



# Pollen Allergies in Romania:

## Optimizing Data Analysis & Raising Awareness

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## Abstract

As pollen allergies are rising in Romania, allergists are noticing the lack of local research in this field. Our project aimed to create a software tool to optimize data analysis and discover correlations between pollen allergies and environmental factors to assist the research team at the Allergology Laboratory at Colentina Clinical Hospital and Carol Davila University in Bucharest, Romania and raise public awareness of pollen allergies. We coded a software tool using Python, gathered data previously collected in Bucharest on pollen counts, chemical pollution and climate, developed a survey to collect lifestyle data, and calculated Spearman's correlation between factors. We determined that grass pollen levels were only correlated with O<sub>3</sub> (ozone) levels, while *Ambrosia* pollen correlated with humidity, precipitation and CO (carbon monoxide) levels. Using data from Google Trends we discovered that the frequency Romanians searched the words "Ragweed" and "Allergy" correlated strongly with various environmental factors. We compared our results to studies from other countries and found the majority were consistent with our findings. Most of our lifestyle survey respondents were from urban areas, experienced allergy symptoms during the *Ambrosia* season, and experienced allergy symptoms while at work. We concluded pollen allergies are more likely to worsen during dry, warm periods. We saw ozone to be the most inflammatory pollutant. Additional data should be collected over time to confirm the correlations and better understand Romanian lifestyle choices. More development of the pollen collection program is needed to predict and publicize daily pollen forecasts in the future.

## Executive Summary

Pollen allergies have been a problem around the world, affecting millions of people globally (Montagnani et al., 2017) and having a negative impact on the economy (Walker et al., 2016). To address the pollen allergy problem, many countries in Europe and North America have done intensive research and made efforts to help diminish its effect. In Romania, pollen allergies have increased both in quantity and severity. However, until 2014 there was no data collected to study this issue in Bucharest, the capital of Romania, which has been noticeably impacted. Allergists in Bucharest have seen a significant yearly increase in the number of patients with pollen allergies over the last few years and the symptoms they experience can significantly damage their respiratory health (Leru et.al 2018). It is important to make the public aware of the changing pollen levels and provide methods to predict when their allergy symptoms may worsen so that they can prepare and limit the effects on their health.

Allergenic pollen comes from many species. The most common groups are trees, grasses, and weeds, collectively producing pollen almost every month throughout the year. Among all species, *Ambrosia* (commonly known as “ragweed”) leads in pollen count and allergenicity (Leru et al., 2019). Our project focused on investigating the effects of climate change, air pollution, and human activities on the pollen counts of grasses and ragweed. Climate change increases the average global temperature and alters season durations, lengthening the pollen production period (D’Amato et al., 2010). Urbanization also plays an important role, as the number of pollen allergy patients reported from urban areas triples those from rural areas (Cvetkovski et al., 2018). The city provides beneficial growing conditions for invasive species like ragweed (Deutschewitz et al., 2003) and high levels of air pollution worsen allergy symptoms. Lastly, lifestyle choices can have an impact on pollen levels and personal development of an allergy. For example, by using more cars, we are adding to the ambient pollutant levels. Other factors such as medical history, household conditions, diet, whether a person grew up in an urban or rural area also impact the pollen allergy development.

The goal of our project was to help assess the situation of pollen allergies, climate and air pollution in Romania and how they are related, as well as raise awareness of this situation to advocate for better policies and further research. We collaborated with Dr. Polliana Leru and her research team at Carol Davila University and the Allergology Laboratory at Colentina Clinical Hospital to help optimize their data organization and analysis processes to determine which meteorological, environmental and human activity factors affect the rise in pollen allergies.

During our project, the global outbreak of COVID-19 occurred. Travel restrictions and health advisories prevented our group from traveling to Bucharest to carry out our project. However, due to the importance of global climate change and the related medical issues it is causing, including seasonal allergies, we committed ourselves to carry out the project remotely, through electronic communications. Our collaborator, Dr. Leru was equally committed and eager to continue the project, on top of her responsibility as a doctor at a hospital that treated COVID-19 patients.

To accomplish our goal we first obtained and organized the data, then developed our data analysis tool, performed data analysis, gathered missing lifestyle data and finally devised a strategy to raise awareness about the rise in pollen allergies in Romania. In addition, we developed a project website, where we have posted our most important findings, linked here: <https://sites.google.com/view/wpi-iqp/home>.

The data used in our project included many factors such as pollen counts, meteorological factors, air pollution levels and public interest. The pollen data was gathered from the Allergology Laboratory at Colentina Clinical Hospital, where it has been collected using a Burkard pollen trap since 2014. The meteorological data came from the National Meteorological Agency in Romania and included variables such as temperature, relative humidity, wind speed, and wind direction. The chemical air pollution data came from the National Air Quality Monitoring Network stations closest to Colentina Clinical Hospital. Lastly, we used Google Trends to gather data about Romania's public interest in specific search terms over time using the terms "Allergy" and "Ragweed" as an indicator of the number and severity of allergy cases in Romania at different times over the years.

Our data analysis tool is called the "Correlation Machine". It was coded using Python and was designed to perform three main tasks: manage data, calculate Spearman's correlation coefficients and generate graphs with regression models. Pictures of each tab can be found in section 4.1 of this report. Our source code files can be accessed and downloaded from Github: <https://github.com/trschaeffe/PollenTool> The link to our executable file can be found here: [https://drive.google.com/open?id=1HCP7sD6GoTpnJ\\_JSF1R0VvUTVGMOWXey](https://drive.google.com/open?id=1HCP7sD6GoTpnJ_JSF1R0VvUTVGMOWXey)

The first section, or tab, of the Correlation Machine is where data management is performed. The user has the ability to load files into the tool. All files that are loaded are combined into one large file known as the "master". In this tab, the user can also manually add a single data point to the master file and calculate the total daily pollen levels.

The second tab is where all of the calculations are performed between any two categories that the user selects. There are multiple filters that can be optionally applied to the correlation, such as choosing pollen season dates, calculating monthly or yearly averages, or only including data within a certain time period. The user can apply any combination of these filters to the data. After clicking "Calculate", Spearman's correlation coefficient, the p-value (or probability of the correlation's true existence) and a list of the applied filters will appear in a row in the table at the bottom of the tab. This table can be saved as an Excel spreadsheet for future reference.

The third tab is used for generating graphs. Up to six variables can be graphed at a time. The user can select to plot each variable on the left or right y-axis for better visibility of the lines. This tab also allows the user to apply the same data filters as the calculations tab. In addition to those filters, regressions can be plotted by choosing a regression type and entering a year in the future that the line will be extended too. After clicking "Generate Graph", a graph will appear in a new window, which can be analyzed and saved to the computer.

The final tab is called the "Help" tab. In this tab there are links that go directly to Youtube videos with demonstrations of how to perform specific tasks. There is also a link to our user's guide which is a written version of all of the videos put together.

The Correlation Machine was designed to store all available data, perform analysis, generate graphs, and can be adaptive to new data in the future. With an intuitive User Interface and video

instructions, users with any background can learn the tool quickly. Through the development of the tool, we hope to help optimize the current and future data analysis.

Using the Correlation Machine, we generated results to better understand the interactions between pollen levels, pollen symptoms, and various external factors. We found that the total pollen levels in the air are higher on hot, dry days. We did not find any correlation between total pollen levels and PM<sub>10</sub> that we had expected. The only types of pollen that correlated with PM<sub>10</sub> from May until October were *Artemisia* and *Ambrosia*, which we have learned from Dr. Leru is not often confused for PM<sub>10</sub>.

The strongest correlations we found between ragweed pollen levels and meteorological factors were with relative humidity and precipitation during the full pollen season. There is a negative correlation with both of these factors; when there is less moisture in the air, the pollen count is higher. Ragweed pollen levels were also positively correlated to carbon monoxide levels (CO), although there has not been much biological research explaining the relationship between these factors.

The most significant factors correlated to grass pollen levels were ozone (O<sub>3</sub>) and solar radiation, specifically during the peak grass season from April 25 until the end of June. Both showed a positive correlation. While the strongest correlations with O<sub>3</sub> were found looking at yearly averages, the monthly averages were the only scenario with a strong correlation and a statistically significant p-value. Even though we cannot show causation between these factors and grass pollen levels, this correlation suggests that there may be some link between the O<sub>3</sub> levels, solar radiation and grass pollen over time.

We were able to find many factors that correlated with the public's interest in searching 'Allergy' and 'Ragweed'. Again the theme of hot, dry, sunny days being the worst for pollen allergies was reinforced through correlations with temperature, humidity, and solar radiation. Ozone was one of the strongest correlated pollutants, leading us to believe that it is the strongest lung irritant. Other pollutants did not seem to have much of an effect, though they may be an underlying cause of pollen allergies, and many of them are involved in the ozone production process.

After compiling our results together from the correlation machine, we chose to compare these results to studies conducted in other countries to see if our findings were similar or different. First we examined a study conducted in Northern Italy conducted from 1981 to 2007. This study compared grasses and other pollen with temperature, humidity, precipitation, wind speed and solar radiation. They found no significant change in grass pollen over time, while temperature and humidity linearly increased. This resulted in a weak correlation between grasses and temperature, while grasses correlated with humidity (Ariano et al., 2010). In our results we also saw the same constant trend with grass pollen and increasing trends with temperature and humidity. Because this study has significantly more data than our project, and we discovered similar trends and correlations, we expect this trend to hold true over time as more data becomes available.

