DEPARTMENT OF BIOLOGICAL AND
ENVIRONMENTAL SCIENCES

DIFFERENCES ON THE IMPACTS AND ORIGINS OF POLLEN IN FOUR MAJOR SWEDISH CITIES BETWEEN 2014 AND 2019

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[1] Image source: https://www.istockphoto.com/fr/photo/grain-de-pollen-volant-de-bouleau-catkins-de-printemps-gm469967080-62733110?phrase=gregory_dubus+pollen&searchscope=image%2Cfilm

Abstract:

Allergies are widespread in the world and coming from various sources, one of the causes being airborne allergens and especially, pollen. The negative impact of pollen is enhanced by pollution and climate change which are some of the biggest issue humankind is facing today. Pollen can be transported easily through the atmospheric pathway and air currents over thousands of kilometers, making the study and forecast of air currents very useful to predict high pollen episodes. In Sweden, already up to 24% of the population are affected by allergic rhinitis and this number is likely to increase.

In this study I focused on four of the major Swedish cities: Gothenburg, Malmö, Stockholm and Umeå. I chose to compare the cities between them and between two years of high pollen counts, 2014 and 2019. I first studied the differences on the impact of pollen on allergy sufferers. I studied and tested the correlation between the pollen counts, the prescription rate and number of patients per 1000 inhabitants of antihistaminic drugs, between the two years and in the four cities. In a second part, I studied the backward trajectories of air currents, linked to pollen counts, to establish both a potential maximum area of coverage from the pollen traps, and, the potential origins of pollen in the Swedish cities during high pollen count days.

The results were interesting, despite a strong correlation between the pollen count and the patients/prescription rate data, I found the later one being up to 31% higher in 2019 than 2014, while, the pollen count was lower in 2019. For the second part of the study, the pollen trap range could not be established, however a list of countries and regions being the most likely origin of pollens has been established for each city. Overall and across the four cities, Sweden, Norway, Finland, Denmark, Germany, Poland, Belarus, Estonia, Latvia and Lithuania are the most likely origins of pollens for the years 2014 and 2019. These data are allowing a more targeted surveillance of these areas, in an attempt to better forecast the high pollen periods and, ease the pollen allergy sufferer's burden.

Keywords: *Pollen, Allergy, Antihistaminic, Airborne transport, Geographical origins*

Summary:

I) Introduction:

Allergies are preponderous in our world. They can come from various sources, from food to medications but also through airborne allergens. These allergens can be dust mites, mold, animal dander but also, pollen. Airborne allergens pose a big threat on the population, allergic rhinitis for example is a disease currently known to affect up to 30% of the world population (“WAO White Book on Allergy | World Allergy Organization,” n.d.), this disease and related others such as allergic asthma, can be heavily induced by pollen (Wang et al., 2018).

Those statistics were issued 10 years ago, and in the meantime the climate has changed, the temperature is still rising (Rahmstorf et al., 2017), there is still a lot of air pollution, in 2019, 99% of the population was breathing air filled with pollutants that exceeded the established limits (“Ambient (outdoor) air pollution,” n.d.). Those criteria among others are aggravating factors for a lot of allergic diseases, especially the ones induced by airborne allergens including pollen where the allergen molecules can also be, through binding with, micrometer size aggregates, for example those formed by black carbon particles, transported even further and deeper into human airways (Behrendt et al., 1997). In fact, the climate change and the pollution induce modifications in plant behaviors. These modifications can be seen such as a shift of the pollination periods (Iwanycki Ahlstrand et al., 2023), longer ones but also, an increase in the pollen output (Frei and Gassner, 2008; Sampath et al., 2023). A threat that we could also be facing is a shift of the species and a takeaway from non-native species, these ones potentially inducing higher allergenic sensitization among the populations (Bartra et al., 2007).

In the past decades, respiratory disorders such as allergic asthma or allergic rhinitis have become more common (Sampath et al., 2023). For instance, there has been a 2-3 fold increase in asthma prevalence in the latter part of the 20th century (Custovic, 2017). Those tendencies are directly linked to Climate Change and moreover, these conditions will get worse coincidently with Climate Change (Beggs, 2004).

Sweden is of course a country that is suffering from those allergic diseases, too. Up to 1 million of Swedish people are affected by allergic rhinitis alone according to Cardell et al. (Cardell et al., 2016) however, Bjerg et al claim that number is up to 2.5 million in a more recent study (Bjerg et al., 2016) . In the same study we could see an increase in the prevalence of pollen allergies among Swedish adults. In the span of 20 years from 1992 to 2012, pollen sensitization has increased from 26 to 39 percent among adults. Thus, the trend is also very much applied to Sweden.

To better consider and assess that impact of climate change and pollution on allergic diseases but furthermore, the impact on the health of Swedish citizens, I decided first, to study the prescription rate of antihistamines drugs in Sweden similarly to a study made in early 2023 (Sitaru et al., 2023). Considering antihistamines drugs are very much used in treatment of various allergic diseases, including the allergic rhinitis for instance ("Antihistamines - an overview | ScienceDirect Topics," 2023; Small et al., 2018), its evolution could be a good indicator of the situation. I studied and tested potential correlation between the pollen counts, the quantity of air pollutants such as NO_2 or $PM_{2.5}$, which we know have negative impacts on allergy sufferers (Behrendt et al., 1997) with, the prescription rate of antihistamines and the number of patients in different regions of Sweden. I could then establish correlations or not between allergenic pollen presence, pollutants quantity and health data. This could give us valuable information regarding the understanding of the direct impact of climate change, pollution and pollen induced allergies on Swedish people's health. This part of the study was applied to the years 2014 and 2019 which were years of particularly high pollen counts.

In a second part I tried to find the potential origin of pollen occurring in different Swedish cities during the years 2014 and 2019. Those 2 years have been chosen considering the data from the Pollen report 2020 driven by the University of Gothenburg and the Naturhistoriska Riksmuseet. These 2 years are showing high levels of birch pollen and are then the years of interest in the study (A.Ekebom and B.Gedda, n.d.). We know weather has a huge impact on pollen and allergens, with factors such as humidity, precipitation and of course temperature. The weather during spring and early summer usually determines the amount of birch and alder pollen for the next year (Dahl and Strandhede, 1996). The weather,on a short term, also affects the day to day pollen concentration in the air by influencing pollen time of residence in atmosphere, which is also impacted by processes like dry deposition, gravitational sedimentation or precipitation, which are scavenging the pollen (Sofiev et al., 2013).

Aside from the time of residence in the atmosphere, weather parameters also affect the release of allergens from the pollen (Beggs, 2004). In dry atmosphere the pollen seems to bevery stable and can keep its content including allergenic molecules for years (Sofiev et al., 2013). However, under certain conditions such as high relative air humidity, thunderstorms, heavy rain or high air pollutants concentrations, the allergen can be released in just a few minutes (Sampath et al., 2023). These weather parameters govern the abilities of pollen regarding its time of residence, the allergens released but also, the ease for different types of pollen to cover larger distances through air currents.

The atmospheric pathway is a very simple and effective way for pollen among other biological agents, to spread over terrestrial areas (Sofiev et al., 2013). While it was for a long time believed to be only a spreading from local environments, the spread of pollen at a continental level (Belmonte et al., 2000) and even an intercontinental level (Blades et al., 2005) have been put to light proving that the weather forecast study would actually be useful to better understand the pollen situation and its evolution.

Through weather studying, the Swedish Pollen Laboratories are in charge of making forecasts of allergenic pollen for 2 to 3 days ahead every week. They deliver pollen reports to the healthcare, to help the doctors making diagnosis and informing the patients about the current pollen and allergen situation, partly but not exclusively with the help of the SILAM tool which is not the one used here. In this second part of the study, I aimed to add even more accuracy to forecasts, this implies, finding the potential maximum area covered by the pollen traps, and, locating the potential origin of the pollen found in our 4 Swedish cities of interest (Gothenburg, Stockholm, Malmö and Umeå), during days of high pollen concentration in the years 2014 and 2019.

The pollen traps used are automatic Hirst-type 7 days volumetric traps (Hirst, 1952). Those traps are designed to sample airborne particles such as fungal spores but also and most importantly here, pollen.

The particles are trapped on an adhesive transparent plastic tape which is supported on a clockwork driven drum. The trapping efficiency can be improved for particles ranging from 1 to 10(Um) by changing the orifices. Even though the efficiency is quite similar from the Hirst model in 1952 ranging from 62.4 to 93.8% (Hirst, 1952), the area covered by these traps has not been established. Considering our 4 cities of interests: Gothenburg, Stockholm, Malmö and Umeå are located on different latitudes and longitudes, the purpose was to find the maximum potential area covered by the traps and to find possible disparities among the cities.

We know that the atmospheric pathway is used by the pollen to spread easily over terrestrial areas. Weather and air currents trajectories are already used with the various meteorological tools (for example the service “Windy” and SILAM) to build forecasts of the pollen situation in

Sweden. To be able to add information through this study, I decided to study the archives of backward trajectories from the years 2014 and 2019. By studying the air currents trajectories, and the countries that the currents pass through, to establish what seems to be the most likely origins of the pollen during the high pollen count days in our cities of interest.

Among this study, I tried to answer two main questions and an additional one. The first main question is: Are there differences of impact on pollen allergy sufferers between 2014 and 2019?

The second question is: What are the potential origins of pollen landing in Sweden during the years 2014 and 2019?

Finally, the additional question was: What is the potential maximum area covered by pollen traps? The data from answering those questions could be useful understand predict even better when will the high pollen episodes occurs in Swedish cities in the years to come.

II) Material and methods:

The study was conducted in Sweden and more specifically in 4 Swedish cities, Gothenburg, Stockholm, Malmö and Umeå. The periods studied here were the years 2014 and 2019, years were the pollen gathered in the traps around Sweden were very high. For the study on top of the various databases that will be talked about later here, the main tools utilized were Microsoft Excel (Office 365 version), Google Earth Pro and the HYSPLIT Model from the National Oceanic and Atmospheric Administration (NOAA).

The study is conducted in different parts as shown on the (Figure 1) down below.

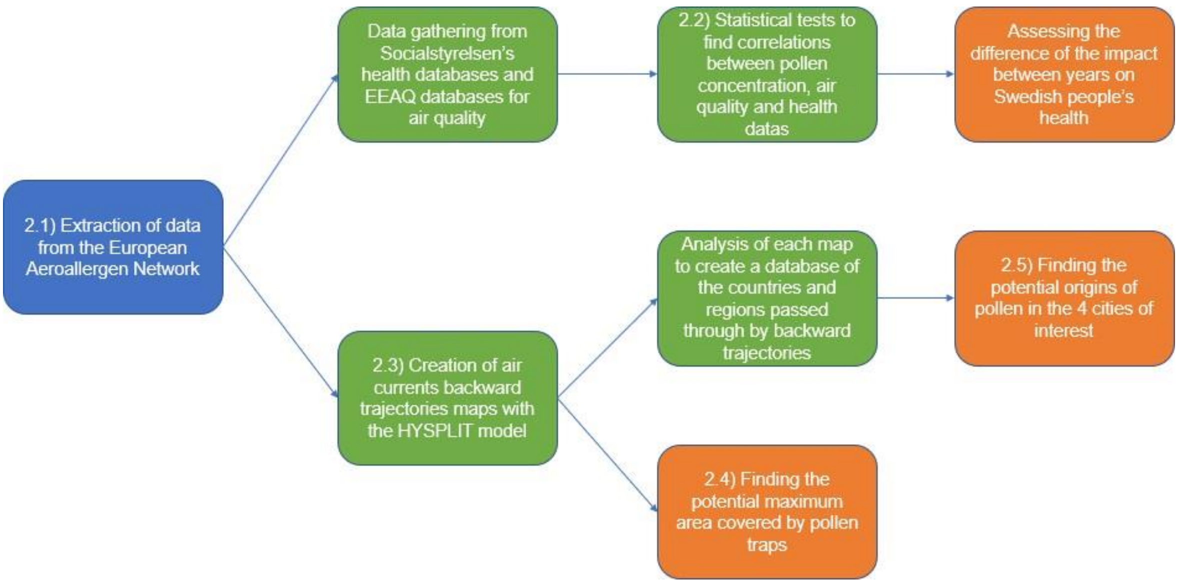

Figure 1: Diagram of the path followed to answer the different questions studied.

2.1) Extraction of the days exceeding thresholds from the European Aeroallergen Network (EAN) database analysis:

The first part was to collect for each city and each year, the high pollen days data. These data were compiled in the EAN database which contains data from pollen traps all over Sweden. These data have been gathered through pollen sampling using Hirst-type 7 days volumetric traps (Hirst, 1952) then pollen was identified with optical microscopy using vertical traverses (Galán et al., 2014). Finally, the daily average pollen counts are expressed as number of pollen grains per cubic meter of air (pollen grains/m^3).

