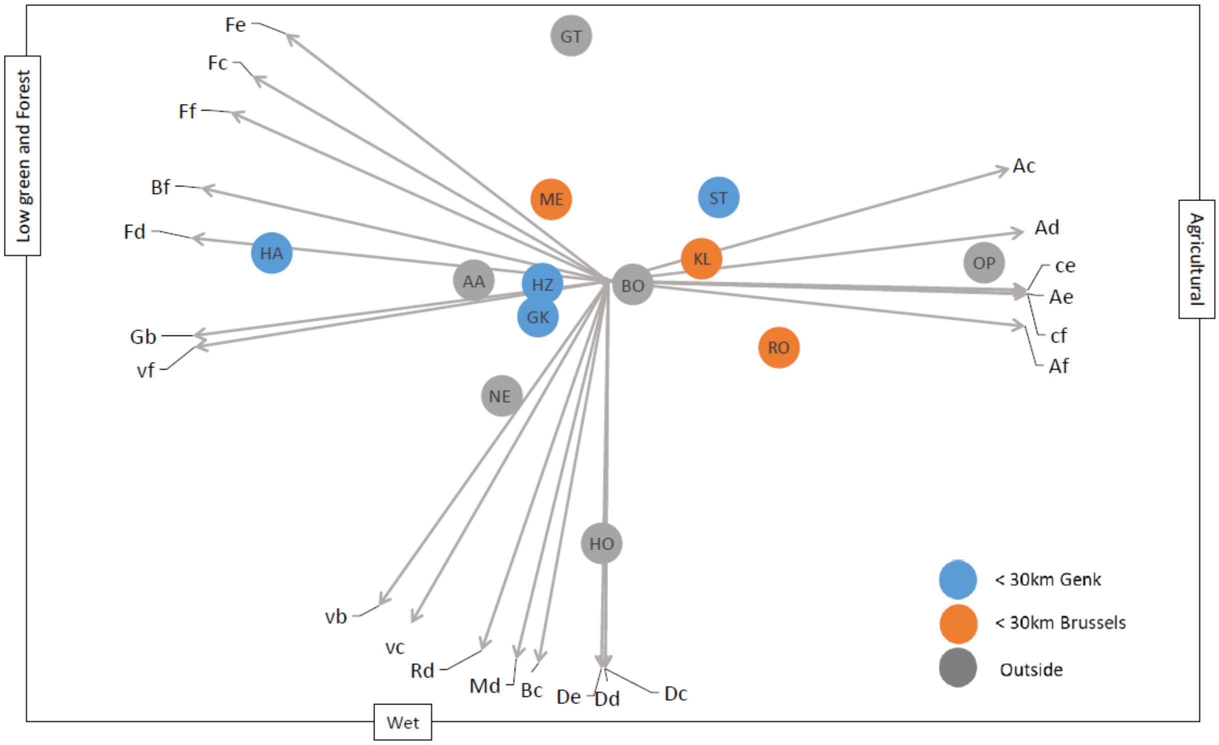


Figure 5: Non-metric multidimensional scaling ordination of the sampling sites based on the airborne pollen taxa composition measured with the passive samplers. The pollen composition is shown in the pie charts.The stress level of the NMDS is 0.11. Key taxa driving the pollen taxa composition at 13 passive pollen sampling sites in Flanders (Belgium). Only correlations with a p-value < 0.1 are shown.



	Agricultural Land cover		Low green cover		Wet land cover		Urban land cover		Buffer (m)
A1	Cereal	B1	Nutrient rich grassland	D1	Reed bed	E	Impervious	a	20
A2	Sugar beet	B2	Bush land	D2	Tidal flats			b	200
A3	Potato	B3	Low green	D3	Salt water			c	500
A4	Hemp & flax	C	Bare soil					d	1000
A5	Fodder crops							e	2000
A6	Orchard							f	5000

Figure 8: Association between local pollen taxa composition and land cover type in Flanders (Belgium) based on non-metric multidimensional scaling. Only correlations with a p-value < 0.1 are shown.



Biological valuation		Antropogenic		Forest and low-green		Wet		Buffer (m)	
c	Mixed value complex	A	Agricultural fields	B	Bushland	D	Dunes and wetlands	a	20
v	Valuable habitat	R	Roads	F	Forest (deciduous)	M	Marsh	b	200
				G	Grassland			c	500
								d	1000
								e	2000
								f	5000

Figure 9: Association between local pollen composition and habitat types in Flanders, Belgium, based on non-metric multidimensional scaling. Only correlations with a p-value < 0.1 are shown.

4. Discussion

4.1 Local variation of pollen composition

Monitoring at the reference stations in Brussels and Genk showed that 2017 was a year of low pollen amounts for *Alnus*, *Betula*, and *Corylus*. Acording to the Belgian Aerobiological Surveillance Network the pollen season of 2017 was rather weak for these trigger trees (Sciensano, 2017). *Quercus* and *Betula*, two pollen taxa known to be transported over long distances (Maya-Manzano et al., 2017; Skjøth et al., 2015), were measured at all sites in the highest quantities (Figure 3). Airborne pollen amounts of *Platanus* and *Aesculus* were low and not measured at every sampling site. These exotic ornamental trees are mainly planted along city streets (Pecero-Casimiro *et al.*, 2019) and were thus not present at more rural sampling sites.

In correspondence with previous studies (Piotrowska and Weryszko-Chmielewska, 2003; Teranishi *et al.*, 2006), we found that the airborne pollen amounts measured by Durham-type passive samplers showed similar taxon-specific distributions over time as the measurements by volumetric samplers (Figures 4-6). But on top of the general patterns, the passive measurements at 2 m height revealed local variations. Nevertheless, the peak densities at 2 m height were measured in the same period as the rooftop-level measurements, as also demonstrated in a study using 3 samplers and one reference station in south-eastern Poland (Kasprzyk *et al.*, 2019). Rojo *et al.* (2019) mention that measurements below 10 m are more heterogeneous. This is mostly the case for herbaceous species and some tree taxa, yet not for *Betula* (Bastl et al., 2019; Rojo et al., 2020). The variation in airborne pollen composition is mostly due to variation in the landscape context rather than the measurement height.

4.2 Landscape context and pollen composition

The taxa *Aesculus, Carpinus* and *Fagus* did not drive the ordination of sample sites (Figure 7). *Carpinus* and *Fagus* pollen amounts were extremely low in 2017, possibly due to masting in previous years. *Aesculus* pollen was only measured at two sampling sites located in the bigger cities in the study area, i.e. Gent (GT) and Brussels (BR). The tree originates from the Balkan peninsula, but is commonly planted along lanes in European cities (Thomas et al., 2019). In the Belgian rural areas the tree is not found, explaining the absence of *Aesculus* pollen on the more rural sampling sites.

We found different airborne pollen compositions associated to the surrounding land cover and habitat types (Figures 8 and 9). The indirect gradient analysis revealed that the secondary axis of the NMDS showed a strong association with wet land cover types. One of our sampling locations (HO) was located near the Scheldt river. A specific pollen composition including *Betula, Salix, Quercus* and *Alnus* was associated to this riparian landscape context. Kasprzyk *et al. (*2019) sampled airborne pollen in three parks and found that the river valley probably played a role in the dispersal of pollen (specifically *Quercus* pollen*)* from sources upstream along the river. Similarly, Maya-Manzano *et al. (*2017) identified riparian forests as sources of *Alnus* pollen in a 10 km radius around their sampling site. In our results, both *Alnus* and *Quercus* pollen were not solely related to wet land cover types, but also to forests (Figure 7). In Belgium as well as in other European countries, deciduous forests are major sources of airborne *Quercus* pollen (Maya-Manzano et al., 2017; Rojo et al., 2015).

Our results showed that the pollen composition in agricultural areas were characterized by airborne pollen of *Fraxinus, Juglans* and *Populus* (Figure 7-9). In Belgium, *Populus* and *Juglans* are often present in wood lots or in tree rows along the agricultural fields (Pardon *et al.*, 2019). Similarly, *Fraxinus*, *Juglans* and *Populus* trees are commonly found along roads in rural areas in Europe (Tóth *et al.*, 2016). Additionally, Rojo *et al. (*2015) reported that poplar stands commonly occur near rivers and contribute to the elevated *Populus* pollen levels measured in Guadalajara (Spain). We also observed that airborne *Populus* pollen were not strictly related to the agricultural context but also to wet land cover types (Figure 7-9). *Populus* plantations are indeed often found on alluvial river valley soils (Smulders et al., 2008).

Urban green areas are important sources of pollen as reported in other research (Rojo *et al.*, 2015; Weinberger *et al.*, 2016). In our results, pollen of *Platanus* and *Corylus* were mainly associated with urban landscapes. Rojo *et al. (*2015) reported that for the city of Guadalajara, parks within a 1.5 km radius of the sampling location were significant sources of *Platanus* pollen. García-Mozo *et al. (*2016) noticed that increased urbanization has led to increased amounts of *Platanus* pollen in the air in Toledo (Spain). In Western Europe, *Platanus* is commonly used as an ornamental tree, which is planted in urban parks or along city streets (Flora van Nederland, 2014; Selmi et al., 2016). Markedly different airborne pollen compositions have been associated with urban and rural areas. The degree of urbanity has been observed as a determinant of pollen concentration for grasses in Finland (Hugg et al., 2017).

4.3 Local pollen scale

We found that local airborne pollen variations are rarely driven by the surrounding landscape at a fine local scale (20-500 m), but rather at a meso-scale (1-5 km). Werchan *et al. (*2017) reported that fine-scale vegetation sampling in a radius of 100 m around 14 gravimetric pollen traps in Berlin could not explain the differences in pollen abundance. However, within cities, airborne pollen amounts have been found to vary at spatial scales as small as 200 m (Charalampopoulos *et al.*, 2018) and 500 m (Weinberger *et al.*, 2016).

Charalampopoulos *et al. (*2018) measured airborne tree pollen at 1.5 m height on 6 sites within the city of Thessaloniki (Greece), with an average 2.1 km distance between the nearest sampling sites. They showed that airborne pollen measurements at the 6 sampling sites were more similar than the vegetation within a 200 m radius around the sampling site, indicating that airborne pollen compositions at a given location are not necessarily representative of the land cover composition at that location but rather reflect a mixture from sources found in the wider area. A broader meso-scale would thus be necessary to explain the airborne pollen composition. Indeed, their models showed that airborne pollen measurements were not solely influenced by the vegetation directly surrounding the sampling site (200 m), but also by the vegetation at the nearest sampling site (0.55-5.77 km away) (Charalampopoulos *et al.*, 2018).

Katz and Carey (2014) measured airborne pollen of common ragweed *(Ambrosia artemisiifolia*) across Detroit (Michigan, USA) using 34 Durham samplers installed at 1.5 m above the ground. The pollen amounts were related to vegetation and land use types at both 10 m and 1 km scales. For weeds, such as *Ambrosia* spp., fine spatial scales of 10 m are relevant when measuring at 1.5 m height. For tree pollen, larger scales are probably more relevant. For birch specifically, (Bogawski et al., 2019b) found that pollen concentrations measured at 18 m height were related to crown surface in a 500-1500 m buffer around the pollen trap. Maya-Manzano et al. (2017) found that local airborne *Platanus* pollen compositions were associated with the abundance of Platanus trees within 200 – 1500 m depending on the wind direction. Our results are thus in line with recent research results, demonstrating that local airborne tree pollen composition is predominantly determined by vegetation and landscape composition at meso-scales (1-5 km). Nevertheless, we only studied woody plants and these findings might not apply for other pollen types. For herbaceous pollen types smaller local effects have been observed (Peel et al., 2014; Rojo et al., 2020; Skjøth et al., 2013).