We also compared our results to studies conducted in the United States. In one study, conducted from 1995-2009, results showed that the length of the *Ambrosia* pollen season correlated directly to the number of frost free days and latitude. These findings suggest that areas at higher latitudes

are more affected by climate change, shown by the increasing length of the frost free periods each year. For latitudes above 44°N, the season increases as much as 13-27 days in 2009 compared to 1995. Even though analysis with temperature within our project was inconclusive, Romania has an average latitude of 45.9432° N, therefore, it is likely that over the years, with more data collected, one will also observe the increase in *Ambrosia* season duration due to climate change (Ziska et al., 2010).

Based on the correlations we made and findings from other research, we did a prospective analysis to produce future predictions for two major events taking place in Bucharest, climate change and pollution awareness. As the climate continues to warm, more pollen will be generated. Hot, dry days were shown to be the worst for pollen allergy symptoms. We observed lower average humidity and higher average temperatures in our analysis, meaning Bucharest will experience more of these days and worsening allergy symptoms. Regarding pollution, Bucharest's PM<sub>2.5</sub> and PM<sub>10</sub> level, both tend to peak well above the European Union legal limits. Without any intervention, these chemicals will continue to cause lung irritation, which can lead to the development of pollen allergies in more people. Fortunately, pollution activism has been brought to attention by independent companies such as Airly and Aerlive, and hopefully Romania will begin to take action on reducing its pollution level, possibly preventing many people from developing allergies.

Lifestyle is another factor associated with pollen levels and symptoms. We distributed our lifestyle survey to an *Ambrosia* sufferer Facebook group in Romania. We received 92 responses and 87% of them are affected by pollen allergies (including ragweed, trees, and grasses). 47% are from Muntenia region where Bucharest is located and 63% reported to grow up in urban areas. This finding justifies the common assumption that urban areas are most affected by pollen allergies. The sufferers reported to experiencing their symptoms throughout the year, but especially during ragweed season, suggesting that ragweed sensitization is the most common of allergies. However, since people also have their symptoms in other months, we can conclude that many are affected by more than just ragweed. We also found that pollen allergies are not so much genetically driven, and instead are more likely to be impacted by environmental factors. This is evident as the majority of respondents said they did not have any family or personal history of respiratory diseases. Although it is true that the majority of Romanians choose cars as their primary mode of transportation, more studies are needed to determine the relationship between Romanian's car usage and their allergies. Lastly, we found that allergy symptoms at work are surprisingly common. Majority (75%) of the respondents reported to experience their symptoms at work, which can affect their productivity, the quality of their work, and sometimes even their own safety. This finding especially stressed the importance of doing more research to help people cope with the effects of allergies.

To help raise public awareness of pollen allergies in Romania, we designed an educational pamphlet to be distributed in the hospital or online. The pamphlet contains basic information about allergies, factors that contribute to the spread of pollen, common symptoms, and possible treatments or ideas for prevention. In addition, we created a pollen allergies Facebook page where we added short informational posts over the course of our project to provide more specific information about allergies. The pamphlet has also been posted to this page to make it available to

a wider audience. We also linked our survey to this page to gather more responses (<https://www.facebook.com/polleninromania/>).

After the completion of our project, there are a few things we believe could be added or expanded on in the future. Our biggest recommendation is for the continuation of data collection, as this will strengthen the confidence in our results so far, allow more future trends in Bucharest to be determined, and help find more correlations in places where our current data set is limited. Additionally, we believe that calculating and publishing pollen forecasts in Bucharest, adding health data as a factor, collecting more survey results to a statistically significant level, and investigating whether there is a link between COVID-19 and pollen allergies would be useful additions to our project in the future.

At the completion of our project, we compiled and presented all relevant information about pollen allergies from global and local sources, developed a “Correlation Machine” for ease of data analysis, and proved that Romania is observing a similar trend to other countries that are heavily impacted by pollen. Our project team, along with our collaborator, Dr. Leru and her research team believe that with climate change, urbanization, and the immediate threat of COVID-19, it is more important now than ever before to gather more research in Romania regarding pollen allergies in order to protect the health of the public.

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## **Authorship Contributions**

**Deanna Kay** contributed to the writing and editing of every section of the report and production and analysis of results.

**Jessica Kelly** contributed to the writing and editing of every section of the report and the production and analysis of results.

**Tobias Schaeffer** contributed to the writing and editing of every section of the report and the production and analysis of results.

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## Chapter 1: Introduction

The rise of pollen allergies is an issue that continues to negatively impact people's daily lives across the globe. This issue is particularly heightened in Europe, where many invasive species thrive and produce allergenic pollen. Different pollen types from trees, grass, and weeds have been documented to spread rapidly and increase in allergenicity over time. The goals of our project are to develop a data analysis tool that determines the relationships between pollen counts, allergies, pollution, and climate in Bucharest, develop a method for collecting data on Romanian lifestyle practices, and bring awareness to the issue of increased pollen allergy symptoms, including how it can be addressed in an urban environment.

The rise in pollen count and seasonal allergies is affected by city upkeep, climate change, and people's lifestyle practices. Statistics show that urban areas are more affected by this than rural ones. In fact, the number of patients reported from urban areas triples, sometimes quadruples those from rural areas (Cvetkovski et al., 2018). Cities provide an advantageous environment for weeds, which thrive uncontested in loosely packed soil and warmer temperatures. Not only that, with urbanization, people are eliminating or abandoning green spaces, reducing the native biodiversity and leaving the city even more susceptible to invasive species (Deutschewitz et al., 2003).

Climate change and the abundance of air pollution from vehicle emissions in the atmosphere negatively affects the overall health and increases ambient pollen levels. Air pollutants, including bio-pollutants like pollen, create inflammation in the lungs, making people more susceptible to respiratory disease and allergies. Additionally, longer summer and fall seasons are causing pollen, especially from ragweed plants, to spread more quickly, and diseases like allergic rhinitis are becoming more serious (D'Amato et al., 2010).

Additionally, lifestyle is a complex topic that covers activities that directly and indirectly affect the chances of allergy development. Living in a congested city with exposure to high pollen concentration increases the chances of having an allergy. By choosing cars as their primary mode of transportation, people are adding to ambient pollutants that are harmful to the respiratory system. Other factors such as poor diet, hygiene, and limited exercise are related to a person's overall health, adding to the negative effects of pollen allergies. For allergy patients, self-medication is common, due to underestimating the severity of allergies, and inaccessibility to proper healthcare. Relying on over-the-counter medicines or home remedies can lead to future manifestation of symptoms, especially for those with more severe symptoms (Cvetkovski et al., 2018).

Pollen producers have been previously studied in many scenarios by researchers and organizations around the world. One of the most notable organizations is The European Commission Cooperation in Science and Technology, also known as COST. COST analyzed pollen information from 242 pollen traps across Europe and discovered trends in amounts of pollen in these locations daily, annually, and the average amount measured during each season (Sikoparija et al., 2016). However, most of Romania was not included in this data, thus, it remains unclear how pollen information there compares to COST's findings.

Locally, ragweed (*Ambrosia artemisiifolia*), is an invasive species, first introduced to Romania in the Orsova region in 1908 through war supplies arriving from abroad. Since then, it has

quickly spread to the rest of the country (Florincescu-Gheorghe et al., 2019). In 2018, the Romanian Parliament passed a law to control the spread of ragweed, but there is still a gap in knowledge regarding the exact pollen levels of this type and many others in Bucharest and how their change affects seasonal allergies.

In order to narrow this gap, our team created a data analysis tool, named the “Correlation Machine” to help our collaborators, Dr. Polliana Leru and her team at Carol Davila University of Medicine & Pharmacy and Colentina Clinical Hospital organize and analyze data regarding pollen counts, pollution levels, and climate. The Correlation Machine is able to make correlations between the factors involved using Spearman’s correlation coefficients and regression models. It can receive new data, calculate correlations between variables, create graphs for prospective trends, and is well documented with guided manuals to help Dr. Leru and other contributors to use and edit it.

For our analysis, we used previously collected pollen count, chemical pollution, and climate data provided by Dr. Leru and her team, the National Meteorological Agency (Global Surface, 2019) and the National Institute for Research and Development in Optoelectronics. Information on lifestyle and respiratory health, however, were unavailable. We developed and distributed a survey that can complete this missing lifestyle data. The goal of the survey is to demonstrate which Romanian activities impact allergy symptoms and pollen levels. Our survey includes questions to gather information about people’s background, their allergies, transportation usages, household conditions and diet. The full survey can be found in Appendix A. We refined the survey in response to comments from our collaborators and advisors, as well as the responses of the participants. We also supplemented the missing health data by exploring the public interest in allergy-related search terms over time through Google Trends data available from Romania.

Lastly, we aimed to better educate the public on allergy symptoms, available treatments, and how individual choices can impact their symptoms and the environment. We created a Facebook page to increase the online presence of pollen allergy studies and post related information. We also designed an educational pamphlet to be distributed at the hospital or online. With these strategies, we hope to help Dr. Leru and her organizations gather support for further research on this topic.