For each city and each year of the study, the data mining has been focused on the pollen of important genera within the order Fagales and of the family *Poaceae* which were of specific interest because usually present and proven to have a high impact on allergy sufferers. These taxa were *Betula, Alnus, Quercus* and *Poaceae* (D'Amato et al., 2017).

Each of these 4 pollen have thresholds which have been established to quantify days with "high levels" of pollen and days with "very high levels" of pollen, the thresholds provoking allergy symptoms have not been precisely established for all pollen types. In this study they have been fixed from the Swedish thresholds used for public information and the literature (Becker et al., 2021; Geller-Bernstein and Portnoy, 2019). These thresholds are respectively 100 grains/m^3 and 1000 grains/m3 for both *Alnus, Betula* and *Quercus.* And finally, for *Poaceae*, considering the pollen is released near the ground and not dispersed as well, lower counts of pollen are needed to cause allergy symptoms (Kiotseridis et al., 2013) the thresholds have been placed, on a higher end at respectively 30 and 80 grains/m3. For the data collection, all the days exceeding the "high level" thresholds of at least 1 of the 4 pollen have been noted giving us the time periods to study. A pollen index as been created based on the high pollen counts thresholds to conduct the calculation and centralize the pollens data. The pollen index is an average of the pollen count of each type, divided by their respective "high thresholds" value for each day. The pollen count of *Alnus*, *Quercus* and *Betula* type were divided by 100, while the pollen count from *Poaceae* was divided by 30. The average gave us a day-to-day value of the pollen index that will be used further in the study.

2.2) Finding of potential correlations between pollen count, air quality and health data regarding allergy sufferers:

After extracting all the specific days that will be used later on, I first wanted to compare the pollen counts data for each of the cities between the year 2014 and 2019. I did monthly sums of the pollen value for all the cities for each year. That to firstly have tables showing the temporal repartition of high pollen presence and secondly to be able to compare the value between the years 2014 and 2019, to see if the rises or decreases were going to be also seen on the health data.

To see if there were correlations on the scale of a year between pollen count, the number of antihistaminic prescription and the number of allergy sufferer patients in the 4 cities in 2014 and 2019. And, considering that the air quality has a big impact on the allergenicity of pollen (Behrendt et al., 1997) I decided to add 2 parameters regarding air quality for the correlations test. Those are amount of NO_2 and $PM_{2.5}$ which were relevant here because they can have a big impact on allergy sufferers (Knox et al., 1997).

I gathered the data about NO_2 and $PM_{2.5}$ quantity per cubic meter of air during the years 2014 and 2019 on the 4 Swedish cities of interest from the European Environment Agency Air Quality (EEAAQ) E-Reporting databases.

I used the pollen index created to have only 1 value representing the aggregate of our 4 pollen types on each day, I did averages per months considering the data of antihistaminic prescriptions and patients per 1000 inhabitants are listed per month.

Finally, through Excel, and considering our data I conducted a non-parametric test and calculated Spearman's rank correlation coefficients between the pollen indexes during the years, the number of patients and dispensations, per 1000 inhabitants, of anti-histaminic. And in a second phase, I did the same between the health data and the air quality ones regarding NO_2 and $PM_{2.5}$. which I, here again had to compile in monthly averages and not only day data.

The Spearman's rank correlation coefficient is calculated as followed:

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)},$$

Where "rs" is the Spearman's coefficient.

"di=R(Xi)-R(Yi)", "di" is the difference between the two ranks of each observation

And "n" is the number of observations.

2.3) Creation of air currents backward trajectories maps:

After extracting the days of interest, I used the HYSPLIT trajectory model and the database of archive trajectories from the National Oceanic and Atmospheric Administration (NOAA) to create maps of the backwards trajectories of air currents occurring during the days of high pollen count.

Across the 4 cities and the 2 years for the study I've recorded 389 days with at least "high levels" of pollen, and considering that the duration of the periods when the threshold was exceeded varied from 1 to more than 15 days straight, the settings used to build the maps varied a bit. The basic settings used were normal archive trajectories originating in one locality. The meteorology setting was settled to" GDAS (1 degree, global 2006-present)". Then after selecting the timespan that I wanted to study the air currents from, I made sure to check backward trajectories and not forward, to be able to find the origins of the pollen trapped. I then modified the parameters of the model and especially the "runtime", maximum number of trajectories and interval between 2 trajectories considering the periods of days above threshold were from 1 to 7 days. Those adjusted parameters enabled me to create readable maps. This process led to the creation of 109 "periods" containing the 389 days.

The time chosen between each new trajectory was settled from each 2 to 4 hours impacting the maximum number of trajectories displayed on the map to keep it readable. Finally, the altitude of the air currents was important. For each period studied part of the 109 periods, each had 3 distinct maps, one at an altitude of 500m, another one at 1000m and one last at 1500m. Since it is recommended to identify air mass trajectories height within the pressure of 950-10 mb are recommended (Šaulienė and Veriankaitė, 2006) so, here, 500m should reflect transport at a regional scale while 1000 and 1500m will refer to long-distance transportation.

With that process I created around 327 primary maps that will then serve our purpose for our questions regarding the potential area covered by traps and the origin of pollen.

2.4) Finding the potential maximum area covered by the pollen traps:

To test the potential maximum area covered of the Hirst-type 7 days volumetric trap, I used and studied the maps created with the HYSPLIT model, and I found for each city at each year the projected furthest air current trajectory that was ending in our target. Then after finding the point, I used Google Earth Pro to calculate the distance covered by this trajectory to get a potential maximum value of the radius of the area covered by the traps for each city and each year.

2.5) Finding the potential origins of the pollen:

To find the potential origin of pollen, I started by using the maps created representing the air currents backward trajectories. With those trajectories and by following their path I marked the countries that the air currents trajectories pass through and the frequency of it. For this count, the 3 maps at 3 different altitudes for each of the 109 time periods have been aggregated to have the best possible sample of trajectories and no country left behind for all these time periods. This allowed to establish for our 389 days of high pollen, what were the countries who were the most passed through by air currents, so, likely to be the origins of pollen and the cause of the pollen count to exceed the thresholds in our 4 different Swedish cities.

In the meantime, and to be more precise than country level about the origins of the pollen, I divided the map of Europe into smaller pieces with countries being divided from 2 to 9 parts to have a better regional resolution of it. The map has been drawn by hand (Annexe 7).

These more precise data were then, used to find the most probable parts of the countries of interest which could be origins of pollen for the years 2014 and 2019. These results will be then discussed and crossed with land cover data from literature to find the distribution of the trees in Europe which could explain those high pollen days in Sweden.

III) Results:

3.1) Finding of potential differences and correlations between pollen count, air quality and health data regarding allergy sufferers.

3.1.1) Evolution of pollen counts, patients, and dispensations number of Antihistamines per 1000 inhabitants in our 4 cities of interest over a year:

First of all, considering the pollen count between the years, it differed a lot not only across cities but also across pollen types (Table 1):

Table 1: Table representing the rise or decline of the quantity of different types of pollen in 4 Swedish cities comparing the value in 2019 to the ones in 2014, all numbers are expressed in %, green cells express a decrease while red ones express an increase.

2019/2014	Malmö	Umeå	Stockholm	Gothenburg
Alnus	220.071	-51.345	-17.108	-10.63
Betula	-39.193	-49.78	-63.768	-25.811
Poaceae	14.892	-53.662	7.755	-23.105
Quercus	-38.498	0	-94.148	-60.849

There is a global decrease with almost all values going down (Table 1), from 10% considering the *Alnus* case in Gothenburg to more than 94% for *Quercus* pollen in Stockholm. However, there are some cases of increase with the *Poaceae* cases in Stockholm and Malmö and most importantly the *Alnus* case also in Malmö where a more than 220% increase have been recorded. The value from *Quercus* in Umeå is null considering in none of the 2 years have there been records from *Quercus* pollen, with the city being likely located out of the northern border of *Quercus* range (Annexes 8-10). Overall and arguably except Malmö, here, the pollen number seems to be higher in the year 2014 than in the year 2019. Malmö, the city displaying the highest variations is down below (Table 2), the other Tables regarding other cities are in Annexes 1,2,3:

Table 2: Table representing the trapped pollen count in Malmö in the years 2014 and 2019 considering the *Alnus, Betula*, *Poaceae* and *Quercus* pollen types.

Malmö 2014	ALNUS	BETULA	POACEAE	QUERCUS	Malmö 2019	ALNUS	BETULA	POACEAE	QUERCUS
January	0	0	0	0	January	1	0	0	0
February	324	0	0	0	February	2641	0	0	0
March	782	9	0	0	March	860	1	0	1
April	19	21202	25	172	April	99	13082	5	30
May	4	1620	262	677	May	11	818	51	477
June	2	58	1804	1	June	3	26	2575	14
July	0	10	761	2	July	2	9	527	2
August	0	9	78	0	August	1	4	186	0
September	0	16	37	0	September	2	7	61	0
October	0	14	1	0	October	0	1	5	0
November	0	0	0	0	November	0	0	0	0
December	0	0	0	0	December	0	0	0	0
Sum	1131	22938	2968	852	Sum	3620	13948	3410	524

In Malmö, there were very high values of *Alnus* in February 2019 (Table 2), which is the reason why the value is one of the only one higher in 2019 compared to 2014 across the 4 cities. There is a globally lower pollen count for *Betula* and *Quercus* pollen, and, a slightly higher count for *Poaceae*.

Considering the health data, there is an important thing to mention, the data from the cities on their own were not available. So, the data that were used were the ones regarding the respective counties containing the cities of interest.

Those chosen counties are then Skåne ("Sk" in the following figures) for the city of Malmö, Stockholm ("St" in the figures) for Stockholm, Västra Götaland ("VG" in the figures) for Gothenburg and finally Västerbotten ("V" in the figures) for the city of Umeå. The development of the different health data across the months in the different counties chosen but also between the years 2014 and 2019 is shown in Fig.2 & 3.

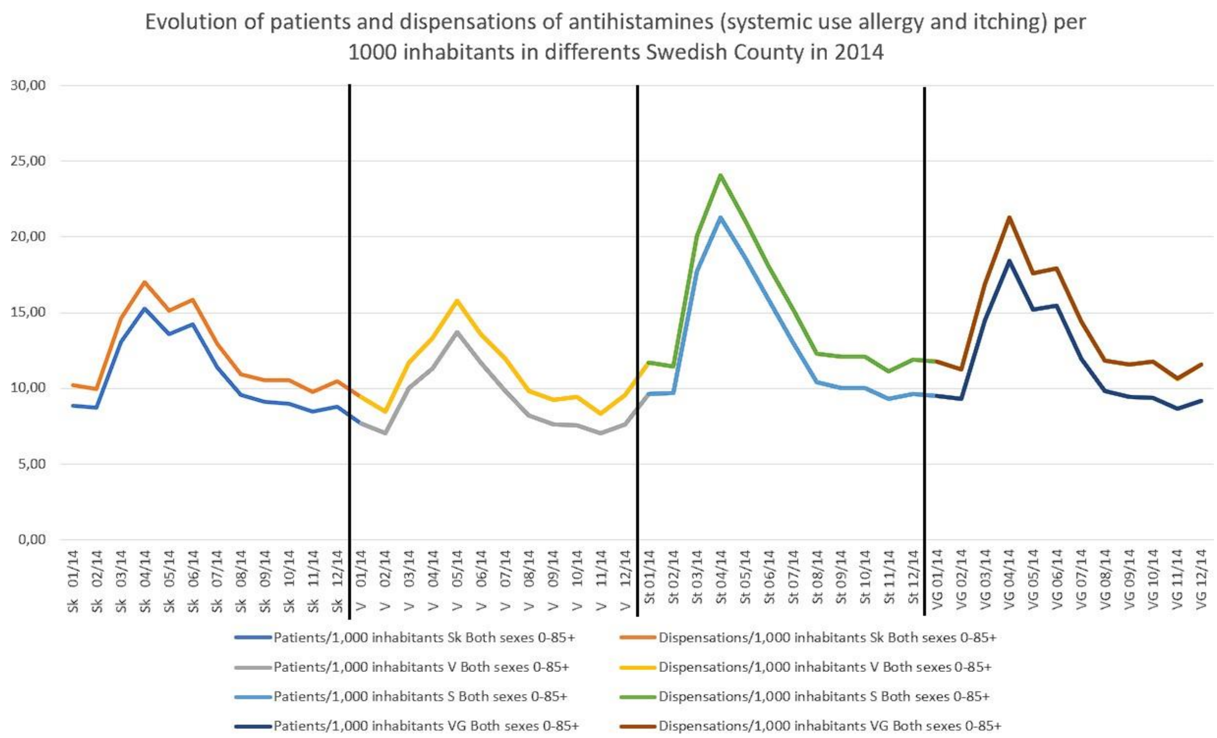

Figure 2: Graphic representation of the development of patient and dispensation of antihistamines drugs per 1000 inhabitants from 0 to 85+ years old regardless of the sexes in different Swedish counties during the year 2014.