4.4 Implications

Many studies have utilized smaller radii of 300-500 m to determine residential greenness for human exposure studies (Fuertes *et al.*, 2016; Gernes *et al.*, 2019; Tischer *et al.*, 2017) among others because intra-urban differences in pollen levels have been observed (Hjort *et al.*, 2016; Weinberger *et al.*, 2016). However, we found that local variations in airborne tree-pollen composition were driven by the landscape context at 1-5 km scale. In urban areas, people visiting a park are not only exposed to the airborne pollen in that park, but also to the airborne pollen from the surrounding landscape (Ciani *et al.*, 2020; Pham-Thi *et al.*, 2019). Therefore, pollen exposure data obtained with methods that use larger buffer sizes (1-2 km) are more likely to yield stronger associations with pollen-related health-outcomes (Browning and Lee, 2017; Su *et al.*, 2019).
Green spaces at the edge of the city impact the pollen levels within the city. Species selection should thus be taken into account even in the greenspaces further away from densely populated areas. On the other hand, removing trees with allergenic pollen within cities might have little to no effect given that the local pollen composition is characterized by the vegetation within 5 km.

Further expansion of the pollen monitoring network with samplers at 2m above ground level might be of interest to study local effects and background concentrations simultaneously. Oteros *et al.* (2019) show a possible method to select optimal sites for automated pollen monitoring in Bavaria (Germany).

5. Conclusion

Passive sampling of airborne pollen demonstrated local variations in airborne tree pollen composition. Urban green spaces, agricultural areas, forests, shrub lands, grasslands and wet land cover types were characterized by marked airborne tree pollen compositions. Associations between local tree pollen composition were driven by landscape characteristics at the meso-scale (1-5 km). The effect of the meso-scale implies that not only green spaces within cities but also around urban areas are expected to influence exposure to allergenic tree pollen within urban areas, potentially affecting the health of a large proportion of the population.

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References

Barton, J., Rogerson, M., 2017. The importance of greenspace for mental health. BJPsych Int. 14, 79–81.

Bastl, M., Bastl, K., Karatzas, K., Aleksic, M., Zetter, R., Berger, U., 2019. The evaluation of pollen concentrations with statistical and computational methods on rooftop and on ground level in Vienna – How to include daily crowd-sourced symptom data. World Allergy Organ. J. 12, 100036. https://doi.org/10.1016/j.waojou.2019.100036

Biedermann, T., Winther, L., Till, S.J., Panzner, P., Knulst, A., Valovirta, E., 2019. Birch pollen allergy in Europe. Allergy 74, all.13758. https://doi.org/10.1111/all.13758

Bogawski, P., Borycka, K., Grewling, Ł., Kasprzyk, I., 2019a. Detecting distant sources of airborne pollen for Poland: Integrating back-trajectory and dispersion modelling with a satellite-based phenology. Sci. Total Environ. 689, 109–125. https://doi.org/10.1016/j.scitotenv.2019.06.348

Bogawski, P., Grewling, Ł., Dziób, K., Sobieraj, K., Dalc, M., Dylawerska, B., Pupkowski, D., Nalej, A., Nowak, M., Szymańska, A., Kostecki, Ł., Nowak, M.M., Jackowiak, B., 2019b. Lidar-Derived Tree Crown Parameters: Are They New Variables Explaining Local Birch (Betula sp.) Pollen Concentrations? Forests 10, 1154. https://doi.org/10.3390/f10121154

Borycka, K., Kasprzyk, I., 2018. Do the threats of alder and birch allergenic pollen differ within an urban area? Urban For. Urban Green. 34, 281–293. https://doi.org/10.1016/j.ufug.2018.07.013

Bratman, G.N., Anderson, C.B., Berman, M.G., Cochran, B., de Vries, S., Flanders, J., Folke, C., Frumkin, H., Gross, J.J., Hartig, T., Kahn, P.H., Kuo, M., Lawler, J.J., Levin, P.S., Lindahl, T., Meyer-Lindenberg, A., Mitchell, R., Ouyang, Z., Roe, J., Scarlett, L., Smith, J.R., van den Bosch, M., Wheeler, B.W., White, M.P., Zheng, H., Daily, G.C., 2019. Nature and mental health: An ecosystem service perspective. Sci. Adv. https://doi.org/10.1126/sciadv.aax0903

Braubach, M., Egorov, A., Mudu, P., Wolf, T., Ward Thompson, C., Martuzzi, M., 2017. Effects of Urban Green Space on Environmental Health, Equity and Resilience, in: Kabisch, N., Korn, H., Stadler, J., Bonn, A. (Eds.), Nature-Based Solutions to Climate Change Adaptation in Urban Areas. Springer, Cham, pp. 187–205. https://doi.org/10.1007/978-3-319-56091-5_11

Browning, M., Lee, K., 2017. Within What Distance Does "Greenness" Best Predict Physical Health? A Systematic Review of Articles with GIS Buffer Analyses across the Lifespan. Int. J. Environ. Res. Public Health 14, 675. https://doi.org/10.3390/ijerph14070675

Bruffaerts, N., De Smedt, T., Delcloo, A., Simons, K., Hoebeke, L., Verstraeten, C., Van Nieuwenhuyse, A., Packeu, A., Hendrickx, M., 2018. Comparative long-term trend analysis of daily weather conditions with daily pollen concentrations in Brussels, Belgium. Int. J. Biometeorol. 62, 483–491. https://doi.org/10.1007/s00484-017-1457-3

Charalampopoulos, A., Lazarina, M., Tsiripidis, I., Vokou, D., 2018. Quantifying the relationship between airborne pollen and vegetation in the urban environment. Aerobiologia (Bologna). 34, 285–300. https://doi.org/10.1007/s10453-018-9513-y

Ciani, F., Marchi, G., Dell'Olmo, L., Foggi, B., Mariotti Lippi, M., 2020. Contribution of land cover and wind to the airborne pollen recorded in a South European urban area.

Aerobiologia (Bologna). 0123456789. https://doi.org/10.1007/s10453-020-09634-y

Clarke, K.R., 1993. Non-parametric multivariate analyses of changes in community structure. Aust. J. Ecol. 18, 117–143. https://doi.org/10.1111/j.1442-9993.1993.tb00438.x

Core Team R, 2017. R: A language and environment for statistical computing.

Cox, D.T.C., Shanahan, D.F., Hudson, H.L., Fuller, R.A., Gaston, K.J., 2018. The impact of urbanisation on nature dose and the implications for human health. Landsc. Urban Plan. 179, 72–80. https://doi.org/10.1016/J.LANDURBPLAN.2018.07.013

D'Amato, G., Cecchi, L., Bonini, S., Nunes, C., Annesi-Maesano, I., Behrendt, H., Liccardi, G., Popov, T., van Cauwenberge, P., 2007. Allergenic pollen and pollen allergy in Europe. Allergy 62, 976–990. https://doi.org/10.1111/j.1398-9995.2007.01393.x

ECOPLAN, 2014. ECOPLAN Monitor [WWW Document]. URL http://www.ecosysteemdiensten.be/cms/

ESRI, 2011. ArcGIS Desktop: Release 10.

Fletcher, M.-S., Thomas, I., 2007. Holocene vegetation and climate change from near Lake Pedder, south-west Tasmania, Australia. J. Biogeogr. 34, 665–677. https://doi.org/10.1111/j.1365-2699.2006.01659.x

Flora van Nederland, 2014. Plataan - Platanus hispanica [WWW Document]. URL https://www.floravannederland.nl/planten/plataan (accessed 2.7.21).

Fuertes, E., Markevych, I., Bowatte, G., Gruzieva, O., Gehring, U., Becker, A., Berdel, D., von Berg, A., Bergström, A., Brauer, M., Brunekreef, B., Brüske, I., Carlsten, C., Chan-Yeung, M., Dharmage, S.C., Hoffmann, B., Klümper, C., Koppelman, G.H., Kozyrskyj, A., Korek, M., Kull, I., Lodge, C., Lowe, A., MacIntyre, E., Pershagen, G., Standl, M., Sugiri, D., Wijga, A., Heinrich, J., Heinrich, J., 2016. Residential greenness is differentially associated with childhood allergic rhinitis and aeroallergen sensitization in seven birth cohorts. Allergy 71, 1461–1471. https://doi.org/10.1111/all.12915

Galán, C., Smith, M., Thibaudon, M., Frenguelli, G., Oteros, J., Gehrig, R., Berger, U., Clot, B., Brandao, R., Group, E.Q.W., 2014. Pollen monitoring: minimum requirements and reproducibility of analysis. Aerobiologia (Bologna). 30, 385–395. https://doi.org/10.1007/s10453-014-9335-5

García-Mozo, H., Oteros, J.A., Galán, C., 2016. Impact of land cover changes and climate on the main airborne pollen types in Southern Spain. Sci. Total Environ. 548–549, 221–228. https://doi.org/10.1016/j.scitotenv.2016.01.005

Gehrig, R., 2019. Representativeness of pollen traps: a review of the national pollen network of Switzerland. Aerobiologia (Bologna). 35, 577–581. https://doi.org/10.1007/s10453-019-09593-z

Gernes, R., Brokamp, C., Rice, G.E., Wright, J.M., Kondo, M.C., Michael, Y.L., Donovan, G.H., Gatziolis, D., Bernstein, D., LeMasters, G.K., Lockey, J.E., Khurana Hershey, G.K., Ryan, P.H., 2019. Using high-resolution residential greenspace measures in an urban environment to assess risks of allergy outcomes in children. Sci. Total Environ. 668, 760–767. https://doi.org/10.1016/J.SCITOTENV.2019.03.009

Hjort, J., Hugg, T.T., Antikainen, H., Rusanen, J., Sofiev, M., Kukkonen, J., Jaakkola, M.S., Jaakkola, J.J.K., 2016. Fine-Scale Exposure to Allergenic Pollen in the Urban Environment: Evaluation of Land Use Regression Approach. Environ. Health Perspect. 124, 619–26.

https://doi.org/10.1289/ehp.1509761

Hugg, T.T., Hjort, J., Antikainen, H., Rusanen, J., Tuokila, M., Korkonen, S., Weckström, J., Jaakkola, M.S., Jaakkola, J.J.K., 2017. Urbanity as a determinant of exposure to grass pollen in Helsinki Metropolitan area, Finland. PLoS One 12, e0186348. https://doi.org/10.1371/journal.pone.0186348

Kasprzyk, I., Ćwik, A., Kluska, K., Wójcik, T., Cariñanos, P., 2019. Allergenic pollen concentrations in the air of urban parks in relation to their vegetation. Urban For. Urban Green. 46. https://doi.org/10.1016/j.ufug.2019.126486

Katz, D.S.W., Carey, T.S., 2014. Heterogeneity in ragweed pollen exposure is determined by plant composition at small spatial scales. Sci. Total Environ. 485–486, 435–440. https://doi.org/10.1016/j.scitotenv.2014.03.099

Kenkel, N.C., Orloci, L., 1986. Applying Metric and Nonmetric Multidimensional Scaling to Ecological Studies: Some New Results. Ecology 67, 919–928. https://doi.org/10.2307/1939814

Kurganskiy, A., Ambelas Skjøth, C., Baklanov, A., Sofiev, M., Saarto, A., Severova, E., Smyshlyaev, S., Kaas, E., 2020. Incorporation of pollen data in source maps is vital for pollen dispersion models. Atmos. Chem. Phys. 20, 2099–2121. https://doi.org/10.5194/acp-20-2099-2020

Lovasi, G.S., O'Neil-Dunne, J.P.M., Lu, J.W.T., Sheehan, D., Perzanowski, M.S., MacFaden, S.W., King, K.L., Matte, T., Miller, R.L., Hoepner, L.A., Perera, F.P., Rundle, A., 2013. Urban Tree Canopy and Asthma, Wheeze, Rhinitis, and Allergic Sensitization to Tree Pollen in a New York City Birth Cohort. Environ. Health Perspect. 121, 494–500.

https://doi.org/10.1289/ehp.1205513

Maya-Manzano, José María, Fernández-Rodríguez, S., Monroy-Colín, A., Silva-Palacios, I., Tormo-Molina, R., Gonzalo-Garijo, Á., 2017. Allergenic pollen of ornamental plane trees in a Mediterranean environment and urban planning as a prevention tool. Urban For. Urban Green. 27, 352–362. https://doi.org/10.1016/j.ufug.2017.09.009

Maya-Manzano, J.M., Sadyś, M., Tormo-Molina, R., Fernández-Rodríguez, S., Oteros, J., Silva-Palacios, I., Gonzalo-Garijo, A., 2017. Relationships between airborne pollen grains, wind direction and land cover using GIS and circular statistics. Sci. Total Environ. 584–585, 603–613. https://doi.org/10.1016/J.SCITOTENV.2017.01.085

Nowosad, J., 2016. Spatiotemporal models for predicting high pollen concentration level of Corylus, Alnus, and Betula. Int. J. Biometeorol. 60, 843–855. https://doi.org/10.1007/s00484-015-1077-8

Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., Mcglinn, D., Minchin, P.R., O'hara, R.B., Simpson, G.L., Solymos, P., Henry, M., Stevens, H., Szoecs, E., Maintainer, H.W., 2019. Package "vegan", Community Ecology Package Version 2.5-6.