During our project the global outbreak of COVID-19 occurred. Travel restrictions and health advisories prevented our group from traveling to Bucharest to carry out the project. However, because of the importance of global climate change and the related medical issues it is causing, including seasonal allergies, we committed ourselves to carry out the project remotely, through various electronic communications. Despite this setback, our collaborator, Dr. Leru was equally committed and eager to continue the project, on top of her responsibility as a doctor at a hospital that treated COVID-19 patients. Because of the restrictions created by this global pandemic, we made a few adjustments to the project to continue to work with our collaborator in Bucharest and our advisors remotely, and these measures will be further explained in the Methodology Chapter.

## **Chapter 2: Background**

In order to tackle the problem of increasing pollen levels and seasonal allergies, we first needed to understand their origins and why these problems should be addressed. We looked at the global scale to understand the current perceptions of pollen allergies around the world, investigate the factors that contribute to this problem, and how other countries have addressed it. We then focused on the local problem in Romania, specifically in Bucharest to identify the gaps in knowledge. Through these steps, we had a broad understanding of pollen and seasonal allergies, allowing us to suggest ways to fill in the missing pieces in Bucharest.

### **2.1 Introduction to the Global Pollen Issue**

Every year, seasonal pollen allergies affect the health of millions of individuals around the world, causing many disruptive symptoms that harm their daily life. The main contributor to seasonal allergic reactions is airborne pollen, produced by different types of trees, grass, and weeds. The most allergenic of these comes from the *Ambrosia* species, more commonly known as ragweed. Ragweed is particularly allergenic due to its ability to produce large amounts of pollen per plant, the highly allergenic particles that make up its pollen grains, and its ability to thrive in the loose soils of urban environments. In addition, ragweed is an invasive species to most parts of Europe and Australia, making ragweed allergies more common in these places (Montagnani et al., 2017).

#### **2.1.1 Seasonal Allergies are Serious and Increasing**

Seasonal allergies can cause general symptoms such as inflammation, watery eyes, runny nose, sneezing, and coughing, but can also be diagnosed in more severe cases like hay fever and/or asthma. As of 2016, it is estimated that 10–30% of the global population is affected by hay fever and 300 million people are affected by asthma (Pawankar et al., 2011). Asthma is the most serious in Europe, with 14 EU countries in the world's top 20 for asthma in adults, costing approximately more than €72.2 billion every year (Walker et al., 2016). Allergy symptoms are serious, and trends in data suggest that the prevalence of asthma and hay fever are rising every year. For example, France's Rhône-Alpes Center of Epidemiology and Health Prevention shows that hay fever prevalence rose from 8% of the local population in 2004 to 12% in 2015 (Schmidt, 2016). This increased occurrence is exacerbated by the quick spread of allergenic plants across the globe.

#### **2.1.2 Ragweed is a Leading Pollen Allergen**

Allergenic pollen comes from many species, with the most common groups being trees, grasses, and weeds. They grow in different seasons, producing pollen from early spring to late fall. Ragweed is a leading invasive weed that produces pollen mainly in the summer into the fall. It prefers to grow in unoccupied or freshly mown ground. Therefore, it favors human-touched lands such as gardens, building sites, cultivated fields, and along roadways. It can produce up to six thousand seeds per plant, which are easily spread by human activities such as farming, gardening, moving soil, and vehicle use (Tamarcaz et al., 2005). In addition, ragweed produces pollen at much higher levels than most plants, at up to a billion grains per plant per season. The allergenic factors of pollen are also much more potent in ragweed than other types of pollen (Montagnani et al., 2017). It only takes 10 grains of ragweed pollen per cubic meter of air to



trigger an allergic reaction (Chen et al., 2018). These characteristics contribute to ragweed pollen's ability to produce a severe immune response. This also makes it one of the greatest species of interest when discussing pollen allergies and bio-pollutants, especially considering its recent spread across continents.

### 2.1.3 Global Spread of Ragweed

While ragweed is native to North America, it has spread to every continent, invading most of Europe, China, and subtropical regions of Australia (Taramarcaz et al., 2005). Figure 1 below shows the current global ragweed status, with the invaded countries shown in red.

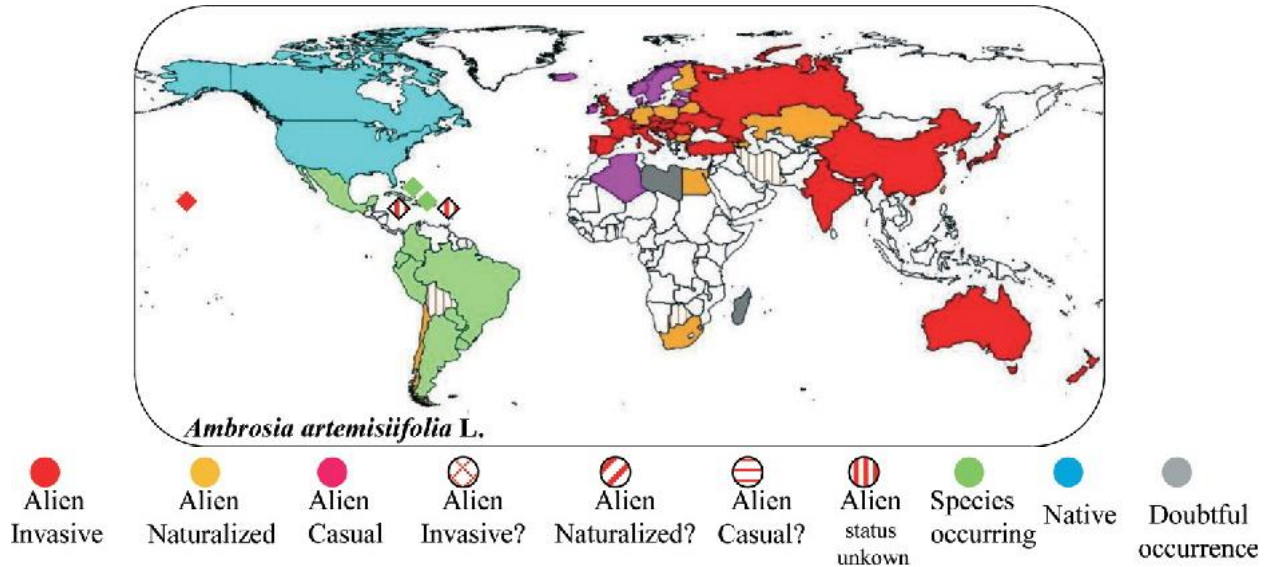


Figure 1: Global distribution of *Ambrosia artemisiifolia*, L. species (ragweed) (Montagnani et al., 2017).

Ragweed spread has mostly affected Europe, where the highly allergenic variety of the plant became widely distributed throughout Europe after World War I through American shipments of food supplies (Hufnagel et al., 2015). Ragweed's extremely high level of pollen production allows it to spread easily within a region upon its introduction. The large-scale spread of allergenic ragweed is mostly attributed to human factors, such as contamination of feedlots and bird seed. It is also susceptible to quick local spread caused by wind (Montagnani et al., 2017).

In the last 30 years, ragweed has been spreading further, reaching Sweden and the Baltic regions, and covering 90% of the Rhone valley travelling from France to Hungary (Taramarcaz et al., 2005). It continues to spread eastward, now covering nearly every Eastern European country. Many countries in Europe are making efforts to understand and manage the spread of ragweed, as well as informing the public about personal health effects they may experience from this issue.

The global spread of ragweed is increasing rapidly and can be attributed to several factors that affect the pollen levels in an urban environment. It is important to understand the relationships between these factors, ragweed pollen and allergy symptoms, as well as how awareness and treatment of symptoms can impact allergy patients of urban environments.

## 2.2 Factors Affecting Pollen

There are many factors that may affect pollen distribution and allergies. In this project, our main focus is on environmental factors such as city upkeep, climate change, and elements of lifestyle. These factors are key to understanding how a city's aerobiology will change and how it will impact the population.

### 2.2.1 The Effects of Urban Maintenance and Land Usage

Cities have been studying the spread of invasive species for decades. The city provides a unique environment for plants to grow that favors some species over others. Neophytes, a category of plants which includes invasive species like ragweed, are some of the best suited plants in the city landscape. Conditions that benefit neophytes are loosely packed soil, warmer air, and lack of competition. Areas where the land has been disturbed and the sun shines are ideal growth spots for these invasive species (Deutschewitz et al., 2003). Another key feature is the interconnected pollen network that one may not anticipate in the urban environment. Using mapping techniques to find proximity to areas that support growth in Hungary, it was found that 65% of the growing space in Debrecen could be traveled by pollen and was therefore biologically connected. While a connection like this helps the many plants native to the environment maintain their diversity, it can also lead to invasive species overrunning the local species and spreading uncontrollably.

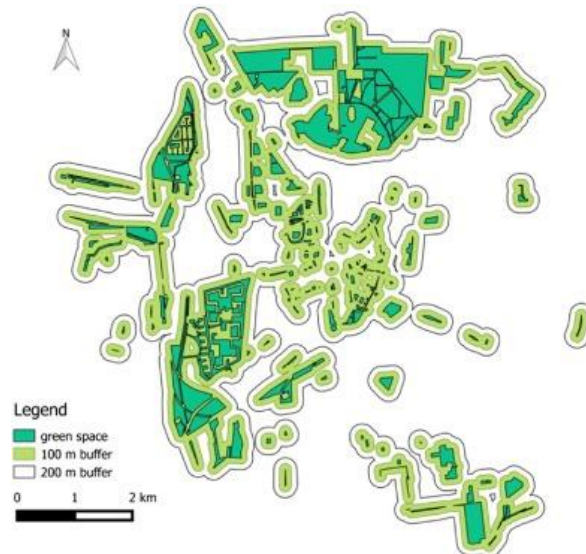


Figure 2: Pollen network of Debrecen (Hüse et al., 2016).