In this graph, the spikes seem to be quite identical for the number of patients or prescriptions of antihistamines. However, they do vary between counties with maximum reached in April and June in Skåne and Västra Götaland. The peak is reached in April in Stockholm before a progressive decline until August. Finally, in Västerbotten, the maximum got reached in May and is noticeably the lowest of the 4 with both maxima (patients and dispensations) averaged 16 and 14 dispensations and patients per 1000 inhabitants respectively. Västerbotten is tailed by Skåne around 17 and 15 then Västra Götaland at 21 and 18, and finally, Stockholm topping it off during the year 2014 at 24 and 22 per 1000 inhabitants (Figure 2). From potentially best to worst the order would be Umeå, Malmö, Gothenburg then Stockholm.

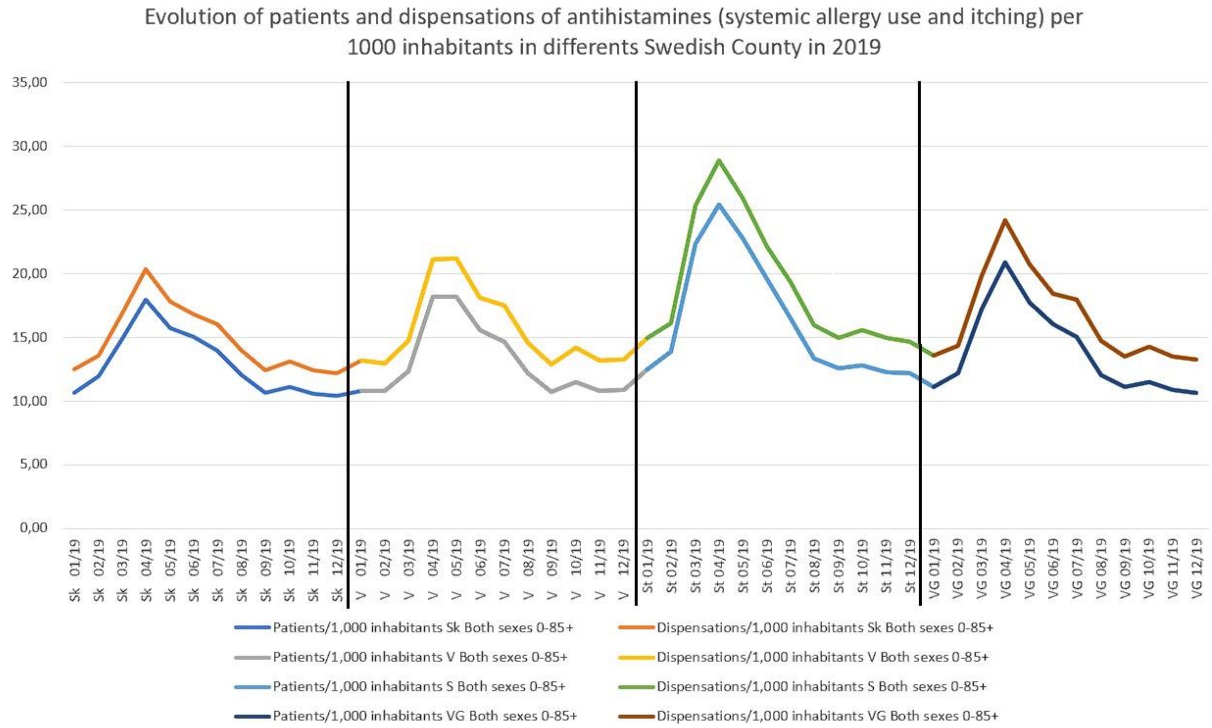

Figure 3: Graphic representation of the development of patient and dispensation of antihistamines drugs per 1000 inhabitants from 0 to 85+ years old regardless of the sexes in different Swedish counties during the year 2019.

In 2019 all maxima are occuring in April with Västerbotten extending also into May (Fig.3). For numbers Skåne and Västerbotten are once again the lowest ones with respective maximum averages of 20;18 and 21;18 dispensations and patients per 1000 inhabitants respectively. Västra Götaland is sitting at 24;21 while Stockholm is at 29;25 topping the year 2019 (Figure 3). The best to worst order would be quiet the same with Umeå and Malmö being much close and Malmö arguably better.

3.1.2) Spearman's Correlation coefficient calculation regarding health, pollen and pollution data:

The Spearman's correlation coefficient has been calculated first between the health data and the pollen index data for each city at each year. Something important to mention is that for the health data, both dispensation per 1000 inhabitants and patients per 1000 inhabitants are about antihistamines (systemic use, allergies, and itching) for both males and females of ages ranging from 0 to 85+ years old (Table 3 and 4).

Table 3: Table of Spearman's correlation coefficient between health data and pollen index in 4 Swedish cities during the years 2014 and 2019 the green highlighted values are the significative ones (p-value<0.05).

City and Year	Patients/1,000 inhabitants and Pollen Index	Dispensations/1,000 inhabitants and Pollen Index2
Umeå 2014	0.551	0.560
Umeå 2019	0.749	0.749
Malmö 2014	0.769	0.769
Malmö 2019	0.799	0.769
Stockholm 2014	0.898	0.898
Stockholm 2019	0.867	0.867
Gothenburg 2014	0.873	0.873
Gothenburg 2019	0.899	0.873

Spearman's correlation coefficient is ranging from -1 to +1 with those values being "perfect" correlations. Various degrees of correlation both positive and negative exist, everything from 0 to 0.3 and from -0.3 to 0 are considered poor to none. Between 0.3 and 0.5 as well as -0.3 to -0.5 is considered as "Fair". For the intervals 0.6 to 0.7 and -0.6 to -0.7 the correlation would be considered "Moderate". Finally, the "Very strong" correlation, would be for coefficient from 0.8 to 0.9 and -0.8 to -0.9 (Akoglu, 2018).

In our case, the Spearman's correlation Coefficient between the health data and our pollen index evolution over the course of a year are, apart from Umeå 2014, all significative and over 0.749. All of the significative coefficients are showing "Moderate" to "Very strong" correlations (Table 3).

When Spearman's correlation was calculated between the concentration of NO_2 and $PM_{2.5}$ in the air and the health data, most of the correlation coefficients were not significant (Table 4).

Table 4: Table of Spearman's correlation coefficients between health data and some air pollutants concentration in the air of 4 Swedish cities during the years 2014 and 2019, the green highlighted values are the significative ones (pvalue<0.05).

County and Year	Dispensations/1,000 inhabitants and NO_2	Patients/1,000 inhabitants and NO_2	Dispensations/1,000 inhabitants and $PM_{2.5}$	Patients/1,000 inhabitants and $PM_{2.5}$
Västerbotten 2014	0.077	0.063	-0.659	-0.615
Västerbotten 2019	-0.168	-0.126	0.252	0.350
Skåne 2014	0.042	-0.035	-0.245	-0.259
Skåne 2019	-0.042	-0.182	-0.018	-0.155
Stockholm 2014	0.637	0.588	-0.294	-0.158
Stockholm 2019	-0.196	-0.273	-0.081	-0.025
Västra Götaland 2014	0.035	-0.035	-0.543	-0.519
Västra Götaland 2019	-0.448	-0.392	-0.133	-0.021

The only significant correlations are first, between patients/dispensations and the amount of $PM_{2.5}$ in the air in Västerbotten county in 2014 showing a "moderate" negative correlation. The second case is in the county of Stockholm in 2014 this time for the NO_2 concentration, here with a "moderate" positive correlation (Table 4).

3.2) Finding of the potential Maximum area covered by Hirst-Type 7 days pollen traps in 4 Swedish cities during the years 2014 and 2019:

The furthest point was selected of the trajectories displayed on the maps created during the "High Pollen Days" to assess a point representing the potential maximum range radius and so the area covered by the pollen traps (Table 5).

Table 5: Table showing the potential range radius of Hirst-Type 7 days pollen traps in 4 Swedish cities during the years 2014 and 2019

City and Year	Maximum radius of the area covered by Pollen traps
Umeå 2014	5150 km
Umeå 2019	2850 km
Malmö 2014	4270 km
Malmö 2019	3200 km
Stockholm 2014	5380 km
Stockholm 2019	6747 km
Gothenburg 2014	3927 km
Gothenburg 2019	3775 km

3.3 Finding which countries and regions are potentially the origins of pollen found in 4 Swedish cities in 2014 and 2019:

To find the potential origins of pollen I did maps with the help of the HYSPLIT model and HYSPLIT archives from the National Oceanic and Atmospheric Administration (NOAA). For each period of high pollen in the cities of interest, I created 3 maps, illustrating 3 different altitudes, 500, 1000 and 1500 meters. An example of what the maps look like is shown in the Figure 4,5 and 6 below for the case of Umeå:

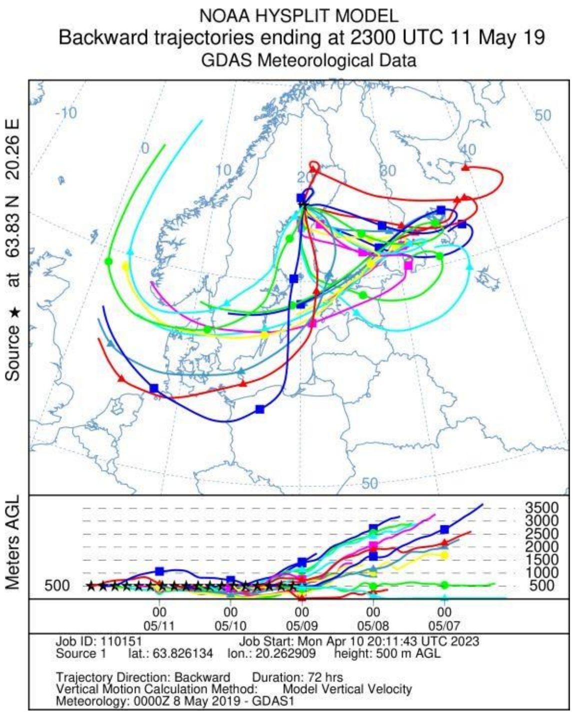

Figure 4: Map of the air currents backward trajectories made with the HYSPLIT model here at an altitude of 500 meters to the city of Umeå from the 9th to the 11th of May 2019

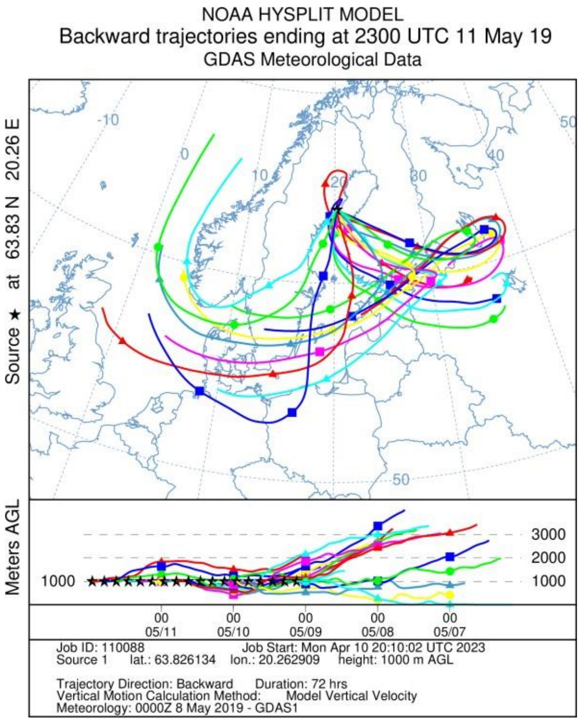

Figure 5: Map of the air currents backward trajectories made with the HYSPLIT model here at an altitude of 1000 meters to the city of Umeå from the 9th to the 11th of May 2019

The air currents backward trajectories of the air of Umeå from the 9th to the 11th of May 2019 (Fig 4-6). That is a period of time where the pollen count was considered as “high”. On these figures, three different altitudes are displayed. Each trajectory is separated from the other by 4 hours span for visibility purpose, so each day is represented by 6 trajectories. For the study each three maps representing high periods were dealt with separately, then aggregated. In the case here I assessed all the trajectories and their path to be able to find which country they were passing through. Here, a lot of countries are passed over, from Sweden to Denmark, a bit of Germany and Poland on the North end of them. However, the biggest density can be seen in South East Finland, West Russia and Estonia. Other countries are also passed over (Norway, Lithuania, Latvia, Poland or even a small part of Belarus and the United Kingdom).