Orlanski, I., 1975. A Rational Subdivision of Scales for Atmospheric Processes. Bull. Am. Meteorol. Soc. 56, 527–530.

Oteros, J., Sofiev, M., Smith, M., Clot, B., Damialis, A., Prank, M., Werchan, M., Wachter, R., Weber, A., Kutzora, S., Heinze, S., Herr, C.E.W., Menzel, A., Bergmann, K.-C., Traidl-Hoffmann, C., Schmidt-Weber, C.B., Buters, J.T.M., 2019. Building an automatic pollen monitoring network (ePIN): Selection of optimal sites by clustering pollen stations. Sci. Total Environ. 688, 1263–1274. https://doi.org/10.1016/J.SCITOTENV.2019.06.131

Pardon, P., Reheul, D., Mertens, J., Reubens, B., De Frenne, P., De Smedt, P., Proesmans, W., Van Vooren, L., Verheyen, K., 2019. Gradients in abundance and diversity of ground dwelling arthropods as a function of distance to tree rows in temperate arable agroforestry systems. Agric. Ecosyst. Environ. 270–271, 114–128. https://doi.org/10.1016/j.agee.2018.10.017

Passali, D., Cingi, C., Staffa, P., Passali, F., Muluk, N.B., Bellussi, M.L., 2018. The International Study of the Allergic Rhinitis Survey: outcomes from 4 geographical regions. Asia Pac. Allergy 8. https://doi.org/10.5415/apallergy.2018.8.e7

Pecero-Casimiro, R., Fernández-Rodríguez, S., Tormo-Molina, R., Monroy-Colín, A., Silva-Palacios, I., Cortés-Pérez, J.P., Gonzalo-Garijo, Á., Maya-Manzano, J.M., 2019. Urban aerobiological risk mapping of ornamental trees using a new index based on LiDAR and Kriging: A case study of plane trees. Sci. Total Environ. 693, 133576. https://doi.org/10.1016/J.SCITOTENV.2019.07.382

Peel, R.G., Hertel, O., Smith, M., Kennedy, R., 2013. Personal exposure to grass pollen: relating inhaled dose to background concentration. Ann. Allergy, Asthma Immunol. 111, 548–554. https://doi.org/10.1016/J.ANAI.2013.09.002

Peel, R.G., Ørby, P. V, Skjøth, C.A., Kennedy, R., Schlünssen, V., Smith, M., Sommer, J., Hertel, O., 2014. Seasonal variation in diurnal atmospheric grass pollen concentration profiles. Biogeosciences 11, 821–832. https://doi.org/10.5194/bg-11-821-2014

Pham-Thi, N., Thibaudon, M., Monnier, S., Besancenot, J.P., 2019. The air we breathe: The influence of pollen sources in urban green spaces. The example of Lyon. Rev. Fr. Allergol. https://doi.org/10.1016/j.reval.2019.07.002

Piotrowska, K., Weryszko-Chmielewska, E., 2003. Pollen count of selected taxa in the atmosphere of Lublin using two monitoring methods. Ann. Agric. Environ. Med. 10, 79–85.

Rojo, J., Oteros, J., Pérez-Badia, R., Cervigón, P., Ferencova, Z., Gutiérrez-Bustillo, A.M., Bergmann, K.-C., Oliver, G., Thibaudon, M., Albertini, R., Rodríguez-De la Cruz, D., Sánchez-Reyes, E., Sánchez-Sánchez, J., Pessi, A.-M., Reiniharju, J., Saarto, A., Calderón, M.C., Guerrero, C., Berra, D., Bonini, M., Chiodini, E., Fernández-González, D., García, J., Trigo, M.M., Myszkowska, D., Fernández-Rodríguez, S., Tormo-Molina, R., Damialis, A., Kolek, F., Traidl-Hoffmann, C., Severova, E., Caeiro, E., Ribeiro, H., Magyar, D., Makra, L., Udvardy, O., Alcázar, P., Galán, C., Borycka, K., Kasprzyk, I., Newbigin, E., Adams-Groom, B., Apangu, G.P., Frisk, C.A., Skjøth, C.A., Radišić, P., Šikoparija, B., Celenk, S., Schmidt-Weber, C.B., Buters, J., 2019. Near-ground effect of height on pollen exposure. Environ. Res. 174, 160–169. https://doi.org/10.1016/J.ENVRES.2019.04.027

Rojo, J., Oteros, J., Picornell, A., Ruëff, F., Werchan, B., Werchan, M., Bergmann, K.-C., Schmidt-Weber, C.B., Buters, J., 2020. Land-Use and Height of Pollen Sampling Affect Pollen Exposure in Munich, Germany. Atmosphere (Basel). 11, 145. https://doi.org/10.3390/atmos11020145

Rojo, J., Pérez-Badia, R., 2015. Spatiotemporal analysis of olive flowering using geostatistical techniques. Sci. Total Environ. 505, 860–869. https://doi.org/10.1016/j.scitotenv.2014.10.022

Rojo, J., Rapp, A., Lara, B., Fernández-González, F., Pérez-Badia, R., 2015. Effect of land uses and wind direction on the contribution of local sources to airborne pollen. Sci. Total Environ. 538, 672–682. https://doi.org/10.1016/J.SCITOTENV.2015.08.074

Romero-Morte, J., Rojo, J., Rivero, R., Fernández-González, F., Pérez-Badia, R., 2018. Standardised index for measuring atmospheric grass-pollen emission. Sci. Total Environ. 612, 180–191. https://doi.org/10.1016/j.scitotenv.2017.08.139

Sciensano, 2017. Archive 2017 | AirAllergy.be [WWW Document]. URL https://airallergy.sciensano.be/archive/2017 (accessed 1.10.20).

Selmi, W., Weber, C., Rivière, E., Blond, N., Mehdi, L., Nowak, D., 2016. Air pollution removal by trees in public green spaces in Strasbourg city, France. Urban For. Urban Green. 17, 192–201. https://doi.org/10.1016/J.UFUG.2016.04.010

Skjøth, C.A., Baker, P., Sadyś, M., Adams-Groom, B., 2015. Pollen from alder (Alnus sp.), birch (Betula sp.) and oak (Quercus sp.) in the UK originate from small woodlands. Urban Clim. 14, 414–428. https://doi.org/10.1016/j.uclim.2014.09.007

Skjøth, C.A., Ørby, P. V., Becker, T., Geels, C., Schlünssen, V., Sigsgaard, T., Bønløkke, J.H., Sommer, J., Søgaard, P., Hertel, O., 2013. Identifying urban sources as cause of elevated grass pollen concentrations using GIS and remote sensing. Biogeosciences 10, 541–554. https://doi.org/10.5194/bg-10-541-2013

Smulders, M.J.M., Beringen, R., Volosyanchuk, R., Vanden Broeck, A., Van Der Schoot, J., Arens, P., Vosman, B., 2008. Natural hybridisation between Populus nigra L. and P. x canadensis Moench. Hybrid offspring competes for niches along the Rhine river in the Netherlands. Tree Genet. Genomes 4, 663–675. https://doi.org/10.1007/s11295-008-0141-5

Su, J.G., Dadvand, P., Nieuwenhuijsen, M.J., Bartoll, X., Jerrett, M., 2019. Associations of green space metrics with health and behavior outcomes at different buffer sizes and remote sensing sensor resolutions. Environ. Int. 126, 162–170.

https://doi.org/10.1016/j.envint.2019.02.008

Teranishi, H., Katoh, T., Kenda, K., Hayashi, S., 2006. Global warming and the earlier start of the Japanese-cedar (Cryptomeria japonica) pollen season in Toyama, Japan, in: Aerobiologia. Springer Netherlands, pp. 91–95. https://doi.org/10.1007/s10453-006-9023-1

The European Academy of Allergy and Clinical Immunology (EAACI), 2016. Advocacy Manifesto: Tackling the Allergy Crisis in Europe - Concerted Policy Action Needed. Brussels.

Thomas, P.A., Alhamd, O., Iszkuło, G., Dering, M., Mukassabi, T.A., 2019. Biological Flora of the British Isles: *Aesculus hippocastanum*. J. Ecol. 107, 992–1030. https://doi.org/10.1111/1365-2745.13116

Tischer, C., Gascon, M., Fernández-Somoano, A., Tardón, A., Lertxundi Materola, A., Ibarluzea, J., Ferrero, A., Estarlich, M., Cirach, M., Vrijheid, M., Fuertes, E., Dalmau-Bueno, A., Nieuwenhuijsen, M.J., Antó, J.M., Sunyer, J., Dadvand, P., 2017. Urban green and grey space in relation to respiratory health in children. Eur. Respir. J. 49, 1502112. https://doi.org/10.1183/13993003.02112-2015

Tóth, A., Kuczman, G., Feriancová, Ľ., 2016. Species composition and diversity of non-forest woody vegetation along roads in the agricultural landscape. Cent. Eur. For. J. 62, 56–66. https://doi.org/10.1515/forj-2016-0007

Twohig-Bennett, C., Jones, A., 2018. The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. Environ. Res. 166, 628–637. https://doi.org/10.1016/J.ENVRES.2018.06.030

von Hertzen, L., Haahtela, T., 2006. Disconnection of man and the soil: Reason for the asthma and atopy epidemic? J. Allergy Clin. Immunol. 117, 334–344. https://doi.org/10.1016/j.jaci.2005.11.013

Vriens, L., De Knijf, G., De Saeger, S., Guelinckx, R., Oosterlynck, P., Van Hove, M., Paelinckx, D., 2011. De Biologische Waarderingskaart. Biotopen en hun verspreiding in Vlaanderen en het Brussels Hoofdstedelijk Gewest., in: Mededelingen van Het Instituut Voor Natuur- En Bosonderzoek. INBO.M.2011.1, Brussels, p. 416.

Weinberger, K.R., Kinney, P.L., Robinson, G.S., Sheehan, D., Kheirbek, I., Matte, T.D., Lovasi, G.S., 2016. Levels and determinants of tree pollen in New York City. J. Expo. Sci. Environ. Epidemiol. 28, 119. https://doi.org/10.1038/jes.2016.72

Werchan, B., Werchan, M., Mücke, H.G., Gauger, U., Simoleit, A., Zuberbier, T., Bergmann, K.C., 2017. Spatial distribution of allergenic pollen through a large metropolitan area. Environ. Monit. Assess. 189. https://doi.org/10.1007/s10661-017-5876-8

Supplementary material

Table S1: Area fractions (%) of **habitat types from the biological valuation map** around sampling sites: Ghent (GT), Hoboken (HO), Bornem (BO), Mechelen (ME), Kessel-Lo (KL), Aarschot (AA); Oplinter (OP), Sint-Truiden (ST), Hasselt (HA), Genk (GK), Heusden-Zolder (HZ) and Neerpelt (NE). The table stretches over multiple pages.