Figure 2 demonstrates the pollen network of Debrecen, Hungary, where the green space represents areas that plants can grow. The interconnectivity of these spaces is key in understanding how seemingly small changes can proliferate through the environment (Hüse et al., 2016). Empty urban lots provide an abundance of land for these non-native species to grow in. Non-native plants in Canada have been found to thrive in what is known as “medium” urban environments, found by algorithmically analyzing satellite images. These medium environments do not include downtown areas, nor the suburbs, but represent the in-between level of urbanization. The invasive weeds are able to grow in empty lots without competition from larger plants and are given plenty of sun to quickly establish a homogenous culture. Other studies also confirm that the downtown area of the cities generally have lower pollen counts than their

surroundings (Blouin et al., 2019). Like empty lots, abandoned urban structures and undeveloped areas also present a ripe opportunity for pollen species to take advantage of the unmaintained land and spread into these areas (Cariñanos & Casares-Porcel, 2011).

The usage of city space has many effects on pollen and the symptoms it produces in allergic individuals. Urban green spaces are a critical part of city planning and design, providing a break from the otherwise uninterrupted landscape of unnatural structures. These amenities are not only considered important to the mental health of citizens, but can also provide some of the answers to reducing the symptoms of allergens if developed properly (Cariñanos & Casares-Porcel, 2011). Parks produce a large amount of their own native pollen but with good maintenance, they will produce lower levels of invasive pollen. The diverse pollen profile of a well built and maintained park reduces severe pollen allergies and helps filter the polluted city air. It can also increase the environment's biodiversity by spreading its seeds beyond the park's edges. Some sources claim that up to 30% of harmful allergenic pollen could be eliminated by a green space. Great care and commitment must accompany these parks, which are otherwise at risk of being overrun by a single species, similar to other abandoned city features. Those responsible for planting the park must take great care in selecting robust, native, low pollen producing, and diverse plants to ensure that it will have a positive impact on the public. Suggestions can even go as far as to say that the genders of the plants should be selected to have more female plants that do not produce pollen (Cariñanos & Casares-Porcel, 2011). By artificially adding a strong and native plant population back into a city, the biological network that connects the arable land of the city would allow biodiversity to spread back through the city (Hüse et al., 2016). Similarly, urban wastelands can also be maintained with native plants and utilized against invasive species (Montagnani et al., 2017). The continued financial and manpower commitment of a city is vital to employing these solutions, though they offer ways to restore some balance to the pollen levels of a city.

### **2.2.2 The Effects of the Climate**

*Ambrosia* season begins in late summer to early fall, and ends by the date of the first frost. Milder winters and warmer seasonal temperatures lengthen the frost-free period, leading to an earlier and longer ragweed season duration. Using simple regressions for data collected in 1995-2009, researchers have determined that the increase in duration of the ragweed pollen season correlates with latitude in North America. For latitudes above ~44°N, the season increases as much as 13-27 days in 2009 compared to 1995. This is consistent with findings from the Intergovernmental Panel on Climate Change (IPCC), stating that global warming is affecting seasonal temperature and duration, thus, impacting aeroallergen seasons (Ziska et al., 2010).

Natural phenomenons such as thunderstorms and heavy rains, possibly increasing due to global warming, also exacerbate the symptoms of pollen allergies. A severe storm in Australia in 2016 caused 10 allergic-asthma deaths and approximately 9000 people were hospitalized. It was proven that during the storm, pollens (grass and mold in this case) were brought to ground level, rainwater penetrated the pollen shell and released fine allergenic granules that could access the lower airways. Even those without asthma can experience bronchoconstriction due to such events (D'Amato et al., 2018).

The combination of climate change and urbanization also worsens the situation and introduces more environmental risk to human health. In urban areas, emissions from the increasing use of

vehicles and factories, combined with the “urban heat island” effect, add to the rise in temperature and the greenhouse effect. Air pollutants and dust caused by urbanization enter the human body through the airways and damage the inner membranes of organs. This triggers the immune system, thus making it more sensitive to allergenic pollen. Air pollutants contain nitrogen oxide gases, particulate matters (PM), and ozone, which cause inflammation in the lungs and create allergies or bronchial asthma. PM<sub>2.5</sub>, PM<sub>10</sub>, and NO<sub>2</sub> are confirmed to have a long term impact on mortality and morbidity due to increased risk in cardiovascular and respiratory diseases (Sanyal et al., 2018). Since people are consuming more energy sources and emitting more gas and fuel from vehicles, air pollution is increasing. As a result, respiratory allergy and asthma is also increasing, more in urban than rural areas. Health problems are especially significant during the time of this project, as the COVID-19 pandemic is causing serious respiratory concerns and the need to address such issues has become much more evident.

In the United States, children living near major roads have increased risk of respiratory disease, as well as deficits in lung function. A study done on 5277 children in Southern California showed that children living within 500m of a major freeway are 10 times more likely to develop pollen related rhinitis if they are already sensitized to at least one pollen group. This study, among others in the US, linked air pollutants to the development and exacerbation of respiratory diseases (Zhou et al., 2018).

In addition, global warming and climate change worsen the situation because they cause changes in the concentration and distribution of gases, as well as lengthening the seasons when allergenic pollens are the most prevalent (D’Amato et al., 2010). A study in Mongolia supported the theory that urbanization does in fact correlate with the rise in respiratory diseases (Nicolaou et al., 2005). Not only that, pollution also increases the allergenic potential of pollen and the growth of some plants, including *Ambrosia* (Chirilă & Florescu, 1990).

### **2.2.3 The Effects of Lifestyle**

Although climate plays a large role in the rise of pollen and, in turn, pollen allergies, it is not the only factor that contributes to this global problem. As the most dominant species in the world, humans can greatly affect the environment, and our lifestyle remarkably influences the pollen concentration and allergies. Lifestyle umbrellas many categories: behaviors that affect the climate, exposure to pollen and other allergens, and attitudes towards healthcare. These factors collectively contribute to the complexity of pollen-related issues.

Since 1990, the number of allergy patients have drastically increased. Many attribute this to the growing lifestyle of staying indoors, leading to the development of different forms of allergies. Being indoor for the majority of their activities leads children to have increased sensitization to the indoor allergens such as dust mites and fungi spores. Additionally, children in the United States spend a lot of time indoors in front of a screen and consume a diet of more processed food. These habits decrease physical activity and encourage obesity, which is linked to asthma (Platts-Mills, 2016).

#### **a. Behaviors that affect the climate**

Cities are expanding and there is a growing need to travel further and more frequently. As a result, people are choosing cars as their main means of transportation, especially in big

metropolitan cities. Automobiles offer great benefits, especially convenience and efficiency. However, when more vehicles are used, more air pollutants are being emitted to the environment. Gas emission accounts for 23% of the total energy-related carbon dioxide equivalent emissions (IPCC, 2014) and doubled from 4.9% to 8.6% of the total Greenhouse gas emission (World Bank & World Development Indicators, 2018). By adding more pollutants to the environment, we are increasing our risk of having respiratory diseases (Te & Lianghua, 2019).

### b. Exposure to pollen and other allergens

Exposure to pollen and other allergens correlates with the likelihood of having a respiratory disease. Exposure can happen through many sources, including environmental exposure, both indoor and outdoor, and diet/hygiene (Gilles et al., 2018). Figure 3 below summarizes how different environmental factors interact to contribute to human health.

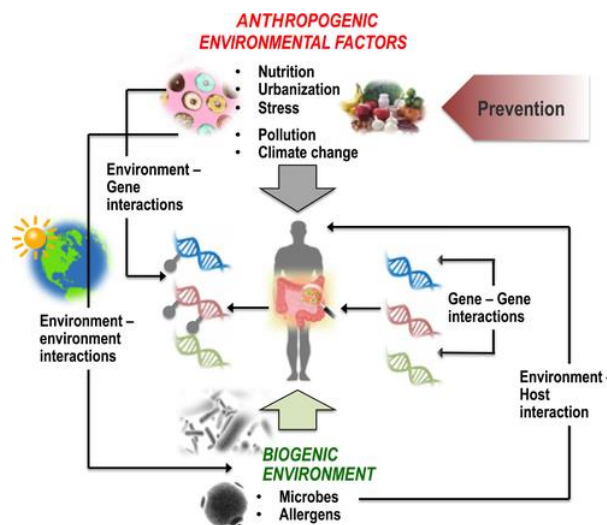


Figure 3: Anthropogenic environmental factors (Gilles et al., 2018)

#### *Environmental Exposure: Both Indoor and Outdoor*

A study done in Melbourne, Australia showed that infants have a higher chance of having aeroallergen sensitization, asthma, and hay fever when they are exposed to ambient levels of pollen in the first 6 months after birth. Even though these babies are high-risk subjects, it links high pollen concentration to sensitization and poses a possibility of a solution to lower the risk of contracting these diseases with early intervention (Erbas et al., 2012).