All the high pollen periods have been studied that way to be able to establish a list for the most probable countries that could be the origin of pollen found in Stockholm, Umeå, Gothenburg and Malmö in 2014 and 2019. For the values, “H” being the days above high levels of pollen in 2014, “VH” being the days above very high levels of pollen and the “SUM” being the sum of High and very high days of 2014 and 2019 (Fig 7). Here below is only displayed the city of Gothenburg, but the same figures for the other cities have been done (Annexes 4,5,6).

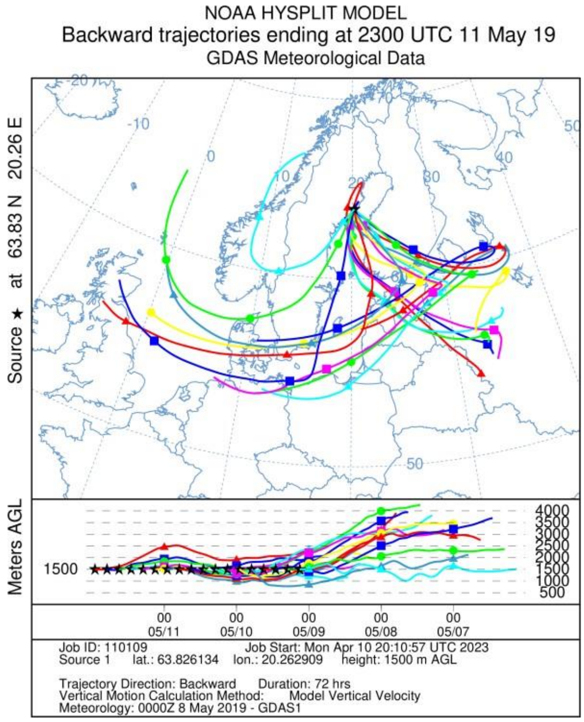

Figure 6: Map of the air currents backward trajectories made with the HYSPLIT model here at an altitude of 1500 meters to the city of Umeå from the 9th to the 11th of May 2019

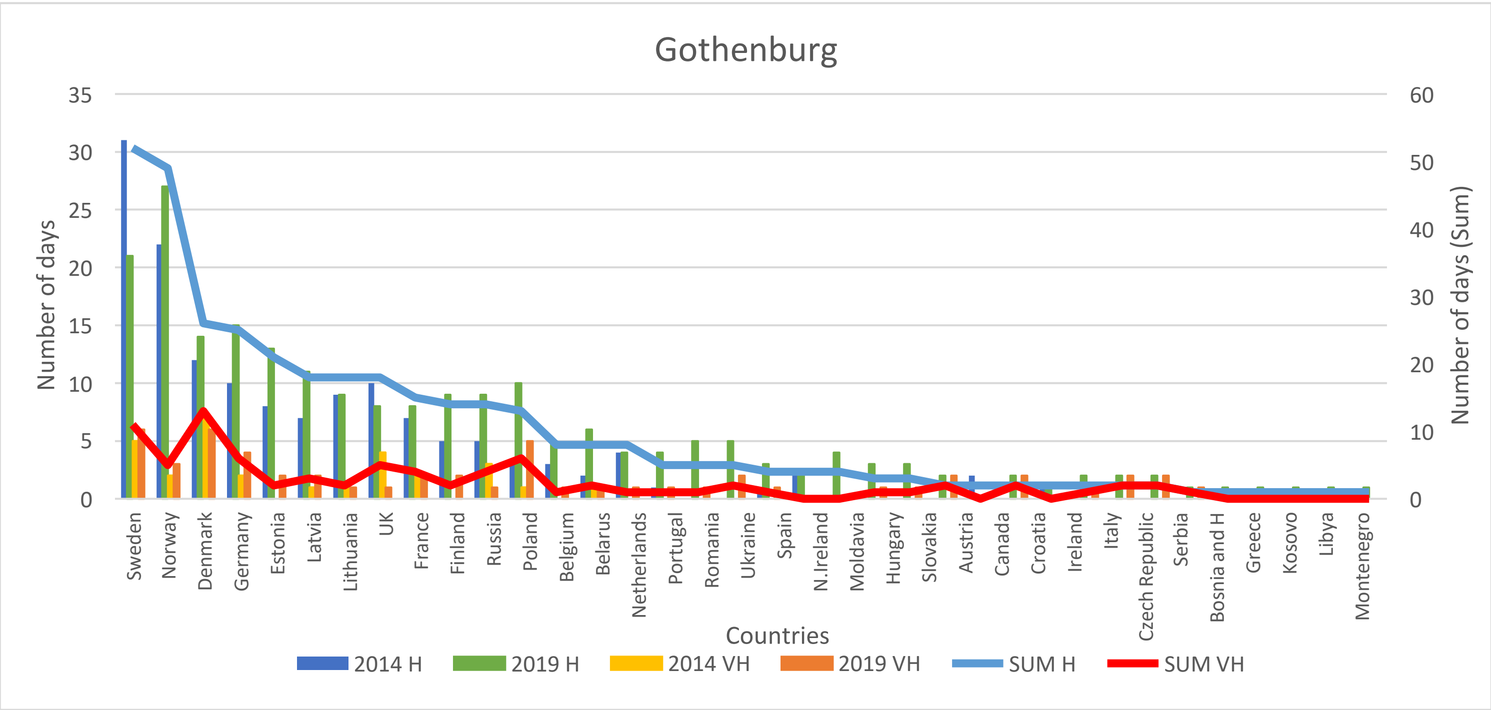

Figure 7: Graphic representation of the countries most passed through by air currents landing in Gothenburg duringdays with high or very high levels of pollen in 2014 and 2019.

There is a clear display of the most probable origins of pollen found in Gothenburg. By aggregate of the results found for 2014 and 2019, it seems that the country who got the most passed through was Sweden, followed by Norway and Denmark; Germany, Estonia, Latvia, and Lithuania are also high in the count, however they do not seem to be a huge part of the "Very high" pollen days. Finally, among the most probable country, the UK, France, Finland, Russia and Poland, which in its case do seem to be a potentially high contributor of very high pollen days in Gothenburg, can also be selected (Figure 9).

While assessing the different countries as potential origins and in an attempt of a higher resolution data, I decided to divide the different countries into smaller parts, from 2 to 9. A new map has been then created (Annexe 7), this map allowed me to count, in the same way as for the countries, the number of air currents trajectories passing through, and especially for the countries being the most probable origins of pollen. These countries and the newly created "regions among them" have been compiled (table 6-9).

Table 6: The number of days of the countries which got passed through, each cell illustrating a region of the country and displaying the values of respectively 2014/2019 air currents landing in Stockholm during high pollen levels days, with the first line detailing the color code compared to the total number of high pollen count days in the city.

Percentage	10%		20%		30%		40%		50%		60%		70%		80%		90%
Country	**NW**	**NE**	**SW**	**SE**	**N**	**S**	**E**	**W**	**C**	**CE**	**CW**	**CSE**	**CSW**	**CNE**	**CNW**	**CN**	**CS**
Germany	6/6	7/7	2/5	0/0	8/6	0/0	9/0	11/5	8/5	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Belarus	8/1	11/1	10/3	11/0	9/2	8/0	9/1	8/4	8/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Denmark	11/13	9/13	9/12	10/9	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Estonia	15/0	17/0	17/1	17/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Finland	14/4	2/4	13/5	11/4	0/0	0/0	0/0	0/0	0/0	13/4	14/4	0/0	0/0	0/0	0/0	0/0	0/0
Latvia	13/4	16/3	12/4	13/3	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Lithuania	9/11	6/3	7/12	6/2	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Norway	2/0	2/0	19/15	19/16	0/0	0/0	0/0	0/0	34/8	0/0	0/0	20/9	19/9	10/0	10/0	0/3	0/0
Poland	13/4	18/12	16/0	16/4	15/3	17/0	15/9	19/0	16/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
UK	10/2	11/2	10/4	11/4	7/4	0/0	0/0	0/0	0/0	0/0	0/0	8/4	8/4	9/4	11/4	0/0	0/0
Sweden	11/0	12/2	27/18	29/14	0/0	0/0	0/0	0/0	0/0	0/0	0/0	46/24	28/16	18/3	16/6	0/0	0/0

The countries which, across 2014 and 2019 are the more likely to be the origin of the pollen found in Stockholm and so the highest displayed values are respectively; Sweden with the South section of the country being dominant, Norway with here again the middle and South section of the country but also, Poland especially for its East part and Denmark for its North part. All of these regions could be origins for at least 20% of the total high pollen days in Stockholm across 2014 and 2019. In some cases, some countries or part of some countries are not put to light considering they weren't found in trajectories of a specific year, some can be pointed out, Estonia, Finland or even Latvia which have very high values in 2014 but small to none in 2019 making them not show out (Table 6).

Table 7: The number of days of the countries which got passed through, each cell illustrating a region of the country and displaying the values of respectively 2014/2019 air currents landing in Gothenburg during high pollen levels days, with the first line detailing the color code compared to the total number of high pollen count days in the city.

Percentage	10%		20%		30%		40%		50%		60%		70%		80%		90%
Country	**NW**	**NE**	**SW**	**SE**	**N**	**S**	**E**	**W**	**C**	**CE**	**CW**	**CSE**	**CSW**	**CNE**	**CNW**		**CS**
Germany	10/11	7/7	1/4	0/0	1/9	0/0	3/2	5/11	4/3	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Denmark	11/12	1/11	10/11	1/10	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Estonia	1/8	1/8	1/8	1/8	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Finland	0/0	0/0	5/8	4/8	0/0	0/0	0/0	0/0	0/0	0/9	1/5	0/0	0/0	0/0	0/0	0/0	0/0
France	6/5	2/6	0/4	0/0	3/5	0/0	2/4	3/8	3/4	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Latvia	7/11	7/11	7/11	7/11	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Lithuania	9/9	9/9	9/4	9/4	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Norway	0/0	0/0	16/25	20/27	1/0	0/0	0/0	0/0	15/2	0/0	0/0	18/18	14/11	0/0	0/0	11/0	0/0
Poland	3/7	1/6	1/5	1/6	3/6	1/5	1/9	1/10	1/9	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
UK	0/7	0/7	6/6	8/6	6/0	0/0	0/0	0/0	0/0	0/0	0/0	5/1	5/1	0/4	0/4	4/0	1/0
Russia	3/0	0/0	0/5	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/9	0/0	0/0	0/0	5/9	0/0	0/0
Sweden	7/0	4/2	31/21	1/10	0/0	0/0	0/0	0/0	0/0	0/0	0/2	4/2	13/8	2/4	8/2	3/0	0/0

Considering Gothenburg, the highest found values were for Sweden on its South part, Norway here again on its South 1/3rd, Denmark and also Germany, notably the North part of it. Estonia, Latvia and Lithuania with fairly high numbers across the 2 years are also worth mentioning. Finland and the UK are taking a part of it. the Center part of Poland from East to West is can be mentioned being near the limit of detection, this due to high numbers but only for the 2019 year not resulting in an over threshold value when added to 2014 values (Table 7).

Table 8: The number of days of the countries which got passed through, each cell illustrating a region of the country and displaying the values of respectively 2014/2019 air currents landing in Malmö during high pollen levels days, with the first line detailing the color code compared to the total number of high pollen count days in the city.

Percentage	10%		20%		30%		40%		50%		60%		70%		80%		90%
Country	**NW**	**NE**	**SW**	**SE**	**N**	**S**	**E**	**W**	**C**	**CE**	**CW**	**CSE**	**CSW**	**CNE**	**CNW**	**CN**	**CS**
Germany	18/13	16/10	4/3	2/3	15/15	0/3	3/9	13/11	8/12	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Belgium	8/9	7/9	7/9	7/8	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Belarus	4/2	3/2	8/0	6/1	4/2	7/0	5/0	7/1	5/1	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Denmark	28/21	28/20	28/31	31/37	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/2	0/0	0/0	0/0	0/0	0/0
France	10/6	9/4	0/8	0/0	11/8	0/0	8/7	10/5	7/7	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Lithuania	6/5	6/5	7/5	8/5	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Norway	0/0	0/0	10/8	12/3	1/0	0/0	0/0	0/0	10/0	0/0	0/0	13/7	12/2	5/0	5/0	0/0	0/0
Netherlands	9/8	8/8	8/8	8/8	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Poland	14/14	12/5	7/11	6/6	14/8	4/2	6/3	7/7	7/5	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Czech Rep	6/4	4/7	6/4	6/7	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
UK	0/3	0/3	4/5	5/5	4/5	0/0	0/0	0/0	0/0	0/0	0/0	2/8	2/8	2/10	2/10	0/0	1/0
Russia	3/2	0/0	0/1	0/1	0/0	0/0	0/0	0/0	0/0	0/0	1/0	0/0	3/0	0/0	3/5	0/0	0/0
Sweden	6/2	8/2	29/14	22/2	0/0	0/0	0/0	0/0	0/0	0/0	0/0	9/0	9/8	8/0	8/0	0/0	0/0

In the case of Malmö, the highest potential origin is by far Denmark, especially its South East part, Sweden is also high on its South part. Then to be noted is Germany, especially on its North and West parts, Poland is also showing especially its North West part linking to the German's Northern part. A few other countries could also be origins of pollen, countries such as France, the Southern quarter of Norway, the Netherlands, Belgium, Lithuania the Center 1/3rd of UK and a very small part of Czech Republic (Table 8).