		GT	HO	BO	ME	RO	KL	AA	OP	ST	HA	GK	HZ	NE
20 m	Stagnant Water	0	0	0	0	0	0	0	0	0	0	0	0	0
	Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heath land	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dunes & wetland	0	0	0	0	0	0	0	0	0	0	0	0	0
	Beech forest	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bushland	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grassland	0	0	0	0	0	0	0	0	0	0	0	0.7488	0
	Small landscape elements	0	0	0	0	0	0	0	0	0	0	0	0	0
	Poplar	0	0	0	0	0	0	0	0	0	0	0	0	0.2072
	Swamps	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other broadleaf forests	0	0	0	0	0	0	0	0.0264	0	0	0	0	0
	Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oak forest	0	0	0	0	0	0	0	0	0	0	0	0	0
	Ruderal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Urban area	1	1	1	1	1	1	1	0.9736	1	1	1	0.2504	0.7928
	Valleys	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	0	0	0	0	0	0	0	0	0	0	0	0	0
200 m	Stagnant Water	0	0	0	0	0	0	0	0	0	0	0	0	0.002041
	Agriculture	0	0	0	0.577083	0.078112	0	0.023582	0.770562	0.382083	0	0	0.09488	0
	Heath land	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dunes & wetlands	0	0	0	0	0	0	0	0	0	0	0	0	0
	Beech forest	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bushland	0	0.159448	0.066611	0	0	0	0.029265	0	0	0	0.117034	0.067688	0

	Grassland	0.012829	0	0	0	0.07052	0	0.155097	0.039486	0	0.362809	0.029528	0.25661	0.159595
	Small landscape elements	0.009651	0	0	0.104353	0.022282	0.030451	0.034871	0.000991	0.006111	0.025457	0	0.131991	0
	Poplar	0	0	0	0	0	0	0	0	0	0	0	0	0.385011
	Swamps	0	0	0	0	0	0	0	0	0	0	0	0	0
	Other broadleaf forests	0	0	7.99E-05	0	0	0	0	0.012398	0	0.022388	0	0.031176	0
	Coniferous forest	0	0	0	0	0	0	0	0	0	0	0	0.018515	0
	Oak forest	0	0	0	0	0	0	0.005284	0	0	0	0.086661	0.003461	0
	Ruderal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Urban area	0.934121	0.840552	0.933309	0.318564	0.829086	0.969549	0.751902	0.165739	0.611806	0.589346	0.766776	0.385438	0.370264
	Valleys	0	0	0	0	0	0	0	0	0	0	0	0	0
	Roads	0.0434	0	0	0	0	0	0	0.010823	0	0	0	0.010241	0.083088
500 m	Stagnant Water	0	0	0	0	0	0	0	0	0.009775	0.003184	0.002021	0.005522	0.03755
	Agriculture	0	0	0.010576	0.194385	0.200967	0.013649	0.091371	0.662889	0.592621	0.014641	0	0.048575	0.18941
	Heath land	0	0	0	0	0	0	0	0	0	0	0	0.000942	0
	Dunes & wetlands	0	0.007837	0	0	0	0	0	0	0	0	0	0	0
	Beech forest	0	0	0	0	0.006457	0	0	0	0	0	0	0	0
	Bushland	0	0.206206	0.040585	0	0	0.002541	0.033709	0.00255	0.01569	0.038056	0.044669	0.035178	0
	Grassland	0.040977	0.03843	0.016675	0.068926	0.229585	0.01941	0.143845	0.166444	0.003164	0.241005	0.016484	0.254395	0.197523
	Small landscape elements	0.067607	0	0.015404	0.089935	0.095235	0.22382	0.05896	0.059993	0.037142	0.016077	0.016693	0.084733	0.004298

	Poplar	0	0.006479	0	0	0.00411	0	0	0	0.071305	0	0	0.011803	0.093735
	Swamps	0	0	0	0	0	0	0	0	0	0	0	0	0.002326
	Other broadleaf forests	0.015744	0	0.006386	0	0	0.002754	0.008916	0.001983	0	0.0456	0.000286	0.022895	0.00081
	Coniferous forest	0	0	0	0	0	0	0.020396	0	0	0	0.039468	0.012177	0.007593
	Oak forest	0	0	0	0	0	0.013415	0.085235	0	0.013998	0	0.099431	0.025236	0
	Ruderal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Urban area	0.839752	0.714047	0.876471	0.635638	0.463646	0.72441	0.557568	0.085303	0.249753	0.569848	0.764781	0.419251	0.429539
	Valleys	0	0	0	0	0	0	0	0	0.006551	0.001674	0.016168	0.077656	0
	Roads	0.03592	0.027001	0.033903	0.011116	0	0	0	0.020838	0	0.069915	0	0.001638	0.037215
1 km	Stagnant Water	0	0.019259	0.030138	0	0.000309	5.7E-05	0.010639	0.011255	0.011014	0.006278	0.014699	0.030171	0.010181
	Agriculture	0	0	0.035065	0.055122	0.26392	0.068996	0.086351	0.432248	0.477876	0.046289	0	0.06166	0.217867
	Heath land	0	0	0	0	0	0	0	0	0	0	0.000108	0.000236	0
	Dunes & wetlands	0	0.016137	0	0	0	0	9.04E-05	0	0	0	0	0	0
	Beech forest	0	0	0	0	0.010589	0	0.001954	0	0	0	0	0	0
	Bushland	0.039859	0.117097	0.035771	0.022734	0.01056	0.010786	0.061525	0.001561	0.025274	0.061049	0.026271	0.052064	0.002729
	Grassland	0.021871	0.077007	0.116091	0.068854	0.219579	0.061726	0.22084	0.28617	0.092419	0.291562	0.008524	0.206016	0.189978
	Small landscape elements	0.069954	0.043625	0.011064	0.087147	0.08435	0.222226	0.034605	0.074206	0.103405	0.066738	0.01877	0.072837	0.032902
	Poplar	0	0.005781	0.041351	0.013386	0.024813	0.000166	0.011243	0.005126	0.07578	0.004714	0	0.027856	0.061143

	Swamps	0	0.019139	0	0	0	0	0	0	0	0.005021	0.010502	0	0.000799
	Other broadleaf forests	0.010012	0.004627	0.013428	0	0.007143	0.003824	0.048389	0.008072	0.005746	0.045987	0.014292	0.03502	0.010105
	Coniferous forest	0	0	0	0.007514	0.002818	0.000467	0.011991	0	0	0	0.036449	0.012135	0.020642
	Oak forest	0	0.024289	0	0	0.007566	0.009219	0.095112	0	0.046524	0.006045	0.067595	0.061851	0.002546
	Ruderal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Urban area	0.835809	0.513623	0.684941	0.740338	0.363165	0.612742	0.393523	0.171619	0.151813	0.402211	0.726118	0.340367	0.410424
	Valleys	0	0.001766	0.009334	0	0.00519	0	0	0	0.010149	0.004114	0.046078	0.093534	0
	Roads	0.022495	0.157651	0.022817	0.004905	0	0.009792	0.023738	0.009744	0	0.059992	0.030593	0.006254	0.040686
	Stagnant Water	0.00335	0.016479	0.032219	0.032132	0.001312	0.011097	0.00875	0.031412	0.003461	0.002685	0.0073	0.015084	0.04704
	Agriculture	0.004469	0.037162	0.110829	0.061943	0.275955	0.123756	0.136383	0.462483	0.303367	0.054994	0	0.028488	0.172433
	Heath land	0	0	0	0	0	0	0.004326	0	0	0.002244	0.014867	0.006175	0.011659
	Dunes & wetlands	0	0.009422	0.001386	0	0	0	0.00013	0	0	0	0	0	0.000739
	Beech forest	0	0.001021	3.07E-06	0	0.002647	0	0.001721	0	0	0	0	0	0
	Bushland	0.046686	0.052312	0.015583	0.038594	0.005977	0.035005	0.0375	0.010133	0.015321	0.038303	0.02994	0.052291	0.006284
	Grassland	0.065374	0.166754	0.131162	0.122619	0.272239	0.069172	0.190912	0.26124	0.138429	0.269873	0.036548	0.152654	0.159067
	Small landscape elements	0.087167	0.105207	0.055929	0.068849	0.092223	0.139125	0.0542	0.06537	0.198566	0.058482	0.048475	0.070687	0.055822
	Poplar	0.001996	0.034745	0.150557	0.010867	0.049613	0.000867	0.007186	0.014971	0.072539	0.009655	0.000488	0.015363	0.04679
2 km	Swamps	0.001699	0.01099	0.000998	0.001245	0	0.001446	0	0.009777	0.000654	0.002802	0.007007	0.001828	0.013399

	Other broadleaf forests	0.040737	0.011927	0.010999	0.004937	0.005084	0.008865	0.032902	0.011789	0.004695	0.030541	0.014286	0.032791	0.021152
	Coniferous forest	0	0.008019	0.001817	0.004199	0.001733	0.001533	0.01536	0.000145	0.001253	0.001433	0.110134	0.074795	0.053821
	Oak forest	0.002277	0.027096	0.002031	0.027825	0.003715	0.016983	0.091451	0.001182	0.06596	0.020811	0.083685	0.082224	0.008539
	Ruderal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Urban area	0.64833	0.40255	0.446062	0.600987	0.273827	0.575111	0.385342	0.124404	0.190516	0.429173	0.592628	0.401045	0.365719
	Valleys	0.004836	0.015397	0.007647	0	0.015675	0.000592	0.005839	0.001434	0.003238	0.004553	0.016743	0.058784	0.000311
	Roads	0.093081	0.10092	0.032778	0.025805	0	0.016449	0.027999	0.005661	0.002	0.074452	0.037899	0.007791	0.037226
5 km	Stagnant Water	0.011306	0.011376	0.027362	0.026678	0.001847	0.006679	0.006092	0.005693	0.01081	0.019293	0.013766	0.009395	0.015711
	Agriculture	0.069305	0.119663	0.228526	0.086613	0.252944	0.2256	0.194397	0.457118	0.27558	0.089883	0.006224	0.037065	0.219428
	Heath land	2.8E-06	0	0.00016	0.00017	1.97E-05	0.000738	0.001888	0	0	0.002049	0.019597	0.035261	0.003293
	Dunes & wetlands	0	0.003333	0.006376	0	0	0	2.09E-05	0	0	0	0.000137	0	0.00014
	Beech forest	0.003956	0.001969	0.000495	0.000472	0.007977	0.013543	0.001797	5.12E-05	0.000269	0	0	0	3.76E-05
	Bushland	0.031874	0.031735	0.022738	0.040816	0.012232	0.024809	0.038418	0.00652	0.011344	0.031728	0.04141	0.037896	0.006357
	Grassland	0.169135	0.185828	0.155136	0.199254	0.299272	0.089219	0.204719	0.195009	0.141586	0.250753	0.083577	0.170655	0.188174
	Small landscape elements	0.087959	0.083143	0.058125	0.090865	0.057747	0.086925	0.063096	0.089241	0.238426	0.072534	0.062808	0.076441	0.032175
	Poplar	0.004867	0.013659	0.104836	0.020538	0.036813	0.008456	0.027738	0.012991	0.051344	0.01571	0.000506	0.005561	0.027518
	Swamps	0.002781	0.00525	0.008653	0.004792	0.002431	0.002508	0.000886	0.001905	0.002239	0.003554	0.005977	0.00424	0.00289
	Other broadleaf forests	0.025877	0.017784	0.009358	0.022495	0.00769	0.017218	0.020302	0.010836	0.008652	0.029346	0.019145	0.03581	0.015836

	Coniferous forest	0.001797	0.001584	0.002107	0.008351	0.001742	0.023893	0.050996	0.001173	0.001237	0.013969	0.193161	0.113493	0.121217
	Oak forest	0.004862	0.013753	0.00738	0.018252	0.011382	0.051594	0.067814	0.009443	0.031367	0.035874	0.069089	0.068216	0.019643
	Ruderal	0	0	0	0	0	0.000335	0	0.000357	0	0	0	0	0
	Urban area	0.516412	0.425804	0.276243	0.449744	0.284205	0.416814	0.298311	0.198696	0.21645	0.380866	0.428111	0.365354	0.326765
	Valleys	0.004662	0.011802	0.033602	0.002528	0.018918	0.00868	0.008733	0.001747	0.002348	0.006627	0.013711	0.026548	0.00797
	Roads	0.065204	0.073318	0.058902	0.028431	0.004782	0.02299	0.014793	0.009221	0.008346	0.047815	0.042782	0.014066	0.012846

Table S2: Area fractions (%) of **habitat evaluation from the biological valuation map** around sampling sites: Ghent (GT), Hoboken (HO), Bornem (BO), Mechelen (ME), Kessel-Lo (KL), Aarschot (AA); Oplinter (OP), Sint-Truiden (ST), Hasselt (HA), Genk (GK), Heusden-Zolder (HZ) and Neerpelt (NE). The table stretches over multiple pages.