That being said, exposure to the environment should not be completely inhibited. Studies have indicated that rural environments provide exposure to beneficial aerosols. Cowshed dust, for example, produces an immune modulatory that is good for the immune system. People living near a traditional farm are less likely to develop allergic responses (Gilles et al., 2018). Similarly, in Europe, the risk of asthma is lowest in the rural farming community, and living close to well-controlled livestock is also associated with a better immune system (Nicolau et al., 2005). Therefore, being exposed to natural immunological stimulants during childhood may help build immunity to pollen allergies.

Not only the outdoor environment, but the condition of one's own inhabiting space can also negatively affect respiratory health. In South Asia, a study shows that children are more susceptible to wheeze (28.7% vs 12.5%) when they live in an old-fashioned and congested city (Gilles et al., 2018). In Bucharest, humidity and ventilation were found to be the main cause of respiratory allergies. Apartments with higher levels of humidity and insufficient ventilation had more pathogenic fungi spores, increasing the likelihood of contracting bronchial asthma (Chirilă & Florescu, 1990). In the US, many attribute the increasing number of allergy patients to the growing habit of staying indoor that leads to the sensitization of different forms of indoor allergens, such as dust mites and fungi spores (Platts-Mills, 2016).

### *Diet and Physical Health*

Not only the exterior environment, but what happens inside our own body can also affect allergy development. A person's microbiome is dependent on their diet and dictates his or her immune system, which is linked to the resistance to having an allergy. In rural areas, studies are being done suggesting that using unpasteurized milk and increasing endotoxin exposure can cause the body to produce more proteins that benefit the immune system (Nicolaou et al., 2005). In westernized societies, lifestyle can be overly protective, as children have little exposure to farm animals, less food diversity, more processed food, and less contact with siblings or peers because of increased time being indoors. This lifestyle lowers the immune system and can lead to future hypersensitivity to particles such as allergens (Gilles et al., 2018).

Atopic Dermatitis (AD), also known as eczema, is a common allergic disease among the US population. Heat, sweat, body pain, sleep deprivation, fatigue, and depression make exercising challenging and cause a decrease in physical activities in AD patients, making them susceptible to many health risks (Silverberg et al., 2016). Adults with eczema who have decreased physical activity, smoke and consume alcohol are at higher risk of developing cardiovascular and cerebrovascular diseases (Silverberg, 2015). They are also more likely to have a higher body mass index (BMI) and are at a higher risk of obesity, hypertension, diabetes, and high cholesterol, especially those who also experience fatigue or insomnia (Silverberg et al., 2015). Even though the risk of developing a cardiovascular disease is low, children with asthma and hay fever have a higher chance of obesity and vice versa (Silverberg, 2016).

Exposure to the environment and choosing a balanced and hygienic diet is crucial to maintaining a good immune system, therefore decreasing the likelihood of developing an allergy. However, not all air particles and food options are beneficial to human health, thus, a good overall knowledge about these factors is needed to fully understand how to best build up the immune system.

### **c. Attitudes towards healthcare**

When having an allergic disease, perspective towards disease management is an important factor in the extent and severity of the symptoms. A study was done in Australia to determine the perspectives of 47 adult allergic rhinitis patients on disease management. It shows that patients are usually confident in their ability to control the disease themselves. They often seek over-the-counter treatments and delay or avoid seeking help from professional health care providers. They reported feeling fatigued and uncomfortable in their daily lives. However, the financial burden

and being mistaken for having an infectious disease discourages them from going to a clinic. The combination of blind self-confidence and financial obstacles makes many patients opt for self-treatment, which can have a negative effect on the disease if done incorrectly. Inappropriate treatment at the onset of allergies can lead to future diagnosis of a more severe form of respiratory disease (Cvetkovski et al, 2018).

### 2.3 Addressing the Problem on a Global Scale

Pollen allergies have become a global issue. Many countries across the globe have begun studying pollen and its relationship to climate change, air pollutants, and lifestyle, in order to take preventative measures and develop better methods for dealing with the increase in the pollen production and allergies. This helps us understand what the implications of similar data in Bucharest may be.

#### 2.3.1 Efforts in Croatia

In the South-East region of Europe, a study in Croatia studied the correlation between pollen levels and ragweed sensitization. The data they gathered is summarized in Table 1 below.

Categories of Ragweed Pollen Level	Average Total Annual Ragweed Pollen Grains m <sup>3</sup>	Pollen Area Name	Children Recruited		Ragweed Sensitized	Restricted Ragweed Sensitized
			Number	%	%	%
High	13,079	Slavonski Brod	540	13.45	15.19	6.04
Medium-high	8275	Osijek	582	14.50	17.53	7.41
Medium	5189	Zagreb	1324	32.98	15.79	9.97
Low	422	Mediterranean	1568	39.06	1.98	0.64
Total			4014			

Table 1: Ragweed pollen levels and children sensitized

The results of this study showed that high levels of pollen in the atmosphere correlates with ragweed sensitization, associated with allergic response, rhinitis, and asthma, for children 2-13 years old. It suggested that ragweed control is the best approach to reduce this risk (Agnew et al., 2018).

A year later, the same group in Croatia performed a follow-up study to examine the severity of allergies in children. Their parents were asked to record the children's symptoms and medications each day over 306 days. The time span was enough to account for 3 pollen seasons. Children were the focus of this study because they often carry allergy symptoms into adulthood, and have less complex medical histories. The surveys were completed for 85 children for a total of over 10,000 entries. Survey questions asked the parents for their location, daily weather, observed air pollution, and household conditions. The answers to the survey were matched with daily pollen counts based on their locations. The results from these surveys were used to determine the threshold pollen level that would cause these children to exhibit symptoms. The three main symptoms caused by ragweed pollen were examined separately. Eye symptoms proved to be the most immediate response to pollen, followed by nasal, then bronchial symptoms. More specifically, it took four days for children to exhibit watery, irritated eyes after

pollen counts reached symptom-causing amounts. Their results also showed that if the children took preventative medication one day before their symptoms were supposed to start, it highly reduced the effect that those symptoms had on their body (Jones et al., 2019). This important information can help people treat their symptoms earlier if they are able to understand how the current pollen count affects the start of their symptoms. This information is helpful in drawing conclusions about symptoms in Bucharest and aid in developing information about personal symptom management.

### **2.3.2 Advancements in Western Europe**

In another study, a group of researchers from across all of Europe came together to analyze pollen count data from 66 stations over 16 years (1995-2010) to examine a multitude of variables: start, end and duration of the ragweed pollen season, maximum daily pollen count, first frost, last frost, and number of days in the frost-free period. These variables were all compared to their geographical coordinates. This data found three highly infected areas: the Pannonian Plain (encompassing much of Romania), Western Lombardy, and the Rhone-Alps region. The study found that all the variables were longitude dependent because the temperature changes the most over different longitudes. These variables also varied greatly based on altitude because at high altitudes the lack of oxygen stops the growth of plants. There were no significant trends based on latitude because much of Europe's varying geography with both mountainous and valley regions (Matyasovszky et al., 2018). In this study, there is only one pollen trap located in Romania out of the 66 total pollen traps located near the city of Timișoara in western Romania, about a 7-hour drive from Bucharest. Therefore, the data found in this study gave us no information about how pollen counts vary in Bucharest. However, this data from other areas of Europe was valuable to further focus our studies in Bucharest to analyze the most important information.

A different group of allergists and scientists from The European Commission Cooperation in Science and Technology (COST) came together to try to understand spatial and temporal variations of *Ambrosia* pollen in Europe in order to develop a strategy to manage invasive species in the future. They compiled 10 years of pollen count data for this study that spanned from 2004 to 2013. Not all 242 pollen traps collected data for the entirety of the 10-year span. Only 143 locations were included because they had 8 or more years of data. Seasons that were missing 7 or more days of pollen trap data during ragweed season were also removed from the data. The study found that the number of days when *Ambrosia* pollen grains were recorded decreased as distance away from infested areas increased. Figure 4 displays which of the 242 locations in this study showed the highest number of days where ragweed pollen was present (Sikoparija et al., 2016).