Table 9: The number of days of the countries which got passed through, each cell illustrating a region of the country and displaying the values of respectively 2014/2019 air currents landing in Umeå during high pollen levels days with the first line detailing the color code compared to the total number of high pollen count days in the city.

Percentage	10%		20%		30%		40%		50%		60%		70%		80%		90%
Country	**NW**	**NE**	**SW**	**SE**	**N**	**S**	**E**	**W**	**C**	**CE**	**CW**	**CSE**	**CSW**	**CNE**	**CNW**	**CN**	**CS**
Belarus	0/6	0/1	1/6	0/6	0/1	1/1	0/1	1/6	0/3	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Estonia	1/7	1/7	1/3	1/5	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Finland	2/3	0/4	5/7	4/2	0/0	0/0	0/0	0/0	0/0	9/3	7/4	0/0	0/0	0/0	0/0	0/0	0/0
Latvia	2/1	2/5	2/1	2/5	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Lithuania	4/3	2/6	5/3	2/6	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Norway	0/0	0/0	6/0	6/0	0/2	0/0	0/0	0/0	11/2	0/0	0/0	3/0	3/0	2/0	2/0	0/11	0/0
Poland	1/0	4/1	0/0	4/2	0/3	0/0	2/1	0/0	0/2	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
UK	0/0	0/0	0/0	0/0	4/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Russia	7/3	0/0	0/0	0/0	0/0	0/0	0/0	1/0	0/0	0/0	0/0	0/0	0/0	0/0	4/3	0/0	0/0
Sweden	2/10	4/15	0/3	0/5	0/0	0/0	0/0	0/0	0/0	0/0	0/0	6/7	7/3	27/18	15/9	0/0	0/0
Ukraine	4/0	0/0	3/0	0/0	3/0	3/0	0/0	3/0	3/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0

The last case is about Umeå, here Sweden is leading the way heavily with its Center North East (CNE) part accounting for more than 70% of the high pollen days which is also the part where Umeå is located. The North half seem to have a big participation overall. Other countries are worth to be mentioned, for example Norway, with heavy differences from one year to another for the Center and Center North parts. Finland, on its South West and Center East parts notably, and, finally there are countries such as Lithuania, Belarus, Estonia, Latvia, Poland or even Russia all being potentially accountable for at least 10% of the high pollen days in 2014 and 2019 combined. The values displayed for Umeå are the lowest among the 4 cities studied here (Table 9).

IV) Discussion:

1) <u>Differences on impact of pollens on allergy sufferers between 2014 and 2019:</u>

Through this study about the pollen in four different Swedish cities namely Gothenburg, Stockholm, Malmö and Umeå, a few questions have been issued and studied. The first part was about the impact of pollen on the Swedish citizens health and its development in time. The study is based on two years, 2014 and 2019 (Figures 2 and 3). The pollen count comparison showed that in most cases except the *Alnus* pollen in Malmö, which displayed 220% higher values, and minor slightly higher values for *Poaceae* in Malmö and Stockholm (respectively around 14 and 7%), the pollen count was much lower in 2019 compared to 2014, the number of pollen trapped regarding its type has been lowered from 10 up to 94% between the two 2 years. Those data are in agreement with Ekebom and Gedda 2020 (A.Ekebom and B.Gedda, n.d.). Going towards my first thought was that if these lower values were representative of all allergenic pollen, and, if strong correlations could be found between the pollen count and the dispensation/patients rate of antihistaminic drug, the latter should be noticeably lower for the year 2019 than for the year 2014.

For the health data the curves are very similar between 2014 and 2019 with peaks occurring at a relatively similar period around April or May and still high in June in some cases (Skåne and Västerbotten in 2014 for example) which is concording with the highest pollen count periods during the years with highs from *Alnus, Betula* and *Quercus* pollen occurring successively (Table 2). However even though the shape is similar, and despite the pollen counts previously seen to globally be lower in 2019, the maximum rate of prescription and number of patients per 1000 inhabitants is higher in every county in 2019 compared to 2014. This is very interesting considering rises up to 31%, in the case of dispensations per 1000 inhabitants in the county of Västerbotten. This rate is indeed very high especially considering the “Moderate” to “Very strong” correlations found between pollen count and health data showing again, that pollen from *Alnus, Betula, Quercus* and *Poaceae* had a direct impact on the well-being of allergy sufferers.

I thought that those contradictory results could be explained by other factors such as air quality which can affect allergy sufferers both directly and indirectly through pollen modifications (Bartra et al., 2007; Behrendt et al., 1997; Knox et al., 1997; Sampath et al., 2023). However, the results from the air pollution correlation analysis could not explain that idea. I could only find two significative correlations between NO_2 or $PM_{2.5}$ in the air and the health data, both being in 2014, one being a positive correlation in the county of Stockholm with NO_2 concentration and the second one being a negative one with $PM_{2.5}$ in the county of Västerbotten. In the way it has been studied, there is not a distinct effect on allergy sufferers. A more in-depth analysis of all air pollutants and their potential coordination effects with pollen allergy sufferers could be done but, in this study, it does not show confidence to assess it as one of the big factors contributing to the bigger proportion of patients and dispensation of antihistaminic in 2019.

Considering the pollen and air pollution data are among cities, while the health data are regarding the counties this could potentially be a reason why the correlations results are as they are, despite choosing the biggest cities inside those counties, local differences among small cities could play a heavy part. A more precise way would be to be able to gather health data from the cities only specifically. In the end and for the first part of this study I found different things, first of all, a lower count in the pollen count between 2014 and 2019 however and even though I found true correlation between pollen counts and health data regarding allergy sufferers, the numbers of patients and dispensations of antihistaminic drug were up to 31% higher. I didn’t find a decent correlation between the health data and the air quality that could have added explanation to the situation. By looking at the pollen count data it shows that in the case of Umeå, the pollen counts of *Alnus* and especially *Poaceae* are much lower than in the other cities (Annexe 1-3; Table 2). Considering Umeå is showing the lowest number for the health data during both years, it is possible that those type of pollens have a higher impact on allergy sufferers. However, the case of Malmö is very close to Umeå regarding health data, this while having much higher pollen counts of every type and in both years. Considering the localization of both counties and cities, different sensitization rates and biological differences between Swedish people could be reasons behind this uneven reaction towards pollens allergens (Haahtela, 2019).

Despite not finding a potential explanation, those results could be linked and a continuity to a previous study (Bjerg et al., 2016) where a pollen sensitization rise between 22 to 31% have been found in Swedish people between the years 1990 and 2008. A change of pollen counts, longer blooming periods (Frei and Gassner, 2008) an increasing air pollution but also, biological differences, a population growth including a high rate of immigration with people that potentially are more prone to pollen induced allergies, especially from allergens they did not encounter during infancy when tolerance is induced (Kalyoncu, 1996). These could be some of the determining factors part of, or, to be added to the popular hypothesis of a progressive impoverishment of gut microbiome. This impoverishment leading to a lower tolerance towards natural allergens (Haahtela, 2019), and, driving this pollen sensitization over the years not only in Sweden but in all Western countries. Finally, and importantly, meteorological factors such as humidity, pressure or temperature variations could be one of the most determining factors considering their huge impact on both pollen, pollution and patients, for the actual days and the future ones (Grundström et al., 2017).

2) <u>Maximum area covered by pollen traps and potential origins of pollens in Swedish cities in 2014 and 2019:</u>

As preamble I tried an approach to estimate the potential maximum area covered by those traps. In the data collected, Stockholm was on average the location where the pollen traps experienced the highest area covered with up to a 6747km radius with an air current originating from the USA. Malmö had the smallest with air currents coming from the North Greenland and the North Pole. The area covered seem to differ among the years and the cities but this is mostly due to the method of calculation which has a lot of variables. It is based on air currents analysis and not on a specific pollen grain that would be tracked, also the timespan of study could have had an impact. For example a study of the air currents over 3 days might give trajectories coming from further away resulting in a potential longer area covered from the pollen traps. However, this brings the issues with that approach. Firstly, some of the trajectories are originating from places where there is no vegetation, it isn’t possible to draw a circle with the maximum radius to assess a potential area covered by the pollen traps per city, air currents landing in our cities are mostly following established path and not coming from all around the cities. Secondly, the pollen would in most cases not stay in the atmosphere for more than a few days (Sofiev et al., 2013), this part of the study did not in the end give much more valuable information about the true area covered by Hirst-Type 7 days pollen traps.

The procedure I used to find the potential origins of the pollen gave various, both expected and unexpected results. After assessing and exploiting the different created maps one thing stands out, in most cases Sweden was the country where the highest numbers meaning the most air currents trajectories fly through were found (Tab 6-9). This was to be expected considering the cities of interest are Swedish ones, however for one of them it’s not the case, and this is the city of Malmö where Denmark is the country most passed through, which can be explained by its geographic position and the air currents landing in Malmö not crossing much land areas of Sweden in their path. For all the cities a case-by-case study has been conducted.

Stockholm: all parts of Sweden were involved but mostly the Southern half of it, the Southern half of Norway as well. This was expected considering a lot of air currents were coming from Greenland's and Norway's seas, those air currents were also passing through UK and Denmark. On the Eastern side there are a lot over Finland, Estonia, Latvia, Lithuania and Belarus then going through Poland and the Northern part of Germany. Also, a lot of variations between the 2 years were seen especially for Finland, Estonia, Latvia, Belarus, the Southern quarter of Poland or even the Northern quarter of Sweden, with very high numbers recorded in 2014 while being small to null in 2019. This could explain why I found a decreasing number of pollen trapped in Stockholm for the *Quercus* and *Betula* types with decrease of 63% and 94% respectively. Indeed, considering the maps from the European Forest Genetic Resources Program and literature (Skjøth et al., 2008) in Annexe 8, 9 and 10 for *Quercus robur* and *Q.petraea* a lot of specimens are located in Germany, Poland, but also some in Belarus, Lithuania, Latvia and Estonia. For the situation of *Betula Pendula* and *B.pubescens* I also used the figures in Annexe 10 and 11 from the literature (Beck et al., 2016; Skjøth et al., 2008). By crossing those figures Estonia, Latvia, Belarus, Poland, or Finland are showing big population of the *Betula* genus. Their much lower to non-participation in 2019 could be one reason for the major decrease of *Betula* and *Quercus* pollen counts. These countries were then likely origins of most of these pollen in 2014, on a more consistent basis the most likely origins across the 2 years are in order: the Southern 2/3rd of Sweden, the Southern 1/3rd of Norway, Denmark in a whole, Western half of Lithuania and the Northern half of Germany which have shown relatively high numbers for both years, on top of containing in one or some of their parts *Alnus, Quercus, Betula* (Durrant et al., 2016; Skjøth et al., 2008) and of course *Poaceae*. Finally, the air currents coming from Poland, Belarus, Finland, Latvia, Estonia, and the Northern quarter of Sweden are also to be considered, indeed they could be the origins of pollen during the very high pollen days on top of the high ones (Annexe 4).

Gothenburg: the number of registered pollen grains was lower in 2019 than in 2014 from 10% less for *Alnus*, to around 25% for *Poaceae* and *Betula* and 60% for *Quercus* pollen type. However, there is not a big difference between the two years regarding the number of each country parts except the Center Northern part of Norway which had big numbers in 2014 but not in 2019. This could explain the lower numbers for a part about *Alnus* but not *Betula*, except, if those were very high pollen days. Considering the most likely origins, the South of Sweden and especially the South West is showing high numbers as it is where Gothenburg is located. There are very high numbers in close-by areas such as the Southern quarter of Norway but also Denmark in its all and, the Northern third of Germany. Finally, and once again the Southern third of Finland, Estonia, Latvia and Lithuania are showing relatively high numbers, Poland is displaying decent numbers but only for the year 2019 not allowing it to pass the threshold even though those days were mostly related to very high pollen days (Figure 7). All of the countries and part of countries above are actually viable potential origins of the pollen considering the gathered results, the tree species distribution and density (Skjøth et al., 2008), they should be watched at to predict the pollen situation in the city of Gothenburg.