		GT	HO	BO	ME	RO	KL	AA	OP	ST	HA	GK	HZ	NE
20 m	Less valuable habitat	1	1	1	1	1	1	1	1	1	1	1	0.2504	0.7928
	valuable and less-valuable habitat	0	0	0	0	0	0	0	0	0	0	0	0.5832	0
	Mixed Value Complex	0	0	0	0	0	0	0	0	0	0	0	0	0
	less-valuable and very-valuable habitat	0	0	0	0	0	0	0	0	0	0	0	0	0
	Valuable Habitat	0	0	0	0	0	0	0	0	0	0	0	0.1656	0.2072
	Valuable & very-valuable habitat	0	0	0	0	0	0	0	0	0	0	0	0	0
	Very-valuable habitat	0	0	0	0	0	0	0	0	0	0	0	0	0

200 m	Less valuable habitat	0.9735534	0.8405552	0.9992822	0.8446644	0.93127	0.9695549	0.81755	0.9486999	0.9952997	0.8183699	0.8141139	0.5106977	0.45005
	valuable and less-valuable habitat	0.0136637	0	0	0.1553556	0.05307	0	0.1479001	0.05031	0.0047003	0	0.0295528	0.2793577	0.1649939
	Mixed Value Complex	0	0	0	0	0	0	0	0	0	0	0	0	0
	less-valuable and very-valuable habitat	0	0	0	0	0	0	0	0	0	0	0	0	0
	Valuable Habitat	0	0.1594448	0.0007188	0	0.0156661	0	0.0292265	0.0009991	0	0.1816331	0.0696772	0.1591366	0.3850111
	Valuable & very-valuable habitat	0.0104777	0	0	0	0	0	0	0	0	0	0	0.0400004	0
	Very-valuable habitat	0.0023351	0	0	0	0	0.0304451	0.0052284	0	0	0	0.0866661	0.0108806	0
500 m	Less valuable habitat	0.8682281	0.7910061	0.9640014	0.7893556	0.7356522	0.7508933	0.7233384	0.8440046	0.8459733	0.8194119	0.7681055	0.5246638	0.7591556
	valuable and less-valuable habitat	0.0746685	0	0.0158733	0.1079336	0.0734722	0.1360339	0.0966955	0.1148066	0.0321966	0.03008	0.0283358	0.1627554	0.13396
	Mixed Value Complex	0	0	0	0	0.0592228	0	0	0.00581	0	0	0	0	0
	less-valuable and very-valuable habitat	0	0	0	0	0.0389554	0	0.0221117	0	0	0	0.0145542	0	0

	Valuable Habitat	0.015808	0.199523	0.01441	0.102708	0.040646	0.02274	0.072569	0.035033	0.091507	0.129628	0.028661	0.15305	0.102927
	Valuable & very-valuable habitat	0.03634	0.001579	0	0	0.044266	0.067596	0	0.000305	0	0.016015	0.06098	0.007736	0
	Very-valuable habitat	0.004885	0.007837	0.005704	0	0.007783	0.022732	0.085235	0	0.030324	0.004859	0.099354	0.151821	0.003958
1 km	Less valuable habitat	0.877039	0.707483	0.779846	0.810768	0.71101	0.707608	0.557953	0.699738	0.682237	0.701878	0.76059	0.471481	0.722606
	valuable and less-valuable habitat	0.064721	0.037274	0.060962	0.054425	0.10977	0.172629	0.072759	0.139756	0.036084	0.080652	0.013809	0.079506	0.145639
	Mixed Value Complex	0.004018	0.005198	0	0	0.023593	0	0.01827	0.009538	0.004115	0	0.00218	0.002045	1.03E-07
	less-valuable and very-valuable habitat	0	0	0	0	0.010275	0.005425	0.007316	0.002051	0.010991	0	0.003635	0.000959	0.006076
	Valuable Habitat	0.02846	0.101956	0.122166	0.113908	0.084565	0.054217	0.196102	0.114784	0.157985	0.188773	0.051246	0.203291	0.082895
	Valuable & very-valuable habitat	0.02226	0.050767	0.003202	0.0209	0.031793	0.046557	0.016177	0.028133	0.021831	0.007544	0.041801	0.02778	0.013922
	Very-valuable habitat	0.003502	0.097323	0.033825	0	0.029903	0.013564	0.131422	0.006	0.086758	0.021153	0.126739	0.214938	0.028862
2 km	Less valuable habitat	0.789	0.571	0.643	0.736	0.658	0.775	0.613	0.688	0.611	0.666	0.647	0.475	0.678

		958	777	504	646	651	362	986	101	156	718	662	445	928
	valuable and less-valuable habitat	0.053821	0.104229	0.08051	0.055318	0.090465	0.115125	0.060648	0.099576	0.053068	0.08609	0.025373	0.064157	0.094458
	Mixed Value Complex	0.001004	0.00355	0.006261	0.00052	0.029876	0.001024	0.007609	0.069568	0.016445	0.007504	0.007525	0.008573	0.002886
	less-valuable and very-valuable habitat	0	0.004039	0.001741	0	0.006792	0.003838	0.003614	0.003823	0.011493	0.00218	0.001531	0.004162	0.004203
	Valuable Habitat	0.110746	0.151776	0.111147	0.111621	0.126761	0.038189	0.160638	0.082327	0.144706	0.16781	0.077643	0.188105	0.136886
	Valuable & very-valuable habitat	0.025619	0.075281	0.047389	0.067198	0.054456	0.022294	0.029507	0.029581	0.072237	0.029035	0.104699	0.07863	0.028948
	Very-valuable habitat	0.018852	0.089347	0.109448	0.028696	0.032998	0.044169	0.123998	0.027025	0.090894	0.040662	0.135567	0.18093	0.053692
5 km	Less valuable habitat	0.742719	0.701481	0.611559	0.651403	0.614067	0.716446	0.574169	0.784827	0.697745	0.634185	0.514429	0.456176	0.631882
	valuable and less-valuable habitat	0.072565	0.106287	0.087008	0.094615	0.089266	0.066219	0.054517	0.07161	0.069968	0.088359	0.036246	0.060574	0.108006
	Mixed Value Complex	0.004082	0.004882	0.017815	0.003929	0.019026	0.004782	0.005982	0.038247	0.019687	0.00924	0.007287	0.013757	0.012436
	less-valuable and very-valuable habitat	0.003256	0.00234	0.004035	0.003525	0.004539	0.006391	0.006296	0.007487	0.008825	0.00537	0.003419	0.004846	0.007537

	Valuable Habitat	0.114932	0.092781	0.098161	0.15547	0.160546	0.063827	0.196269	0.058989	0.098685	0.146198	0.180507	0.182985	0.165982
	Valuable & very-valuable habitat	0.028795	0.03871	0.0427	0.050405	0.054161	0.047269	0.05256	0.015636	0.045923	0.043035	0.13261	0.144949	0.029787
	Very-valuable habitat	0.033651	0.053518	0.138723	0.040652	0.058394	0.095066	0.110208	0.023204	0.059166	0.073614	0.125502	0.136714	0.04437

Table S3: Area fractions (%) of land cover from the ECOPLAN map around sampling sites: Ghent (GT), Hoboken (HO), Bornem (BO), Mechelen (ME), Kessel-Lo (KL), Aarschot (AA); Oplinter (OP), Sint-Truiden (ST), Hasselt (HA), Genk (GK), Heusden-Zolder (HZ) and Neerpelt (NE). The table stretches over multiple pages.

		GT	HO	BO	ME	RO	KL	AA	OP	ST	HA	GK	HZ	NE
20 m	Pioneer vegetation	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bushland	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orchard shrubs	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orchard	0	0	0	0	0	0	0	0	0	0	0	0	0
	Orchard trees	0	0	0	0	0	0	0	0	0	0	0	0	0
	High green	0.520203	0.259946	0.211806	0	0.046008	0.018357	0.194604	0.21837	0.25321	0.193674	0.008121	0.071845	0.030498
	Low green	0.414939	0.266134	0.56243	0.083113	0.68828	0.811668	0.664829	0.582843	0.521226	0.575686	0.569735	0.184145	0.540694
	Other green	0	0.019878	0	0.022807	0.039852	0	0.050992	0.077527	0.019996	0.005422	0.019996	0	0
	Birch	0	0	0	0	0	0	0	0	0	0	0	0	0
	Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
	Beech - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oak	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oak - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0

	Poplar	0	0	0	0	0	0	0	0	0	0	0	0	0.212771
	Poplar - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deciduous (other)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deciduous (other) - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Larch	0	0	0	0	0	0	0	0	0	0	0	0	0
	Larch - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spruce	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spruce - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Austrian pine	0	0	0	0	0	0	0	0	0	0	0	0	0
	Austrian pine - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scots pine	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scots pine - deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coniferous (other)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coniferous (other) - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grassland (nutrient poor)	0	0	0	0	0	0	0	0	0	0	0	0	0

	Grassland (nutrient rich)	0	0	0	0	0	0	0	0	0	0	0	0.744017	0.188051
	Heathland (dry)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heathland (wet)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dunes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gravle roads	0	0	0	0	0	0	0	0	0	0	0	0	0
	Potatoes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Maize	0	0	0	0	0	0	0	0	0	0	0	0	0
	Cereal	0	0	0	0	0	0	0	0	0	0	0	0	0
	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Legumes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sugar beet	0	0	0	0	0	0	0	0	0	0	0	0	0
	Vegetables	0	0	0	0	0	0	0	0	0	0	0	0	0
	Herbs	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Flax and Hemp	0	0	0	0	0	0	0	0	0	0	0	0	0
	Feed crops	0	0	0	0	0	0	0	0	0	0	0	0	0
	Agriculture (other)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Annual ornamental plants	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perennial ornamental plants	0	0	0	0	0	0	0	0	0	0	0	0	0
	Swamp	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reed beds	0	0	0	0	0	0	0	0	0	0	0	0	0
	Alluvial forest	0	0	0	0	0	0	0	0	0	0	0	0	0