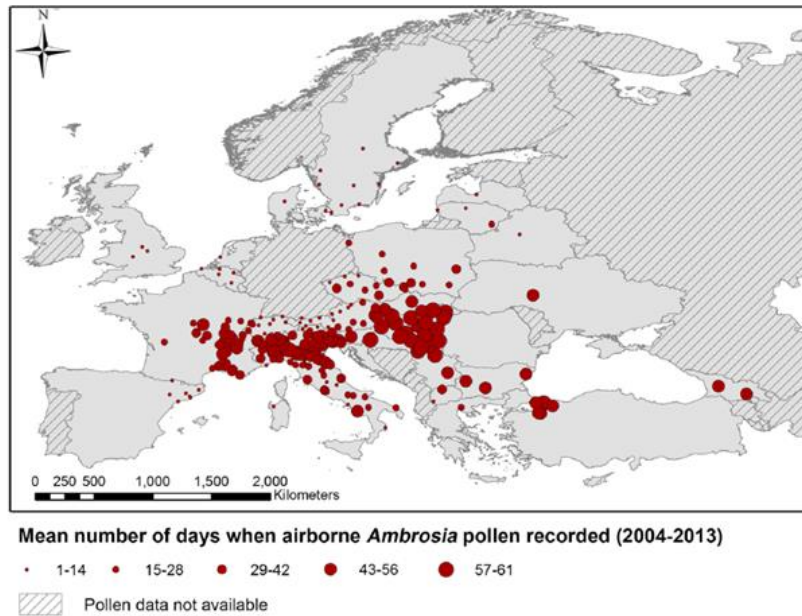


Figure 4: Map from COST study depicting the number of days *Ambrosia* pollen was present (Sikoparija et al., 2016)

Similar to the previous study, only one location in Romania was included in this study (although some symbols overlap the country make it appear that there are more). The symbols closest to Romania showed high levels of ragweed pollen, so if the rest of Romania follows this pattern, there may be a serious need for ragweed management. As Sikoparija et al. stated “It is also important to note for several spatially large countries (i.e. Romania, Turkey and Ukraine) pollen-monitoring networks are not dispersed over the entire territory, and so data included in this study are not representative of the entire area of these vast countries” (Sikoparija et al., 2016). So, although this study provided valuable insight about the change in pollen counts over time, we can only use it for comparative purposes in Bucharest.

The availability of pollen information in Western European cities is very high. Pollen levels and forecasts are published daily to a central website produced by the European Aeroallergen Network. The data is gathered so that maps of Western Europe’s pollen levels during particular seasons can be viewed, as well as predictions of how bad symptoms will be, which is affected by other factors as well. The predictions are based on 10-15 years of data from over 300 collectors. The website also hosts an app, allowing a European allergy patients to be conveniently informed at all times during the allergy season (Pollen Info., 2020). All of this information being available to the public allows allergy patients to make decisions that will help mitigate their suffering during the pollen seasons.

### 2.3.3 Personalized pollen forecast

Allergic rhinitis is also a prevalent disease in Germany and Austria. In order to tackle this problem, especially when the symptoms of each person vary and are dependent on the concentration and level of exposure, people are in the process of creating a personalized pollen-related data service. Using data similar to that shown in Figure 5 below, the service categorizes sensitivity, identifies different types of pollen, and forecasts the symptoms, designed to fit the profile of each individual.

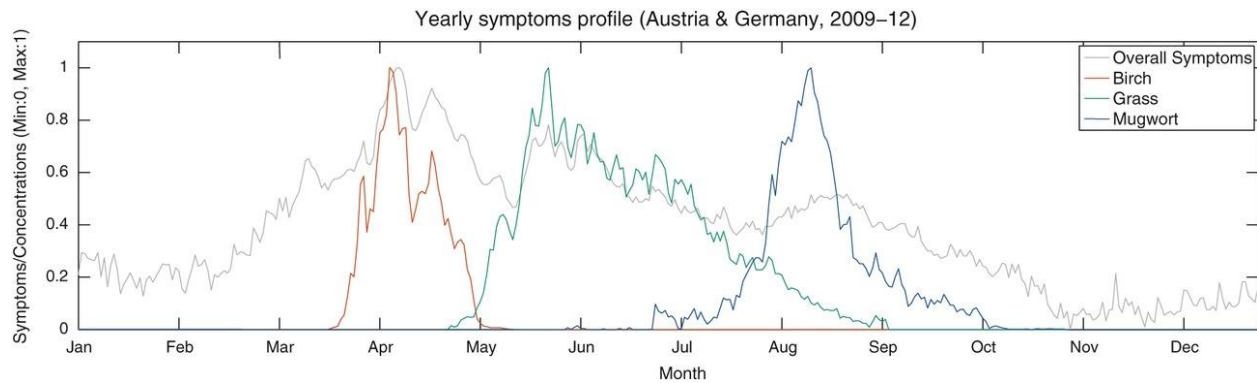


Figure 5: Symptoms profile showing prevalence in late spring and summer (Berger et al., 2013)

The data are collected from Patient’s Hay-fever Diary (PHD), pollen concentration data around Europe from the European Aeroallergen Network (EAN) database (ean.polleninfo.eu), data on air quality and pollen forecasting from SILAM modeling (System for Integrated modeling of Atmospheric composition), and analyzed. It also combines all information using computational intelligence methods (CIMs). The pollen concentration data is updated hourly or bihourly through all stations of the EAN. The amount of information is extremely large, therefore, this project still undergoes development (Berger et al., 2013). This technology would be very helpful to use in our project, however, it requires an extremely large dataset. Bucharest has only been tracking pollen for less than 10 years and the amount of data collected is not enough to draw significant conclusions. In the future, when more data is collected, this technology can be revisited and potentially implemented.

### 2.3.4 Attempted Elimination of Ragweed in Hungary

The chapter, *Why is biocontrol of common ragweed, the most allergenic weed in Eastern Europe, still only a hope?*, by Levente Kiss, presents a story of the failure of a biologist attempting to find a solution to the ragweed issue that plagues Eastern Europe. Funguses that are known to target the plant in North America are found in Europe, but Kiss was unsuccessful in getting the European strain to infect ragweed. Based on the data of others, the biologist knew that introducing the North American leaf beetle also had limited success in the practice. Searching for other predators of the plant led to the discovery of a different beetle, *Ophraella communa*, that seemed to be more successful in diminishing ragweed than the original leaf beetle. The collateral environmental impacts of the beetle were minimal. It shows a heavy preference of ragweed over any other plant, but was reported to cause some damage to sunflower plants when no other food source was given. Just as the Australian government had done in the past, the Hungarian government was strictly opposed to allowing the beetles to be imported. The blocking of the import stunted further investigation into the beetle’s effectiveness, and the European Union, out of fear of introducing a destructive invasive insect, would not fund any research into the matter (Levente, 2007).

A lesson to learn from this failure to reduce the ragweed population in Eastern Europe is a political lesson. While the ragweed is an incredibly irritating plant and causes many people to suffer from its highly allergenic pollen, the European Union, always wary of thoroughly tested innovations, does not believe that importing the beetle is worth the accompanying risks. Whether or not more research could be done to prove the beetle could not survive without ragweed, the

message that the European Union sends is clear. The insight of what the European union believed 13 years ago helped steer our suggestions away from introducing any form of biological control agent, especially since the European public is widely opposed to any genetic or biological changes in agriculture that might in the future hurt human or traditional natural processes.

### 2.3.5 Pollen Allergies in North America

Respiratory allergies have been a major chronic disease in North America since the 1990s (Ziska et al., 2010). Since ragweed originated from this area, it would be helpful to further examine its current research and policy concerning pollen allergies in order to compare this information to what can be seen in Romania today.

In the United States, pollen allergies affect the health of a third of the population and cost the country's economy approximately \$11.2 billion in 2005 (Ziska et al., 2010). Allergy symptoms are usually allergic rhinitis, conjunctivitis and asthma, with allergic rhinitis being the most common. The National Allergy Bureau (NAB) is a section of the American Academy of Allergy Asthma and Immunology Aeroallergen Network (AAAAI) and has been collecting pollen information from 51 pollen stations in the United States and Canada (50 in the US and 1 in Canada) since 2003. Some of the station locations are shown in Figure 6 below:

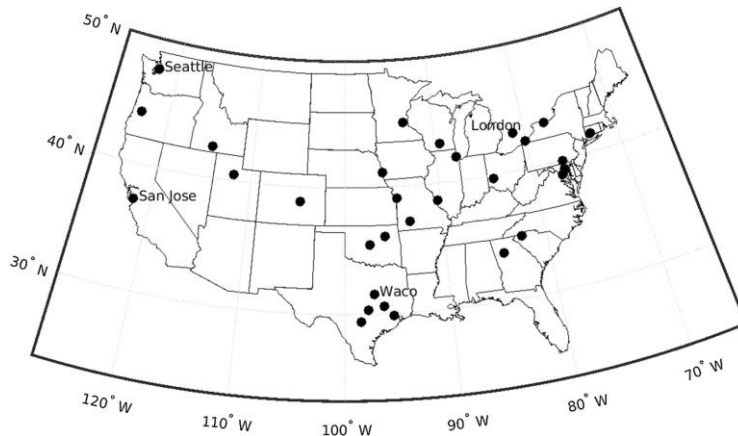


Figure 6: Locations of the NAB stations in the US (Lo et al., 2019)

These stations use Burkard volumetric air samples for pollen data collection, similar to what Dr. Leru has used in Bucharest. Even though tree pollen such as *Quercus* (oak) and *Cupressac* (cedar) are the most abundant, *Ambrosia* (ragweed) remains in the top five most abundant pollen species present. *Ambrosia* season in North America begins as early as July and extends to November (Lo et al., 2019). The calendar for *Ambrosia* pollen measurements at each station are shown in Figure 7 below.