Malmö: this is the only city where 2 pollen numbers were higher in 2019, with respectively 220% for *Alnus* and 14% for *Poaceae* while *Betula* and *Quercus* decreased by 39 and 38% respectively. Regarding the most probable origins there is a big participation in the South of Sweden and an even bigger one occurring in Denmark which was expected here again. The Northern part of Germany is showing high numbers as well as Poland and the Southern third of Norway, all of the countries and part of countries above being potential origins during very high pollen days (Annexe 5). In the case of Malmö, Estonia and Latvia donot seem to have a big impact compared to other cities, the Southern part of Lithuania the Center North of the UK are also included during very high pollen days. France, Belgium and the Netherlands are the remaining relevant ones, those countries also have high numbers of *Quercus, Betula*, and *Alnus* type trees. The Northern half of Sweden participation, with high numbers in 2014 and close to none in 2019, could explain the lower pollen count of *Betula* considering this region is known to have a high population of *Betula* trees. For the *Quercus* pollen decrease, this could be related to the decrease of the number in Belarus with the country being the biggest potential origin of pollen during very high pollen days (Annexe 5) and being close to Poland with high density of *Quercus* (Skjøth et al., 2008). Finally, and most importantly for the huge rise of the *Alnus* pollen, there is not any major difference considering the numbers relative to the 2 years that could favor this type. By studying the numbers shown in Table 2, this is mostly due to a very high pollen number in February 2019 and that is displaying on the maps I built. The origins for this time period could be narrowed to the UK, Denmark, France, Belgium, the Netherlands, the Northern third of Germany and the South quarter of Norway. A bigger than normal activity from the species in at least one of those areas or newly appearing air currents could be determining factors illustrating that substantial rise while the biggest density of *Alnus* trees in Europe is seen between Poland Lithuania and Belarus (Skjøth et al., 2008).

Umeå: the pollen count is lower in 2019 over the board with around 50% lower pollen count for *Poaceae, Betula,* and *Alnus*. Some parts of countries sawdecreases between the 2 years, especially the South and Center of Norway as well as the Center third of Sweden. However, a lot of other parts actually displayed increases such as the North of both Sweden and Norway, which are known to have big populations of *Betula* for example (Beck et al., 2016), making it hard to find a geographically based explanation of the decrease of pollen between the 2 years. Over the course of these 2 years the most probable origin of pollen trapped in Umeå are coming mostly from close by areas, from the Northern half of Sweden, the Center third of Norway and the 2/3rd South of Finland. Also, decent values are displayed in Belarus, Lithuania, Estonia, East of Latvia and North West of Russia. Once again nearly all of these countries to watch after are in some proportion the same as for the other cities despite in the case of Umeå the addition of the North West part of Russia, which hosts big populations of *Betula pendula*, *B.pubescens* and some of *Alnus glutinosa* (Durrant et al., 2016; Skjøth et al., 2008) .

One take is important to understand, for all of the cities I tried to find geographically based explanations related to the decrease or increase of pollen count between the 2 years. However, not only this is very hard to do accurately but in the case of this study these are uncertain. This uncertainty is mainly due because of the studied unit. In that study the unit used was the number of days exceeding the “high pollen concentration” thresholds. This allowed us to have a better guess at the origins of pollen, however, this unit doesn’t take in consideration the actual number of pollen trapped, a just above threshold number for one day will in the end have the same value as a 10 times threshold another day. This choice of unit was helpful on some parts but needs to be taken in consideration while reviewing those attempts at explaining decrease in pollen count between the 2 years based on my geographic results. The way of study has also been, through backward trajectories maps, informative but not completely exhaustive because not displaying all of the trajectories but only the major ones. This procedure also led to a lot of by hand work, from creating the maps with parameters to exploiting them one by one, counting among the countries to finally create the tables exploited. An automatization or a more efficient method could allow to lower the uncertainty due to human manipulation. A potential way to continue this study would be to get if possible precise blooming data for our species in the potential countries of origin, and, try to cross this information with the air currents to have an even stronger certainty between the origins and the targets. Other types of pollen could be studied considering in this study I took 4 of the most prominent and harmful for pollen allergy sufferers. Finally, weather data such as temperature variations could be studied in parallel to assess potential differences.

This to help being even more accurate and exhaustive on the pollen forecasts and the fight to ease the pollen allergy sufferer's life.

V) Conclusion:

This study focused on 4 of the biggest Swedish cities, Stockholm, Gothenburg, Malmö and Umeå. Through the gathering and analysis of various databases, the use of statistical test and the HYSPLIT model, a lot of data have been gathered on the similarities and differences regarding pollen's impact and origin between the cities, but also between our 2 studied years, 2014 and 2019.

I found true correlation between the pollen count of *Betula*, *Quercus*, *Alnus* and *Poaceae* with the health data I gathered regarding antihistaminic patients and dispensations in the counties of our cities. This cementing in its way the impact of pollen concentration on allergy sufferers. I found a global lower pollen count in our cities in 2019 compared to 2014, while, in the meantime, the number of dispensations and patients for antihistaminic was higher. Air pollution is a known factor to affect the pollen and its impact on pollen allergy sufferers however I could not find strong correlations here at least for $PM_{2.5}$ and NO_2 air concentrations. The type of pollen linked to local biological and sensitivity differences could be a reason explaining these unexpected results. The Swedes seemed to be more impacted by allergies in 2019 than 2014 but I can't conclude that it's solely due to pollen induced ones. If I was to rank the cities from the potentially best to worse for pollen allergy sufferers based on the results of thestudy, Umeå would be first followed by Malmö then Gothenburg and finally Stockholm.

After assessing the impact on health, I tried my part to find the potential max area covered by Hirst-Type 7 days pollen traps, however it wasn't successful. Considering the potential origin of pollen in our 4 cities of interest differences were noted both intercity but also interannual variations. As expected and also considering the nature of the study, the surrounding areas of the cities were some of the most likely origins. Even though some differences were seen, some countries were occurring in almost all of the cases of high pollen and even included during some very high pollen days. Those, excluding Sweden, that are worth watching after for a 2 to 3 days prediction are: the Southern thirds of Norway and Finland, Denmark the Northern third of Germany, Poland, Belarus then Estonia, Latvia and Lithuania. A lot of other countries can have impacts as shown in the study, but, considering consistency, these would be the countries to look after both on blooming activities and on-air currents coming from for potential high pollen episodes forecast.

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Annexes:

U 2014	ALNUS	BETULA	POACEAE	QUERCUS	U 2019	ALNUS	BETULA	POACEAE	QUERCUS
January	0	0	0	0	January	0	0	0	0
February	15	0	0	0	February	0	0	0	0
March	1596	0	0	0	March	510	0	0	0
April	97	193	0	0	April	320	4333	0	0
May	0	19818	13	0	May	2	5710	19	0
June	0	228	36	0	June	0	121	69	0
July	2	0	586	0	July	0	0	210	0
August	0	0	34	0	August	0	0	12	0
September	0	0	0	0	September	0	0	0	0
October	0	0	0	0	October	0	0	0	0
November	0	0	0	0	November	0	0	0	0
December	0	0	0	0	December	0	0	0	0
Sum	1710	20239	669	0	Sum	832	10164	310	0

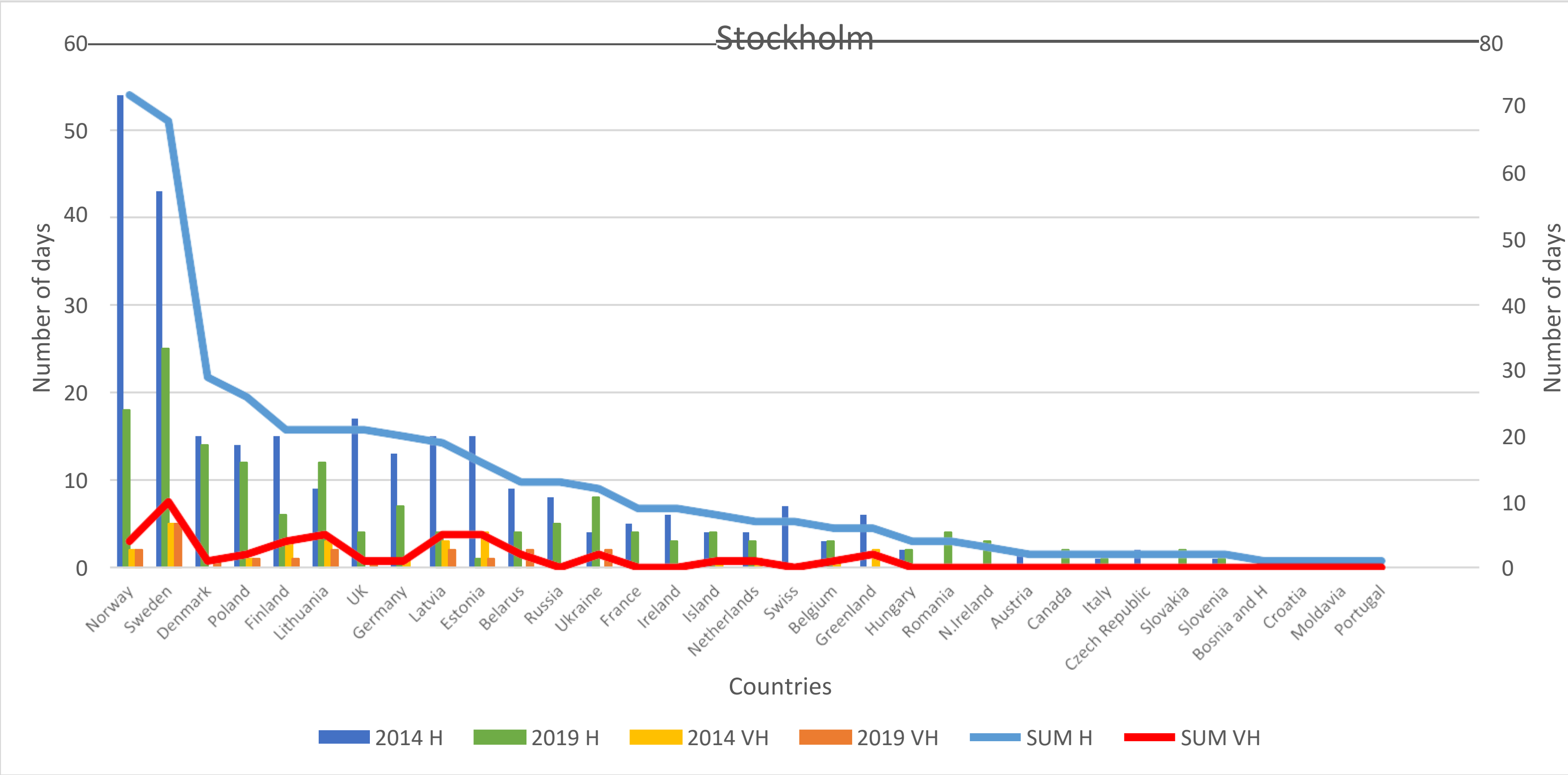
Annexe 1: Table representing the trapped pollen count in Umeå in the years 2014 and 2019 considering the *Alnus, Betula Poaceae* and *Quercus* pollen types.