	Slikken	0	0	0	0	0	0	0	0	0	0	0	0	0
	Schorren	0	0	0	0	0	0	0	0	0	0	0	0	0
	Buildings	0.047641	0.108474	0.202862	0.195336	0.109495	0.126201	0.053336	0.014647	0.041969	0.051651	0.227745	0	0.027993
	Built-up	0	0	0	0	0	0	0	0.004142	0	0	0.019996	0	0
	Impervious surfaces	0.017224	0.345575	0.022908	0.698752	0.116372	0.043781	0.036246	0.102477	0.163606	0.173573	0.154414	0	0
	Stagnant water	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (mesohaline)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (oligohaline)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (fresh)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fresh water	0	0	0	0	0	0	0	0	0	0	0	0	0
200 m	Pioneer vegetation	0	0	0	0	0	0	0	0	0	0	0	0.009835	0
	Bushland	0.005029	0.144999	0.000319	0	0	0	0.029566	0	0	0	0.0673	0.068451	0
	Orchard shrubs	0	0	0	0	0	0	0	0	0.010311	0	0	0	0.004356
	Orchard	0	0	0	0	0	0	0	0	0.125942	0	0	0	0
	Orchard trees	0	0	0	0	0	0	0	0	0	0	0	0	0
	High green	0.069495	0.036701	0.134946	0.143898	0.083835	0.293408	0.1946	0.012284	0.101619	0.046176	0.133551	0.130269	0.017539
	Low green	0.133101	0.165343	0.427018	0.332906	0.374773	0.238254	0.289407	0.065734	0.195685	0.1898	0.26395	0.180411	0.166527
	Other green	0.023691	0.004245	0.017381	0.034933	0.015216	0.024656	0.042823	0.013863	0.014077	0.010095	0.018624	0.009853	0.01825
	Birch	0	0	0	0	0	0	0	0	0	0	0	0	0
	Beech	0	0	0	0	0	0	0	0	0	0	0	0	0
	Beech -	0	0	0	0	0	0	0	0	0	0	0	0	0

	Coniferous													
	Oak	0	0	0	0	0	0	0.003526	0	0	0	0.019077	0.004113	0
	Oak - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Poplar	0	0	0	0	0	0	0	0	0	0.002588	0	0.026722	0.259382
	Poplar - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deciduous (other)	0	0.001593	0.000186	0	0	0	8.36E-05	0.000398	0	0.019542	0.104004	0.012918	0
	Deciduous (other) - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Larch	0	0	0	0	0	0	0	0	0	0	0	0	0
	Larch - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spruce	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spruce - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Austrian pine	0	0	0	0	0	0	0	0	0	0	0	0	0
	Austrian pine - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scots pine	0	0	0	0	0	0	0	0	0	0	0.011484	0	0
	Scots pine - deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Coniferous (other)	0	0	0	0	0	0	0	0	0	0	0	0.015025	0
	Coniferous (other) -	0	0	0	0	0	0	0	0	0	0	0	0	0

	Deciduous													
	Grassland (nutrient poor)	0.009598	0	0	0	0	0.030869	0	0.034444	0.068001	0.033319	0	0.140916	0
	Grassland (nutrient rich)	0	0	0	0.000796	0.066965	0	0.177814	0.00125	0	0.338735	0.027363	0.23073	0.165636
	Heathland (dry)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heathland (wet)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dunes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gravle roads	0	0	0.022865	0	0	0	0	0	0.010655	0	0.017576	0	0
	Potatoes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Maize	0	0	0	0	0.048286	0	0	0.038607	0.190453	0.005449	0	0	0.130694
	Cereal	0	0	0	0	0	0	0	0.453658	0	0	0	0	0
	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Legumes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sugar beet	0	0	0	0	0	0	0	0.249717	0.001087	0	0	0	0
	Vegetables	0	0	0	0	0	0	0	0.000143	0	0	0	0	0
	Herbs	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Flax and Hemp	0	0	0	0	0	0	0	0.000199	0	0	0	0	0
	Feed crops	0	0	0	0	0	0	0	0.017126	0	0	0	0	0
	Agriculture (other)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Annual ornamental plants	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perennial	0	0	0	0	0	0	0	0	0	0	0	0	0

	ornamental plants													
	Swamp	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reed beds	0	0	0	0	0	0	0	0	0	0	0	0	0
	Alluvial forest	0	0	0	0	0	0	0	0	0	0	0	0	0
	Slikken	0	0	0	0	0	0	0	0	0	0	0	0	0
	Schorren	0	0	0	0	0	0	0	0	0	0	0	0	0
	Buildings	0.353072	0.144212	0.132312	0.083922	0.153163	0.161914	0.096912	0.029254	0.125196	0.093883	0.131871	0.045468	0.049088
	Built-up	0.272771	0.154584	0.170013	0.109936	0.086215	0.166242	0.065755	0.046672	0.056132	0.146605	0.128207	0.086211	0.132553
	Impervious surfaces	0.133244	0.33399	0.094959	0.276179	0.171546	0.084634	0.099513	0.036651	0.100842	0.104545	0.076996	0.032625	0.042791
	Stagnant water	0	0	0	0.006798	0	2.44E-05	0	0	0	0.001258	0	0.006454	0.013184
	Tidal water (mesohaline)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (oligohaline)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (fresh)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fresh water	0	0.014334	0	0.010633	0	0	0	0	0	0.008005	0	0	0
500 m	Pioneer vegetation	0	0	0	0.021899	0	0	0.006755	0	0	3.14E-05	0.000378	0.0104	0
	Bushland	0.024581	0.182485	0.007456	0	0	0.002389	0.033488	0	0.014008	0.027666	0.024649	0.02684	0
	Orchard shrubs	0	0	0	0	0	0	0	0	0.056639	7.62E-05	0	0	0.027153
	Orchard	0	0	0	0	0	0	0	0.041844	0.050866	0	0	0	0
	Orchard trees	0	0	0	0	0	0	0	0	0	0	0	0	0
	High green	0.11914	0.047094	0.098757	0.169177	0.045866	0.212456	0.129079	0.007772	0.058373	0.05911	0.102395	0.06769	0.038232

	Low green	0.156144	0.109033	0.296846	0.238193	0.269355	0.263506	0.219406	0.034352	0.116736	0.176251	0.128421	0.18104	0.178126
	Other green	0.025991	0.004351	0.02282	0.032889	0.008495	0.028864	0.039302	0.005671	0.008888	0.008622	0.01584	0.012608	0.01357
	Birch	0	0	0	0	0.003029	0	0	0	0	0	0	0	0
	Beech	0	0	0	0	0	0.001177	0	0	0	0	0	0	0
	Beech - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oak	0	0	0	0	0	0.004772	0.058319	0	0.001496	0	0.018825	0.012625	0
	Oak - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Poplar	0	0.00638	0	0	0.004129	0	0	0	0.072758	0.000876	0	0.02186	0.068695
	Poplar - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deciduous (other)	0.014936	0.000562	0.006441	0	0.002664	0.065268	0.053991	0.00251	0.010786	0.033555	0.102967	0.05607	0.000614
	Deciduous (other) - Coniferous	0	0	0	0	0	0.002119	0	0	0	0	0.014178	0	0.001554
	Larch	0	0	0	0	0	0	0	0	0	0	0	0	0
	Larch - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spruce	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spruce - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Austrian pine	0	0	0	0	0	0	0	0	0	0	0	0	0
	Austrian pine - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Scots pine	0	0	0	0	0	0.008684	0.013502	0	0	0	0.012883	0	0.00123

	Scots pine-deciduous	0	0	0	0	0	0	0	0	0	0	0.024331	0	0
	Coniferous (other)	0	0	0	0	0	0	0.006213	0	0	0	0	0.008846	0.000126
	Coniferous (other) - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Grassland (nutrient poor)	0.04021	0.035295	0.006591	0.065222	0.015244	0.013364	0.00697	0.033702	0.203453	0.085789	0.005619	0.077217	0.000428
	Grassland (nutrient rich)	0	0.003766	0.012671	0.044766	0.219778	0.018316	0.207363	0.141815	0.013718	0.107551	0.008616	0.225723	0.223671
	Heathland (dry)	0	0	0	0	0	0	0	0	0	0	0	0.000776	0
	Heathland (wet)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil	0	0	0.002953	0	0.000616	0	0	0	0	0	0	0	0
	Dunes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Gravle roads	0	0.015445	0.014523	0	0	0.000762	0.002411	0.005626	0.004189	0.005584	0.019154	0.015193	0.000802
	Potatoes	0	0	0	0	0	0	0	3.18E-05	0.000127	0	0	0	0
	Maize	0	0	0.000128	0	0.14559	0	0.00183	0.059473	0.117169	0.039798	0	0.006295	0.125447
	Cereal	0	0	0	0	0.039958	0.000536	0.00627	0.368536	0.051542	0	0	0	0
	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Legumes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sugar beet	0	0	0	0	0	0.012116	0	0.19516	0.081364	0	0	0	0
	Vegetables	0	0	0	0	0	0	0	0.01676	0.011835	0	0	0	0.05809
	Herbs	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit	0	0	0	0	0	0	0	0	0	0	0	0	0
	Flax and Hemp	0	0	0	0	0	0	0	0.000159	0	0	0	0	0

	Feed crops	0	0	0	0	0	0	0	0.016832	0	0	0	0	0.003045
	Agriculture (other)	0	0	0	0	0	0	0	0	0	0	0	0	0.004641
	Annual ornamental plants	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perennial ornamental plants	0	0	0	0	0	0	0	0	0	0	0	0	0
	Swamp	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reed beds	0	0	0	0	0	0	0	0	0	0	0	0	0.001677
	Alluvial forest	0	0	0	0	0	0	0	0	0.005559	0.001336	0.014629	0.074663	0
	Slikken	0	0.007914	0	0	0	0	0	0	0	0	0	0	0
	Schorren	0	0	0	0	0	0	0	0	0	0	0	0	0
	Buildings	0.277228	0.103279	0.18158	0.164104	0.083553	0.145811	0.062787	0.016345	0.044234	0.099865	0.16861	0.057663	0.053131
	Built-up	0.228265	0.10094	0.202721	0.095213	0.065051	0.138221	0.065625	0.026812	0.031169	0.230475	0.225296	0.091828	0.104332
	Impervious surfaces	0.11338	0.351619	0.146098	0.131289	0.096672	0.081563	0.086534	0.015465	0.037267	0.108291	0.109697	0.046876	0.046272
	Stagnant water	0.000125	0	0.000414	0.008943	0	7.54E-05	0.000154	0	0.001613	0.004127	0	0.00116	0.043114
	Tidal water (mesohaline)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (oligohaline)	0	0.026758	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (fresh)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fresh water	0	0.005079	0	0.028305	0	0	0	0.011134	0.006211	0.010997	0.003512	0.004628	0.00605
1 km	Pioneer vegetation	0.001072	0.015388	0.001852	0.018963	0.000505	0.001067	0.049827	0.002269	0	0.002185	0.001087	0.048166	0.00387

	Bushland	0.022443	0.096425	0.021848	0.002561	0.009946	0.007278	0.060218	0	0.023964	0.046052	0.018058	0.043408	0.002428
	Orchard shrubs	0	0	0	0	0.001819	0	0	0.007174	0.014293	0.018057	0	0.000257	0.007353
	Orchard	0	0	0	0	0.001051	0	0.001403	0.040693	0.03197	0	0	0	0
	Orchard trees	0	0	0	0	0	0	0	0	0	0	0	0	0
	High green	0.110149	0.041526	0.081251	0.135551	0.047329	0.19208	0.10077	0.013292	0.031173	0.042599	0.141127	0.040807	0.057233
	Low green	0.1622	0.096865	0.228493	0.197379	0.211667	0.20549	0.121689	0.073016	0.076174	0.111379	0.143655	0.137059	0.144502
	Other green	0.022187	0.005726	0.014476	0.025713	0.00636	0.029159	0.030564	0.012867	0.005442	0.005934	0.014732	0.011904	0.008988
	Birch	0	0	0	0	0.003662	0	0.002292	0	0	0	0	0	0
	Beech	0	0	0	0.000421	0	0.002849	0	0	0	0	0	0	0
	Beech - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oak	0	0.004071	0	0.001836	0.003338	0.002278	0.075641	0	0.004155	0.010364	0.014488	0.037084	0.004759
	Oak - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Poplar	0.000227	0.004835	0.032864	0.010898	0.01977	0.000319	0.034953	0.004728	0.076007	0.012006	7.96E-05	0.028882	0.026685
	Poplar - Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Deciduous (other)	0.008752	0.029323	0.020791	0.019084	0.020943	0.050404	0.036944	0.001939	0.039176	0.031981	0.064907	0.070163	0.024578
	Deciduous (other) - Coniferous	0	0	0	0	0.002028	0.001328	0	0	0	0	0.020985	0.001906	0.004501
	Larch	0	0	0	0	0	0	0	0	0	0	0	0.002019	0
	Larch - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Spruce	0	0	0	0	0.001477	0	0.004704	0	0	0	0.002622	0	0.002679
	Spruce -	0	0	0	0	0	0	0	0	0	0	0	0	0