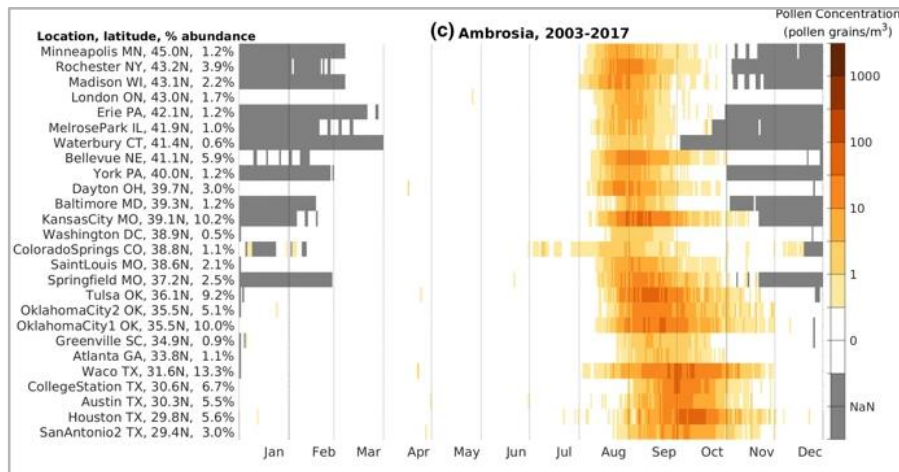


Figure 7: Ambrosia pollen concentration calendar (Lo et al., 2019)

Pollen allergy and related respiratory diseases have been an issue for North America for a long time. With many people affected, the U.S. has been eagerly searching for mitigation strategies.

### 2.3.6 Efforts to Protect People in North America

The United States has made attempts to protect the people from seasonal allergic diseases. There have been efforts to control the environment to reduce the symptoms. Doctors need to obtain the patient's environmental and medical history, and determine which allergens or pollutants they are most affected by. The guidelines for these tests can be found in the reports from the American Academy of Pediatrics. Additionally, for the school environment, the Environmental Protection Agency (EPA) and the Centers for Disease Control and Prevention (CDC) provide online resources on their websites to help families and educators to better control children's exposure to allergens (Matsui, 2016).

For adults, occupational asthma is a great concern, especially for those who work on job sites, accounting for up to 15% of the disabling asthma cases in the US (Cartier, 1994). There are over 200 organic and inorganic allergens for field workers, such as dust, plants, animals, gases and other chemicals (Chan-Yeung et al., 1994). In order to reduce occupational asthma, the Occupational Safety and Health Administration (OSHA) established some permissible exposure limits for some allergenic materials, such as cobalt, nickel, platinum salts, and isocyanates. However, the majority of the materials that cause asthma are still unregulated (Abramson, 2016).

Using the information gathered from the rest of the world and North America up to this point, knowledge can be extended and compared to Romania. The biological mechanisms and invasion of ragweed is known. The impacts of the factors of climate, pollutants, city upkeep, and other diseases are being studied. The efforts of other countries can be used as examples to learn from and can potentially be applied in Romania.

## 2.4 Pollen and Allergies In Romania

The pollen network in Romania is complex, consisting of many types of pollen, including tree, grass, and weed pollen. The abundance and allergenicity of each species differ from each other.

However, with many pollen species in the air, allergic sufferers, especially those with polysensitization, are heavily affected.

#### **2.4.1 Pollen Network in Romania**

In Bucharest, trees produce the first pollen recorded in early spring. Species such as poplar (*Salicaceae*), cypress (*Cupressaceae*), elm (*Ulmaceae*), alder and birch (*Betulaceae*), and fraxinus (*Oleaceae*) in March. In April, mulberry (*Moraceae*), plantanus (*Platanaceae*), Quercus (*Fagaceae*), and Pinus (*Pinaceae*) start to grow. In the summer, grass (*Gramineae*) starts flowering during May and June. Weed season is more dominant in late summer and fall, abundant species are ragweed (*Ambrosia artemisiifolia*) and mugwort (*Artemisia vulgaris*). Among all the species, *Ambrosia* leads in pollen count and allergenicity. (Leru et al., 2019)

The first recorded observation of ragweed in Romania came from the southern region of Orsova, a Danube river port, in 1908, although the allergenic version native to the US had not yet further distributed. Over a time span of many years, the weed spread to the northwest, west, south and southeast areas of the country. There is now evidence that it has spread to all regions of the country and is especially prevalent in the Southern and Central regions (Florincescu-Gheorghe et al., 2019).

#### **2.4.2 North-West and Central Romania**

In northwest and central Romania, allergic rhinitis was more prevalent in the northwest. Severe cases of rhinitis were mostly reported in the Central region and monosensitized patients in the northwest. They also concluded that co-sensitization, meaning sensitization to multiple unrelated pollen groups, likely leads to asthma (Boscan et al., 2019). Once data from a similar study is analyzed in Bucharest, it will provide an interesting comparison to this previous study. It will also contribute to the overall knowledge of pollen allergies in Romania to better inform doctors and patients of the risk factors involved.

#### **2.4.3 Southern Romania**

A study of 447 allergic rhinitis patients from the Central Romanian Plain looked at sensitization for Asteraceae weed pollen, common ragweed, and mugwort. The results were that 17.89% of the test subjects were sensitive to at least one weed pollen, ragweed being the main source. As shown in Table 2 below, the allergies were reported to be mostly moderate to severe, and when caused by ragweed, they are usually more severe and involve a persistent nasal allergy. The demographic of the participants additionally suggested that most patients are from urban locations (80%) (Cvetkovski et al., 2018).

<b>Table 1</b> <b>Ambrosia pollen sensitized patient characteristics</b>	
Age range	5-62 years
Age group most affected	31-40 years (30%)
Gender Female (%) vs Male (%)	52 % vs 48 %
Location Urban (%) vs Rural (%)	80 % vs 20 %
Evolutive forms of allergic rhinitis (%)	Intermittent (8%); Persistent (92%)
Severity forms of allergic rhinitis (%)	Mild (22%); Moderate-severe (78%)

Table 2: Characteristics of the sensitization to ragweed pollen (Cvetkovski et al., 2018).

#### 2.4.4 Bucharest

In Romania, the Allergy Center in Bucharest sees the symptoms of ragweed pollen allergies are serious and increasing. Cases of monosensitization have become more prevalent in the past three years, as seen by the orange bars in Figure 8 below. Significantly more patients also reported or were diagnosed with having moderate to severe symptoms, which poses a serious issue to the public health (Leru & Anton, 2019).

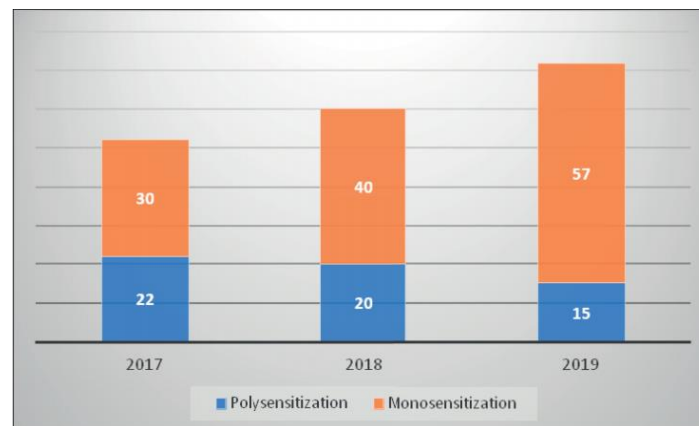


Figure 8: Number of new cases per year and allergic sensitization (Leru & Anton, 2019)

However, this preliminary study is the first of its kind in Bucharest. Much more data needs to be analyzed to fully understand the scope and factors involved in pollen allergies in Bucharest, which will help inform allergy patients of the risk factors and how to better manage their symptoms.

#### 2.4.5 Efforts in Bucharest

Recognizing allergic disease as a pressing issue, the Romanian government started taking actions. In March of 2018, the Parliament of Romania passed a law in an effort to stop the spread of ragweed in Romania. It states that owners and maintenance personnel of public lands such as railways, lakes, and ponds must make an effort to combat the spread of ragweed and destroy such weeds where possible (Florincescu-Gheorghe et al., 2019). However, until the spread of ragweed in Romania is controlled, it is important to deal with the current allergy issue at hand. The first step in dealing with this is understanding the issue in Bucharest and learning about any factors that may be involved through research in related areas.

Because Bucharest has been left out of many studies to date, Dr. Leru from Colentina Clinical Hospital in Bucharest began new efforts to learn about ragweed pollen and allergies in Bucharest. The first pollen trap in Bucharest was set up in 2013, long after many other pollen collection programs across Europe. In May 2019, Dr. Leru published information about the first 5 years of data for this pollen trap, which spans from 2013 to 2018. Their findings indicated higher atmospheric levels of ragweed pollen and a longer pollen season than anticipated (Leru et al., 2018).

With this new data, they also began to look at the number of diagnosed allergies. Their preliminary data showed that the amount of seasonal allergy cases increased 2.5-3 times each year over the course of their data collection. This translates to 2-5 new cases daily during the ragweed season. Most of these new patients are young people who have been living in Bucharest for 2-3 years with relatively high education, implying that sufferers with less knowledge may not realize that they have a treatable disease. Dr. Leru also declares the necessity of further research and further collaboration between Romania and other parts of Europe to share information. This will increase the knowledge of allergies, thereby decreasing the burden of pollen allergies and increasing awareness of the health impacts of ragweed (Leru et al., 2018). Dr. Leru is working towards putting Romania on the map of countries who are serious about researching the health impacts of pollen.