S 2014	ALNUS	BETULA	POACEAE	QUERCUS	S 2019	ALNUS	BETULA	POACEAE	QUERCUS
January	0	0	0	0	January	367	0	0	0
February	104	1	0	0	February	3291	0	0	0
March	4322	4	0	0	March	82	8218	1	4
April	95	22087	1	0	April	17	1230	178	156
May	10	3968	78	2704	May	2	42	1257	1
June	1	133	761	46	June	0	6	151	0
July	1	9	645	0	July	0	2	107	0
August	0	14	83	1	August	1	6	13	0
September	1	8	13	0	September	0	0	2	0
October	2	5	5	0	October	0	0	0	0
November	0	2	0	0	November	0	0	0	0
December	0	0	0	0	December	0	0	0	0
Sum	4536	26231	1586	2751	Sum	3760	9504	1709	161

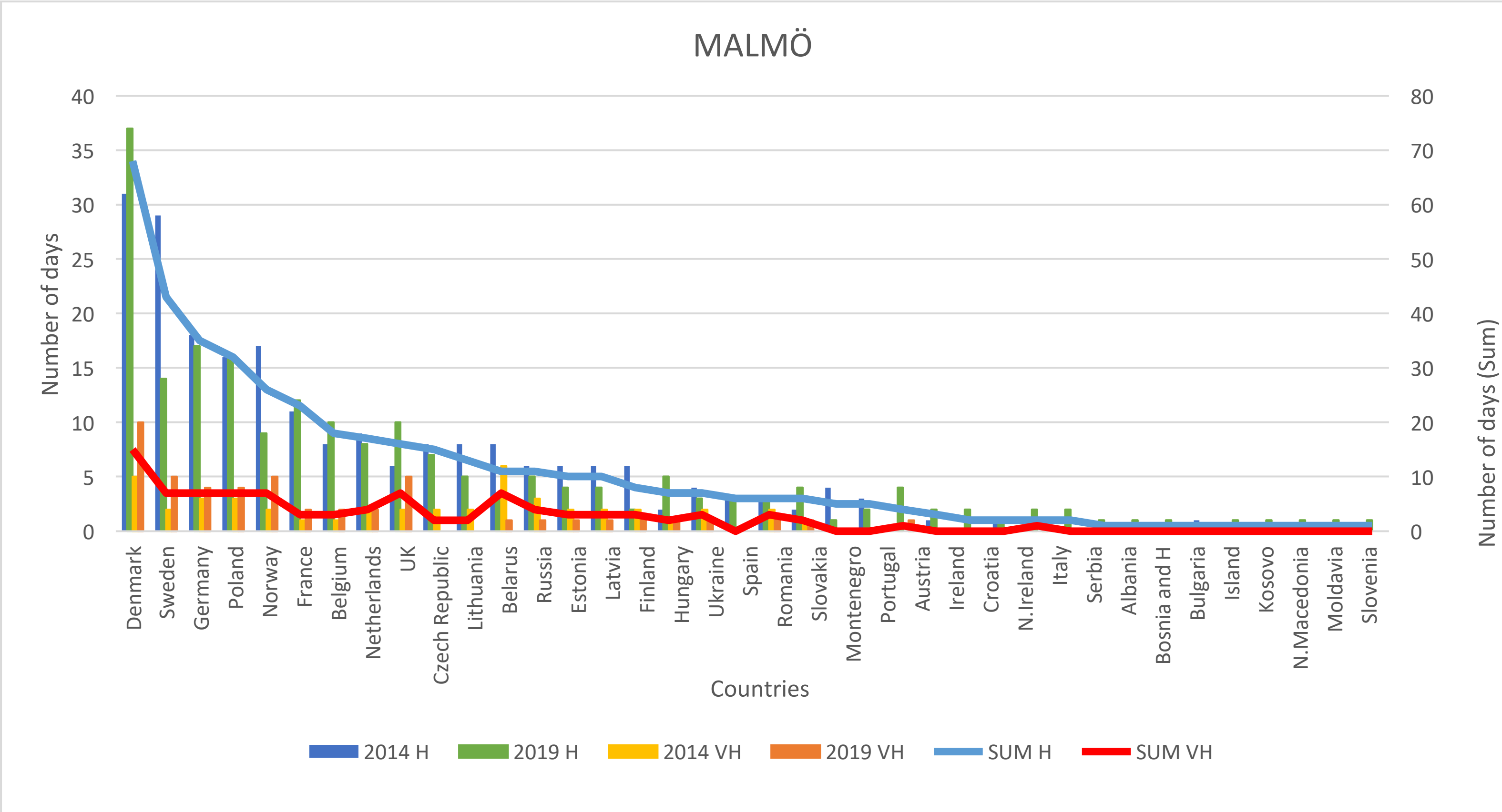
Annexe 2: Table representing the trapped pollen count in Stockholm in the years 2014 and 2019 considering the *Alnus*, *Betula Poaceae* and *Quercus* pollen types.

G 2014	ALNUS	BETULA	POACEAE	QUERCUS	G 2019	ALNUS	BETULA	POACEAE	QUERCUS
January	0	0	0	0	January	0	0	0	0
February	1	0	0	0	February	472	0	0	0
March	1701	27	1	0	March	985	4	0	0
April	26	44068	4	40	April	88	32569	5	21
May	2	784	212	804	May	1	738	55	307
June	0	51	2188	4	June	0	34	1929	4
July	0	13	828	0	July	1	11	477	0
August	1	10	50	0	August	0	3	57	0
September	0	16	27	0	September	0	3	23	0
October	0	0	1	0	October	0	0	0	0
November	0	0	0	0	November	0	0	0	0
December	0	0	0	0	December	0	0	0	0
Sum	1731	44969	3311	848	Sum	1547	33362	2546	332

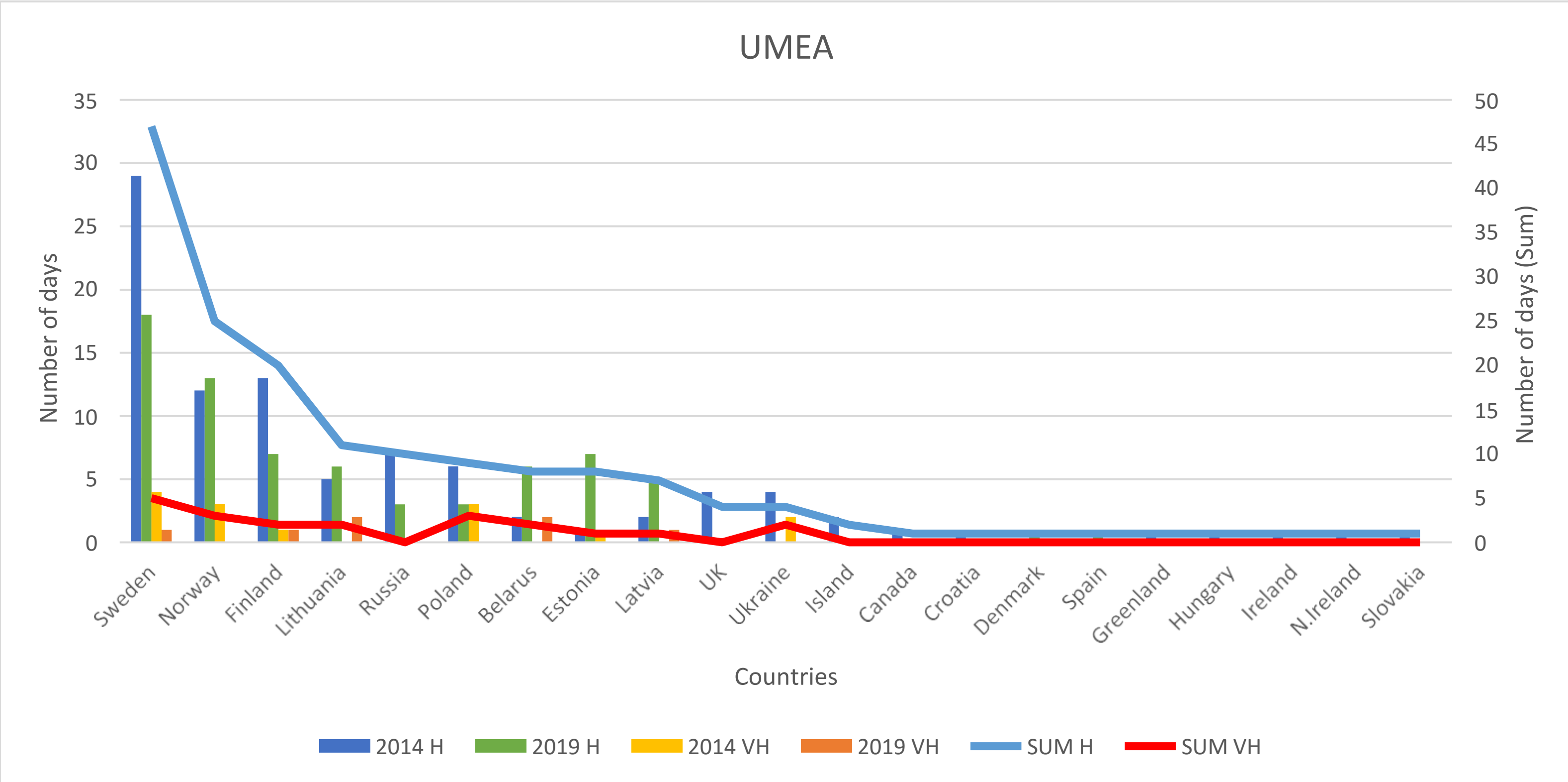
Annexe 3: Table representing the trapped pollen count in Gothenburg in the years 2014 and 2019 considering the *Alnus*, *Betula Poaceae* and *Quercus* pollen types.



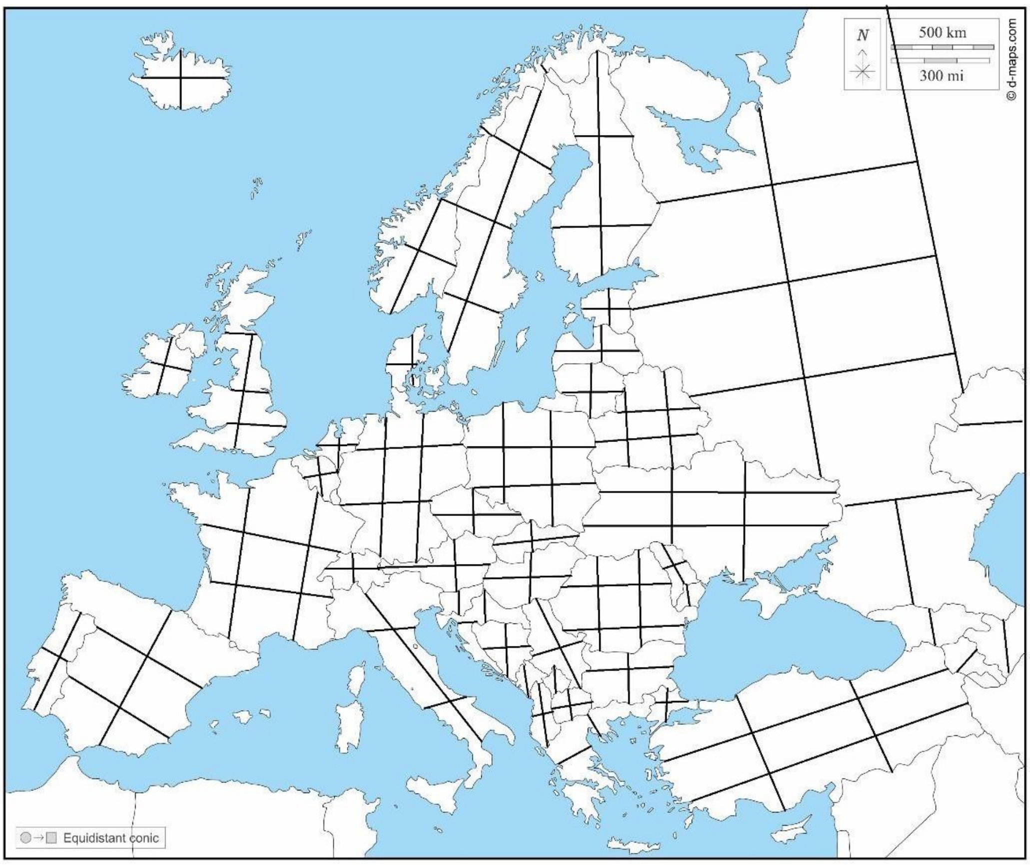
Annexe 4: Graphic illustrating the countries most passed through by air currents landing Stockholm during dayswith high or very high levels of pollen in 2014 and 2019.