	Deciduous													
	Austrian pine	0	0	0	0	0	0	0	0	0	0	0.000836	0	0
	Austrian pine - Deciduous	0	0	0	0	0	0	0.001242	0	0	0	0	0	0.000108
	Scots pine	0	0	0	0	0	0.00281	0.004262	0	0	0	0.01822	0.002164	0.015579
	Scots pine-deciduous	0	0	0	0	0	0	0.003884	0	0	0	0.01169	0	0
	Coniferous (other)	0	0	0	0.004215	0.000705	0.000426	0.00227	0	0	0	0.000279	0.006021	0.001225
	Coniferous (other) - Deciduous	0	0	0	0	0	0	0	0	0	0	0	0.001161	0
	Grassland (nutrient poor)	0.01873	0.043281	0.00573	0.041395	0.030114	0.011181	0.017419	0.027784	0.173896	0.125798	0.003086	0.040249	0.014886
	Grassland (nutrient rich)	0.001891	0.046709	0.096671	0.044516	0.229905	0.079845	0.189344	0.28532	0.130614	0.143995	0.003921	0.167916	0.20285
	Heathland (dry)	0	0	0	0	0	0	0	0	0	0	7.51E-05	0.000194	0
	Heathland (wet)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Bare soil	0	0	0.001434	0	0.000154	0	0	0	0	0	0	0	0
	Dunes	0	0	0	0	0	0	7.76E-05	0	0	0	0	0	0
	Gravle roads	0.028537	0.014833	0.008001	0.029319	7.92E-05	0.000995	0.006551	0.003929	0.001076	0.016674	0.01157	0.013524	0.002061
	Potatoes	0	0	0	0	1.59E-05	0	0	0.000334	6.37E-05	0	0	0	0
	Maize	0	0	0.039456	0.002737	0.108442	0.023401	0.03044	0.093259	0.040152	0.048722	0	0.03538	0.169842
	Cereal	0	0	0	0	0.084102	0.021886	0.001583	0.205847	0.096144	0.004796	0	0.011171	0.012568
	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0

	Legumes	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sugar beet	0	0	0	0	2.1E-05	0.008736	0	0.071876	0.058463	0	0	0	0
	Vegetables	0	0	0	0	0.001448	0	0	0.032344	0.057589	0	0	0	0.016077
	Herbs	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fruit	0	0	0	0	0.000364	0	0	0	0	0	0	0	0
	Flax and Hemp	0	8.14E-06	0	0	0	0.0008	0	0.00018	0	0.00351	0	0	0
	Feed crops	0	0	0	0	0.00047	0	0	0.004755	0	0	0	0	0.000802
	Agriculture (other)	0	0	0	0	0.001833	0	0	0	0.005004	0	0	0	0.054027
	Annual ornamental plants	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perennial ornamental plants	0	0	0	0	0	0	0	0	0	0	0	0	0
	Swamp	0	0	0	0	0	0	0	0	0	0	0	0	0
	Reed beds	0	0.01891	0	0	0	0	0	0	0	0.003476	0.009554	0	0.000419
	Alluvial forest	0	0.00175	0.009115	0	0.005011	0	0	0	0.009584	0.003533	0.041445	0.090557	0
	Slikken	0	0.016202	0	0	0	0	0	0	0	0	0	0	0
	Schorren	0	0	0	0	0	0	0	0	0	0	0	0	0
	Buildings	0.271764	0.090432	0.160065	0.197267	0.067864	0.142032	0.054319	0.035669	0.032543	0.086287	0.145771	0.051376	0.046375
	Built-up	0.235739	0.079961	0.13321	0.109125	0.059831	0.126999	0.089536	0.031642	0.042925	0.17337	0.222053	0.065884	0.081158
	Impervious surfaces	0.113802	0.209156	0.106478	0.136091	0.078526	0.088577	0.06206	0.031608	0.029035	0.083766	0.09436	0.057759	0.04402
	Stagnant water	0.002506	0.00818	0.014284	0.003383	0.000376	5.86E-05	0.003559	0.001874	0.006928	0.005472	0.004833	0.000451	0.020304
	Tidal water (mesohaline)	0	0	0	0	0	0	0	0	0	0	0	0	0

	Tidal water (oligohaline)	0	0.158089	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (fresh)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fresh water	0	0.01833	0.023981	0.019545	0.000843	0	0.014449	0.017601	0.013631	0.020044	0.010568	0.034538	0.030122
2 km	Pioneer vegetation	0.01157	0.010169	0.000988	0.010203	0.005621	0.004976	0.024902	0.01476	0.002835	0.008166	0.021766	0.058794	0.017506
	Bushland	0.02172	0.043232	0.009647	0.017572	0.005589	0.006529	0.029812	0.008621	0.011399	0.030279	0.01857	0.044089	0.007781
	Orchard shrubs	0	0	0	3.98E-06	0.00728	0.000203	0.003996	0.003994	0.006235	0.008184	0	6.44E-05	0.007494
	Orchard	0	0	0.006089	0	0.005255	0.000417	0.00389	0.024207	0.046141	1.53E-05	0	0	0
	Orchard trees	0	0	0	0	6.76E-05	9.62E-05	0	8.01E-05	0.000487	0	0	0	0
	High green	0.084982	0.051685	0.060828	0.107442	0.043778	0.141863	0.080854	0.013731	0.040801	0.047334	0.109331	0.063179	0.06534
	Low green	0.112246	0.103773	0.154611	0.166797	0.165731	0.169724	0.102239	0.05446	0.083579	0.122413	0.157067	0.150704	0.135552
	Other green	0.014021	0.007143	0.008161	0.02127	0.006191	0.028984	0.022933	0.009171	0.006276	0.006641	0.012201	0.012446	0.009371
	Birch	0	5.57E-05	1.44E-06	0	0.000916	0	0.00059	0	0	0	0.000373	0.000139	2.36E-05
	Beech	0.000113	0.000105	0	0.00027	1.43E-05	0.000712	0.000454	0	0	0	0	0	0
	Beech-Coniferous	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oak	0.001632	0.005562	0.000812	0.006136	0.00174	0.006853	0.055229	0.001154	0.045291	0.015847	0.023238	0.033379	0.005861
	Oak-Coniferous	0	0.000996	0	0	0	0	0	0	0	0	0.003258	0.000735	0.001623
	Poplar	0.00205	0.027442	0.104144	0.012665	0.046964	0.001166	0.014848	0.012737	0.069796	0.016478	0.000482	0.016046	0.034762
	Poplar-Coniferous	0	0	0	0	0	0	0	0.000544	0	0	0	0	0
	Deciduous (other)	0.028678	0.051493	0.055716	0.033566	0.010401	0.028747	0.0495	0.006514	0.021633	0.029965	0.065151	0.092572	0.015924
	Deciduous	0	0	0	0	0.000507	0.000332	0.004482	0	0.000355	0.000906	0.021436	0.017228	0.002458

	(other) - Coniferous													
	Larch	7.76E-05	0	0	0	0	0.000122	0.000678	0	0	0	0	0.003413	0
	Larch - Deciduous	0	0	0	0	0	0	0	0	0	0	0	8.03E-05	0
	Spruce	0	0.00015	0.001157	0.000506	0.000369	0.000588	0.001564	0	0.000701	0.000211	0.000857	0.001212	0.00067
	Spruce - Deciduous	0	0	0	0	0	0	0.000119	0	0	2.83E-05	0.000211	0.000463	0
	Austrian pine	0	0	0	0	0	0	0.0011	0	0	0	0.000679	0.009474	0.006996
	Austrian pine - Deciduous	0	0	0	0	0	0	0.000311	0	0	0	0	0.000263	0.00026
	Scots pine	0	0.007325	3.73E-05	0.002649	0	0.000702	0.008859	0	0	0	0.058679	0.031162	0.043005
	Scots pine - deciduous	0	4.86E-05	0	0.000578	0	0	0.004519	0	0	0	0.03763	0.009516	0.000947
	Coniferous (other)	0	0	0.000712	0.003345	0.001149	0.000981	0.002498	0.000145	7.19E-05	0.00084	0.001906	0.010543	0.002904
	Coniferous (other) - Deciduous	0	0	0	8.54E-05	0	0	0	0	0	0.0007	0	0.001849	0.000322
	Grassland (nutrient poor)	0.041375	0.039262	0.010474	0.031534	0.050105	0.020367	0.032012	0.042476	0.072606	0.065523	0.016543	0.027167	0.053067
	Grassland (nutrient rich)	0.016078	0.14326	0.130789	0.092786	0.267585	0.073346	0.167806	0.251201	0.199792	0.195554	0.01556	0.111864	0.14843
	Heathland (dry)	0	0	0	0	0	0	0.004827	0	0	0.001722	0.013153	0.006106	0.011559
	Heathland (wet)	0	0	0	0	0	0	0	0	0	0	0	0	0.000894

	Bare soil	0	0	0.000468	6.72E-06	3.85E-05	0	0	0	0	0	0	0	0
	Dunes	0	0	0	0	0	0	0.000122	0	0	0	0	0	0.000745
	Gravle roads	0.025913	0.008934	0.007403	0.026936	0.000729	0.037775	0.011041	0.008258	0.006198	0.008155	0.015431	0.00972	0.004082
	Potatoes	0	0	5.97E-06	0	9.74E-05	1.58E-05	5.97E-06	0.000177	3.96E-05	0	0	1.99E-06	0
	Maize	0.001353	0.012595	0.075099	0.015582	0.117306	0.040671	0.046404	0.113793	0.038809	0.048306	0	0.017158	0.11421
	Cereal	0.000313	0.005823	0.018923	3.5E-05	0.081943	0.052151	0.034639	0.178979	0.083117	0.012262	0	0.002816	0.011989
	Seed	0	0	0	0	0	0	0	0	0	0	0	0	0
	Legumes	0	0	0	0	0	0.0002	1.59E-05	0	0	0	0	0	0.000873
	Sugar beet	0	0	0	0	0.000368	0.012025	0	0.090264	0.036406	0	0	0	0
	Vegetables	0	0	0.009058	0.000843	0.001568	0.000365	0.00497	0.028845	0.050836	0	0	0	0.004019
	Herbs	0	0	0.001035	0	0.0025	1.79E-05	7.81E-05	7.83E-05	2.59E-05	0	0	0	0
	Fruit	0	0	0	0	0.000645	0	0.000198	1.53E-05	0	0	0	0	0
	Flax and Hemp	0	0.00956	0.004009	0	0.000328	0.000955	0	0.012508	0.018323	0.002589	0	0.000471	0
	Feed crops	0	0	0.002423	0	0.000278	0.000538	0.00048	0.001853	2.17E-05	0	0	0	0.0002
	Agriculture (other)	0	0	0	0.000311	0.001158	0	7.53E-05	0.000324	0.010747	0	0	0	0.014214
	Annual ornamental plants	0	0	0	0	0	0	0	0	0	0	0	0	0
	Perennial ornamental plants	0	0	0	0	0	0	0	0	4.58E-05	0	0	0	0
	Swamp	0.000643	0	0	0.000476	0	0	0	0	0	0.000676	0	0.000811	0.005251
	Reed beds	0.000665	0.010692	0.000866	0.000303	0	0.001369	0	0.007585	0.000644	0.001579	0.006088	0.001005	0.007333
	Alluvial forest	0.004149	0.013067	0.007397	0	0.014876	0.000549	0.005091	0.001427	0.003099	0.004075	0.014719	0.057532	0.000306
	Slikken	0	0.009388	0.001446	0	0	0	0	0	0	0	0	0	0
	Schorren	0	0	0	0	0	0	0	0	0	0	0	0	0

	Buildings	0.221582	0.098522	0.102917	0.160114	0.04893	0.144791	0.071117	0.026806	0.042155	0.100114	0.109232	0.059361	0.054791
	Built-up	0.256872	0.084284	0.086272	0.129867	0.048496	0.122298	0.100338	0.026522	0.049849	0.143676	0.182401	0.07149	0.08759
	Impervious surfaces	0.110686	0.109573	0.073138	0.098103	0.059305	0.087824	0.085763	0.026108	0.035645	0.084019	0.08359	0.060638	0.059595
	Stagnant water	0.003955	0.011177	0.008841	0.007336	0.001324	0.002988	0.006676	0.016136	0.003777	0.003362	0.003445	0.004928	0.029855
	Tidal water (mesohaline)	0	0	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (oligohaline)	0	0.100002	0.01961	0	0	0	0	0	0	0	0	0	0
	Tidal water (fresh)	0	0	0	0.007674	0	0	0	0	0	0	0	0	0
	Fresh water	0.039327	0.034683	0.036922	0.045001	0.003096	0.008757	0.014965	0.016526	0.012265	0.040379	0.007001	0.011582	0.032197
5 km	Pioneer vegetation	0.015642	0.015489	0.011124	0.010965	0.00813	0.010531	0.020767	0.007557	0.005195	0.00896	0.034423	0.043219	0.007405
	Bushland	0.011813	0.024468	0.019095	0.022037	0.006148	0.011783	0.034977	0.005069	0.008191	0.01919	0.031207	0.035262	0.006739
	Orchard shrubs	0.001804	0.00014	0.000556	0.001352	0.00229	0.002166	0.010071	0.005241	0.004226	0.004181	0.000307	0.000393	0.005604
	Orchard	0.000747	0.004035	0.001827	4.15E-05	0.006906	0.000669	0.006943	0.032712	0.114698	0.00614	0	0.000238	0
	Orchard trees	7.86E-05	3.43E-06	8.51E-05	4.14E-05	1.08E-05	4.6E-05	0.000274	0.002326	0.00316	0	0	4.17E-05	6.51E-07
	High green	0.075993	0.057243	0.045818	0.099567	0.039424	0.103601	0.059701	0.026933	0.033323	0.052667	0.063055	0.055281	0.041699
	Low green	0.128276	0.110317	0.111468	0.143336	0.129664	0.113129	0.10343	0.069024	0.089628	0.144325	0.133034	0.138114	0.118426
	Other green	0.009677	0.008987	0.007132	0.016223	0.005072	0.021907	0.024872	0.015851	0.00868	0.007937	0.010189	0.011622	0.010555
	Birch	0.000149	0.000301	6.72E-05	0.000308	0.000356	0.00125	0.000263	2.04E-05	2.63E-06	0.00039	0.000356	0.000166	4.2E-05
	Beech	0.003757	0.000874	0.000204	0.000589	0.006025	0.011505	0.000498	0.000575	0.000761	0.000543	0.000132	7.77E-06	1.11E-05
	Beech-Coniferous	0	0	0	0	0	0.000159	0	0	0	0	0	0	0

	Oak	0.002157	0.004945	0.002398	0.006598	0.004775	0.019199	0.037273	0.005481	0.018334	0.016277	0.020379	0.02686	0.008285
	Oak-Coniferous	0	0.000159	0.000266	0.000121	0	0.000444	0.001613	0	0.001281	0.002496	0.003429	0.002173	0.000468
	Poplar	0.005759	0.01083	0.088473	0.020248	0.034996	0.00896	0.026777	0.011636	0.050824	0.017398	0.000454	0.007361	0.024219
	Poplar - Coniferous	2.05E-05	0	0	0	5.58E-05	2.38E-05	7.47E-05	9.1E-05	0	0	0	0	9.52E-06
	Deciduous (other)	0.026152	0.031158	0.025739	0.034012	0.016469	0.0468	0.038307	0.01045	0.010301	0.032107	0.042962	0.06768	0.010452
	Deciduous (other) - Coniferous	0.000191	0.000402	0.000362	0.001426	0.000184	0.002419	0.004324	0.000142	0.001076	0.004365	0.019945	0.011575	0.003838
	Larch	0.000244	0.000237	0.000103	0.000472	0.000121	0.005398	0.002457	3.87E-05	0.000395	0.000534	0.000323	0.001324	0.001492
	Larch-Deciduous	3.98E-05	0	3.03E-05	0.000126	0	0.001199	0.000206	0	0.000588	9.93E-05	0.000545	0.000343	0.000121
	Spruce	0.000354	2.41E-05	0.000614	0.001159	0.000508	0.001142	0.00212	0.000158	0.00033	0.000635	0.002897	0.001758	0.001202
	Spruce - Deciduous	0	4.51E-05	6.2E-05	8.07E-05	0.000147	0.000116	0.000652	0	3.86E-06	0.000138	8.61E-05	0.000325	0.000362
	Austrian pine	3.76E-05	0	0.000679	0.00024	2.67E-05	0.003275	0.007869	0	0	0.000365	0.009998	0.017376	0.024219
	Austrian pine - Deciduous	0	0	0	0.000134	0	0.000515	0.000419	0	0	0	0.005026	0.000154	0.000796
	Scots pine	0.000804	0.001219	0.000243	0.006098	1.34E-05	0.008322	0.028925	0.000443	0.000366	0.009029	0.110823	0.072223	0.086055
	Scots pine-deciduous	0	7.78E-06	0	0.000675	0	0.002355	0.004911	0	0.000307	0.001177	0.030483	0.013959	0.003333
	Coniferous (other)	0.00052	8.75E-05	0.000952	0.002033	0.000739	0.004165	0.00568	0.000851	0.000158	0.001915	0.006946	0.00786	0.006278
	Coniferous (other) -	4.19E-05	0	0.000111	9E-05	0.000295	0.000785	0.000578	0	0	0.006146	0.026016	0.005129	0.000248

	Deciduous													
	Grassland (nutrient poor)	0.037227	0.039549	0.021707	0.033065	0.033438	0.032689	0.043827	0.047566	0.033701	0.033713	0.025906	0.028662	0.032227
	Grassland (nutrient rich)	0.131712	0.157865	0.18058	0.183732	0.296126	0.08193	0.169394	0.191516	0.166385	0.21435	0.054837	0.125573	0.191156
	Heathland (dry)	1.01E-06	0	0.000153	0.000402	1.92E-05	0.000739	0.003072	0	0	0.001655	0.017689	0.040157	0.003367
	Heathland (wet)	0	0	0	0	0	0	0	0	0	6.93E-05	0.00113	0.001796	1.13E-06
	Bare soil	7.22E-05	0.001608	0.000132	6.34E-05	9.34E-06	0	0	2.55E-06	0	5.64E-05	0.00028	0.00045	0
	Dunes	0	0	0	0	0	0	1.95E-05	0	0	0	0.000137	0	0.000147
	Gravle roads	0.024544	0.006781	0.005358	0.01922	0.006651	0.020627	0.009854	0.005557	0.003911	0.012622	0.014853	0.00509	0.004699
	Potatoes	7.32E-06	9.02E-06	1.46E-05	1.11E-05	7.49E-05	3.24E-05	2.66E-05	0.000121	5.77E-05	5.41E-06	0	3.71E-06	2.28E-06
	Maize	0.040998	0.090344	0.116598	0.033797	0.111019	0.072059	0.089308	0.112407	0.086749	0.076137	0.002761	0.026542	0.153037
	Cereal	0.005876	0.011134	0.023099	0.003161	0.076491	0.105853	0.050338	0.193919	0.075625	0.013874	0.0016	0.00357	0.020211
	Seed	0	9.7E-05	0.000236	0	0.000145	0	7.68E-05	1.86E-05	0	0	0	0	0.000255
	Legumes	0.000292	0	0	0	0	0.000597	0.00059	0.001165	0.000147	0.00013	0	0	0.00039
	Sugar beet	0	7.84E-06	0.00081	0.000188	0.00632	0.020201	0.001779	0.060228	0.022489	0.000875	0	0	3.83E-05
	Vegetables	0.004978	0.001531	0.020287	0.003934	0.002068	0.001315	0.007844	0.030904	0.059954	0.004849	0	0.001973	0.001837
	Herbs	0.000121	0.000111	0.003865	0.001702	4.45E-05	0.000154	0.000494	3.55E-05	0.000415	5.55E-05	0	0	0.002585
	Fruit	3.83E-05	1.11E-05	0	0	0.000565	3.82E-06	0.000163	7.39E-06	0.000453	1.2E-05	0	0.000512	0
	Flax and Hemp	0.001401	0.006705	0.004621	0.001421	0.002556	0.002041	0.001893	0.01013	0.006283	0.00156	0.000164	0.0005	0.003779
	Feed crops	0.001561	0.003764	0.002438	0.001839	0.002696	0.00121	0.001673	0.001182	0.000883	0.001948	0	5.64E-05	0.001271
	Agriculture (other)	0.000324	0.000378	0.000219	0.000274	0.001073	0.000316	0.001096	0.00202	0.013408	0.001175	0	0.000446	0.0028
	Annual ornam	0.000675	1.56E-05	0.000149	3.73E-06	0	0	0.000364	3.33E-07	9.05E-06	1.11E-05	0	0	5.15E-05

	ental plants													
	Perennial ornamental plants	9.84E-07	0	0	6.04E-05	9.82E-05	0	0	0	0.000325	0	0	0	0
	Swamp	0.001449	2.55E-05	5.69E-05	0.001103	0.00082	0.000126	0.000137	0	0.000592	0.000524	0.001787	0.000908	0.000898
	Reed beds	0.000972	0.004662	0.008004	0.003313	0.0012	0.00224	0.000485	0.001549	0.001212	0.002454	0.004929	0.002366	0.001822
	Alluvial forest	0.004268	0.010646	0.029435	0.002434	0.01806	0.008462	0.008249	0.001656	0.002281	0.006123	0.012858	0.025619	0.007419
	Slikken	0	0.003287	0.006249	0	0	0	0	0	0	0	0	0	0
	Schorren	0	2.62E-05	0	0	0	0	0	0	0	0	0	0	0
	Buildings	0.160451	0.11699	0.055991	0.113035	0.059942	0.090704	0.045391	0.044622	0.049038	0.075767	0.079182	0.060601	0.054185
	Built-up	0.165725	0.10897	0.062827	0.102114	0.053855	0.098417	0.061745	0.047726	0.054307	0.108637	0.122788	0.077353	0.067071
	Impervious surfaces	0.078032	0.08279	0.040814	0.071815	0.054856	0.064412	0.062392	0.041696	0.049423	0.065138	0.077141	0.065744	0.059444
	Stagnant water	0.009965	0.009316	0.013977	0.019008	0.002198	0.006474	0.005323	0.004142	0.002596	0.01083	0.009956	0.005717	0.011278
	Tidal water (mesohaline)	0	0.018108	0	0	0	0	0	0	0	0	0	0	0
	Tidal water (oligohaline)	0	0.03455	0.038891	0	0	0	0	0	0	0	0	0	0
	Tidal water (fresh)	0.004079	0	0.010083	0.008469	0	0	0	0	0	0	0	0	0
	Fresh water	0.040971	0.019745	0.035999	0.027864	0.007319	0.007531	0.010484	0.007231	0.017922	0.030415	0.018989	0.005915	0.014661