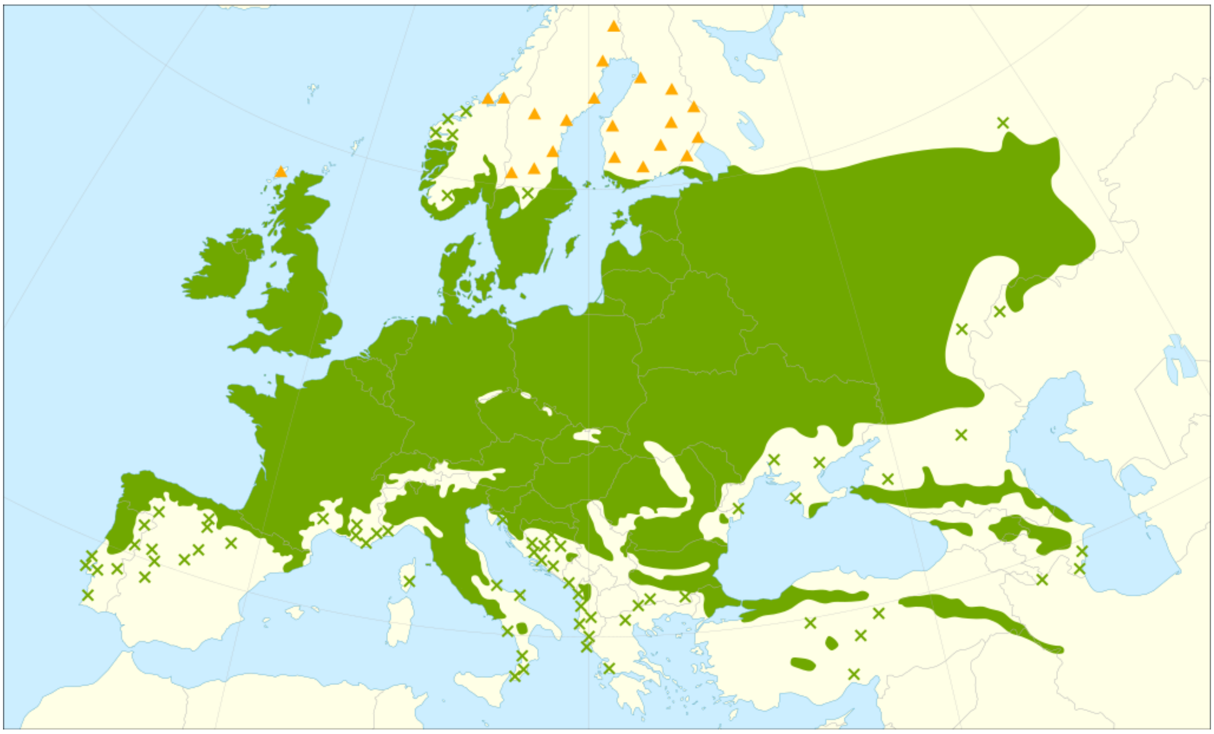
Annexe 5: Graphic illustrating the countries most passed through by air currents landing in Malmö during days withhigh or very high levels of pollen in 2014 and 2019



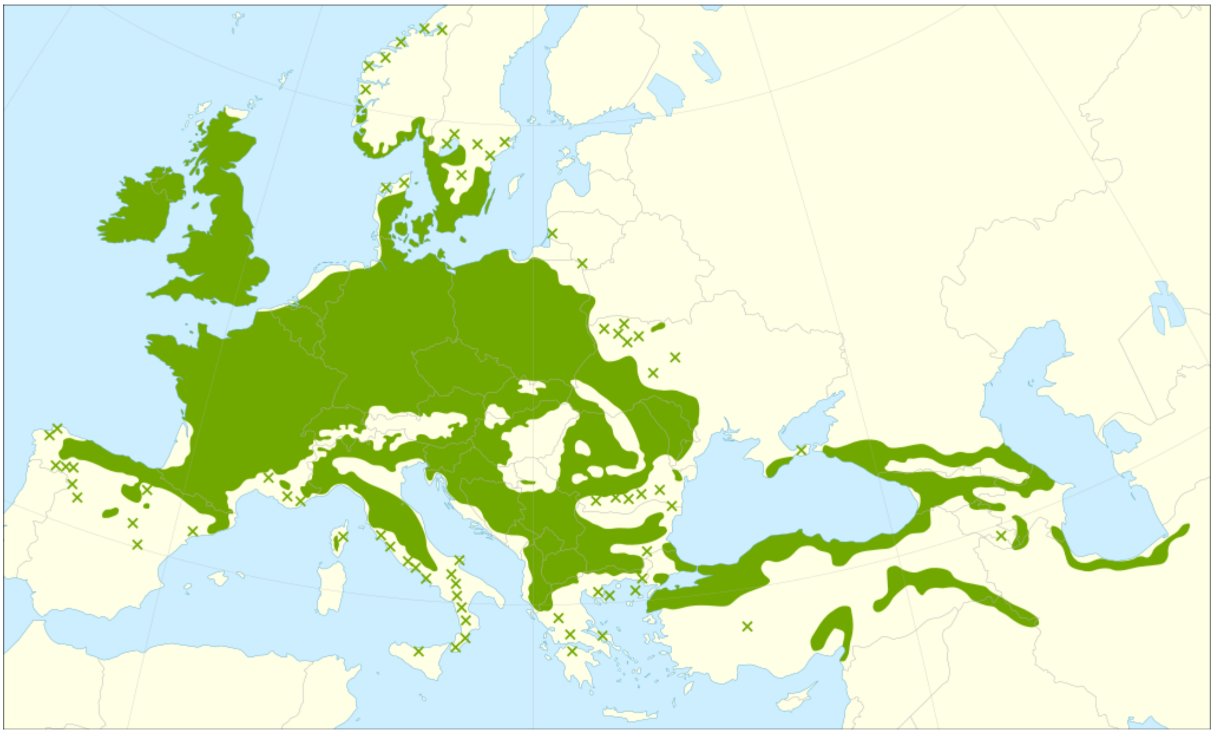
Annexe 6: Graphic illustrating the countries most passed through by air currents landing in Umeå during days withhigh or very high levels of pollen in 2014 and 2019



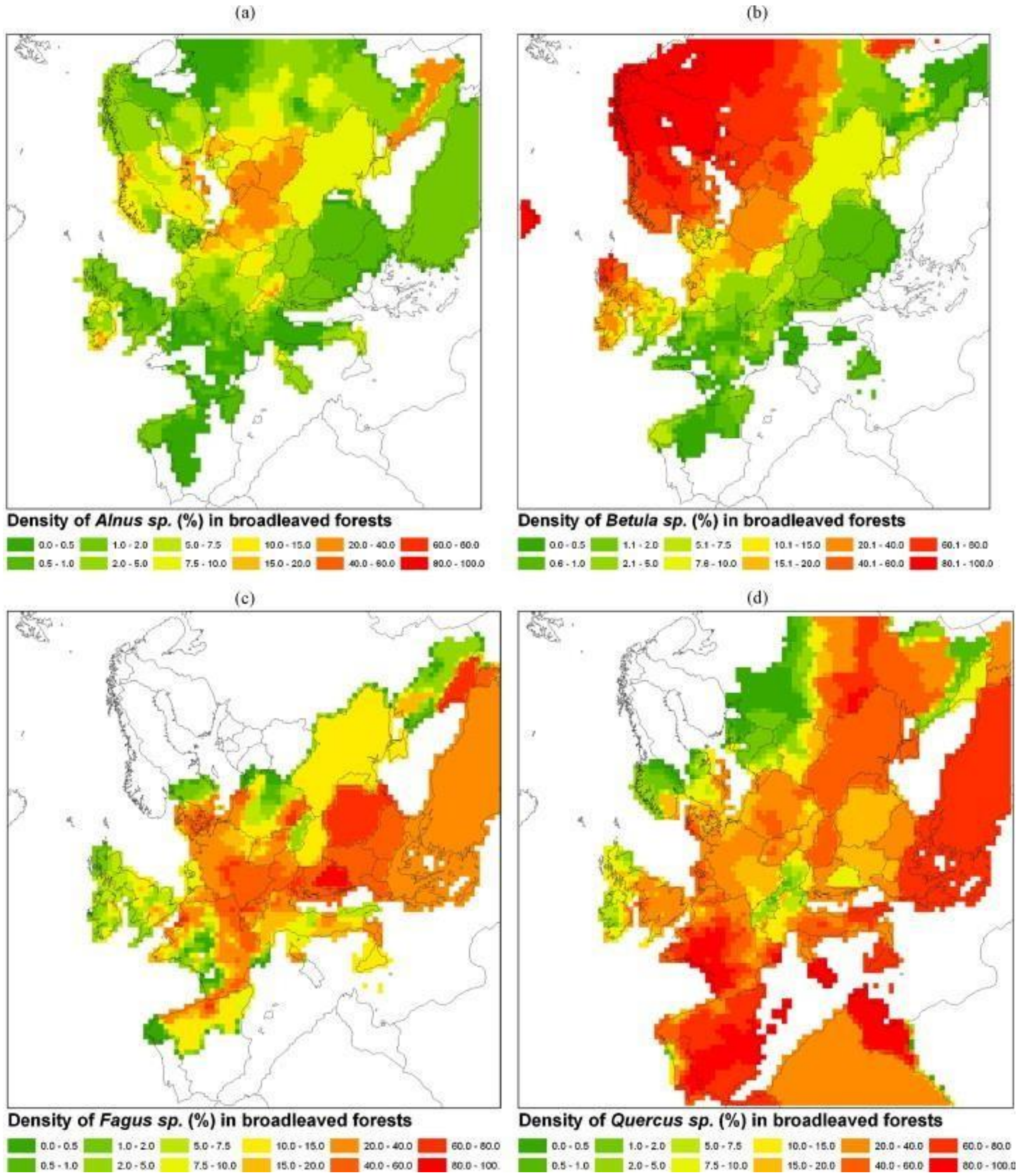
Annexe 7: Map of Europe illustrating a map of the European countries divided in smaller parts.



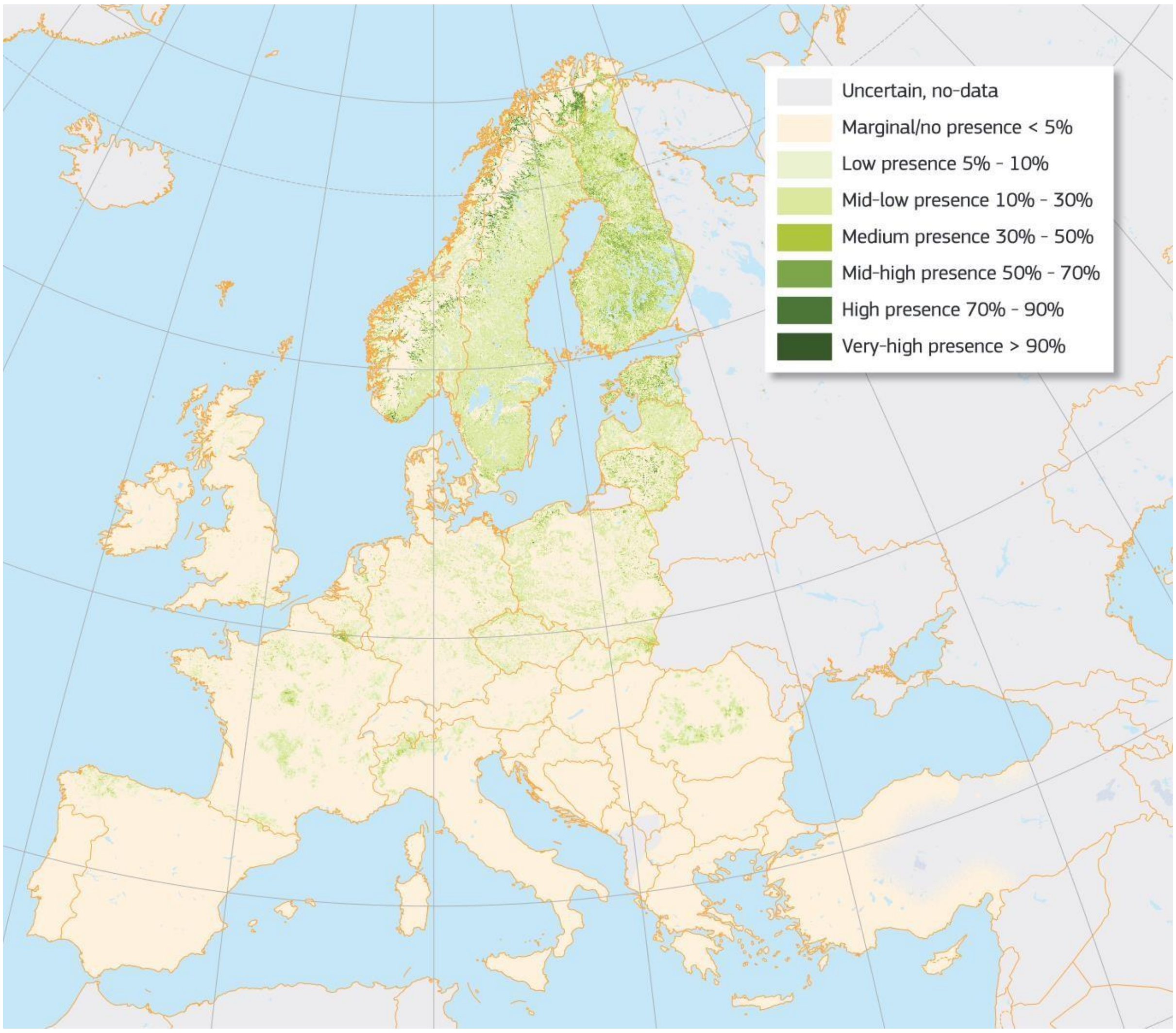
Annexe 8: Map from the European Forest Genetic Resources Program (EUFORGEN) representing the distribution of Quercus robur in Europe



Annexe 9: Map from the European Forest Genetic Resources Program (EUFORGEN) representing the distribution of Quercus petraea in Europe



Annexe 10: Figure representing the gridded density of 4 species among broadleaves trees in Europe, from (Skjøth et al., 2008).



Annexe 11: Map representing the relative probability of presence of the Betula genus from the study (Beck et al., 2016)