#### **2.4.4 Romanian Familiarity with Allergy Symptoms and Treatment**

To inform patients about how to manage ragweed allergies, it is important to know about the symptoms. Common allergy symptoms include inflammation, watery eyes, runny nose, sneezing, and coughing. The most commonly suggested way to reduce allergy symptoms is avoidance, which requires a reduction to exposure to the outdoors and limiting ways for pollen to enter the indoor environment. To help people reduce exposure, there are several internet sources and weather apps that report pollen count data for each day. It is also recommended that people with allergies avoid spending time outside on rainy days and exercise indoors. However, there are other treatment options for people who are unable to limit their exposure or suffer more severe allergic reactions to pollen (Tamarcaz et al., 2005).

The most common of these treatments is over-the-counter allergy medications, such as corticosteroids and antihistamines, which are meant to temporarily alleviate symptoms. However, these may not always improve severe symptoms and require routine taking at specific times of the day in order to be most effective. Ragweed-specific immunotherapy is the only disease-modifying treatment available. Allergen-specific immunotherapy (AIT) involves injecting the patient with ragweed allergen extract through a three year series of treatments. This extract contains the factor Amb 1, which is the most allergenic factor in ragweed pollen, causing 90% of all reactions. AIT allows the patient's immune system to become exposed to the allergen and build up a tolerance to it for the following pollen season. The effects are long-lasting after the three-year treatment period, however, they are costly, therefore, not always recommended as the best treatment (Chen et al., 2018). We took into account this knowledge of the symptoms and treatments to devise a method to enhance awareness of pollen allergy in Bucharest.

### **2.4.5 Romanian Perspective on Health**

Even though there are medically recommended treatments for allergies, it is people's perspective on seasonal allergies and their overall health that determine the actions they are willing to take. Both healthcare specialists and allergy patients' attitude towards this matter play an important role.

#### **a. From a medical perspective**

A German pharmaceutical company from Reinbek, Allergopharma GmbH & Co. KG, hosted The Future of the Allergists and Specific Immunotherapy (FASIT). At this conference, local professionals, including those from Romania, in academia, clinics, regulatory authorities and industry gathered and discussed the shortcomings of the existing immunotherapy service. They reported that even though the number of patients with allergic rhinitis increases and the effectiveness of immunotherapy is also improving, the amount of people that seek this treatment surprisingly decreases. The main concerns are determining the biomarkers to be able to diagnose and treat patients individually and provide early treatment to patients that have a positive response to immunotherapy, and making sure that the results of the effectiveness are not just because of the placebo effect. It appears that the medical professionals are actively putting effort into improving the treatment for allergic diseases (Pfaar et al., 2019).

#### **b. From a Patient Perspective**

The patients also play an important role in their own medical treatment, specifically for allergic diseases. A survey done in northeast Romania showed that most people from the urban area define self-medication as treating an illness by themselves without consulting a doctor. About one-third of the respondents said they took over-the-counter medicines after searching the internet, more than one-third said they chose self-medication because of financial reasons. They did think of the risk, however, under less severe circumstances, they would be more inclined to perform self-medication. They also found that women with higher education are more likely to provide self-medication to their children (Manole et al., 2017). At the Allergy Center in Bucharest, only 20% of the patients seek assistance from a healthcare provider within the first month of having allergic symptoms. The remaining 80% of the survey takers reported seeking medical advice only after 7 months to 10 years (Popescu & Tudose, 2011).

### **2.4.6 Areas for Improvement**

The city of Bucharest has made some positive steps in addressing the pollen issue, but there remains room to improve. The public seems to be unaware about the increasing pollen levels. There is little pollen information available for ordinary citizens, and the depth of data is lacking when compared to the distribution of public information in other European countries.

To begin, the public may lack understanding about pollen allergies. The seasonal, irritating but non-lethal symptoms of allergies may not be enough to drive one directly to a hospital. The profile of someone who gets diagnosed with pollen allergies is typically someone who has been living in the city for 2-3 years (Leru et al., 2018). Therefore they may not be able to properly recognize allergy symptoms as they occur.



Unfortunately for those with allergies, the pollen information in Romania is not readily available. The one pollen trap in the country has its past readings available on polleninfo.org, but the data set has not been updated since 2016. As a result, the live readings are not available on a day-by-day basis. (Berger et al., 2016). The live pollen data can be a very useful tool for helping the public mitigate their symptoms, for example, limiting outdoor time and medicating to reduce exposure to high pollen levels on a given day (Fritz, 1986).

Studies performed on pollen data in Romania thus far are not as in-depth as the rest of the European Union's. Reasons for this include the novelty of the collector device in Bucharest and the lack of multiple collectors. Compared to other European Union studies, which can correlate latitude, longitude, and elevation to pollen at different times of the allergy season, or can linearize years' worth of trends, the single data point showing the pollen readings of Romania show that there is more that could be done. (Pollen Info., 2020).

Bucharest's cityscape has changed rapidly over the years since 1990. A case study of Băneasa's neighbourhood revealed the extent to which the city has been affected by the expanding economy. Băneasa was chosen for its close relations with the capital Bucharest, meaning the changes made to one closely reflect the other. The overall effects on Băneasa are that around 8% of its green space was lost over 11 years (Scăunas et al., 2019). The significance of this finding relates to the idea that urbanization creates conditions that allow invasive species to quickly dominate the under-maintained areas and lower biodiversity, making pollen allergies more severe for the locals. With these changes being representative of the development of Bucharest, it gives an explanation to the rise in allergy symptoms.

Romanian allergists have agreed that more research and more air data is required to form better opinions on the pollen situation in Romania, though they confirmed that an increased number of patients have come to them with ragweed allergies in recent years (Leru et al., 2018).

## **2.5 Awareness Campaign and Public Outreach**

With the increasing number of seasonal allergy patients in Romania, and the lack of available information regarding their symptoms, it is important that the gap in the public knowledge is addressed. It seems that the public may also appreciate having access to local pollen information for prevention and avoidance, as well as preparation and planning. (Medek, et al., 2019).

### **2.5.1 Different Strategies to Raise Awareness**

A public awareness campaign can help raise awareness, educate, and increase interest in the respiratory allergy research. Research on different awareness campaigns show that there are three main approaches that prove to be effective: using still images, multimedia, and utilizing the involvement of the government and community.

#### **a. Still images**

Still images such as photographs and posters can replace lengthy words and sentences to convey a message effectively. They should always be included as part of a public outreach program, as is suggested by a study on the performance of the two European Years campaign to raise awareness about common European issues (Cmeciu et al., 2014). Print media, such as posters and

billboards, are widely used for their accessibility and informative quality. Still images can also be seen on social media and websites. As technology evolves and the number of internet users increases, social media and websites are major platforms for many campaigns to utilize and provide more in-depth knowledge (Iannacone & Green, 2014).

### **b. Multimedia**

Multimedia, such as video and audio, is another approach. The Australian campaign to educate the public about skin cancer had commercial videos on television, radio, and websites (Iannacone & Green, 2014). The public outreach program by the Office of Public Health Preparedness and Response in the Centers for Disease Control and Prevention (United States) sent its subscribers videos providing advice on how to prepare for natural or manmade winter hazards in 2011. They also reported that more than half of the videos (54%) were watched on cell phones, 32% on computers, and the rest by people searching the internet. 21% of the participants, who did not have internet connection in their phone, still received and were able to watch the videos. This suggests that at this time cell phones are the most effective platform to deliver a multimedia message, although anti-spam laws might create some complications (Bandera, 2016).

### **c. Government and community**

During the awareness campaign on skin cancer in Australia mentioned above, the government and community also participated. The government funded most of the campaigns and passed legislation, from sunscreen testing and UV protection ratings on clothing to restricting tanning devices. They also provided educational sessions at schools, and encouraged local clinics and hospitals to inform their patients about skin cancer (Iannacone & Green, 2014).

## **2.5.2 Choosing the best strategy**

In order to choose the best strategy for our campaign, we need to fully evaluate the message we will convey, the Romanian people's current understanding of the message, and different ways the people might perceive this message because of the nature of Romanian culture.

### **a. The Message to Convey**

The key aspects that determine the success of an awareness campaign are the message (54%), visual identity (24%), social cause (16%), and concept (6%), according to a study done on 50 Communication and Public Relations students in Romania. Social campaigns usually aim to influence the emotions of the people, which is the first step to reach their belief and change their behavior. The report of this study suggested that by targeting emotions, these campaigns can catch people's attention positively and effectively (Petrovic & Dobrescu, 2013). In Romania, it is important to understand the social and cultural aspects of its history. Before the emergence of Communism, Romania was a peasant society whose characteristics included a higher collectivism index than individualism, meaning most people valued the community and helping others more than "every man for himself". Under Communism, ideal collectivism was reinforced, however, due to the highly diverse society, the process was unsuccessful. The totalitarian government put the Romanian people under repression, making them obey but also creating a distrust against the authorities. Therefore, even though Romania used to be a peasant society, true collectivism and national identity were not quite established. (Gallagher, 2005).

Since the history of Romania is complex, with a long heritage of authoritarianism, we believe that appealing to the traditional sense of communal responsibility and reminiscing about the past, awareness campaigns can reach Romanians in a more emotional way, which can help convey the message. The question was, how could we present the message to effectively influence people?

### **b. The Challenges**

The advertising industry in Romania is still relatively new and was negatively perceived when it was first introduced. In a study on how people perceive advertising and its socio-economic effects, Romanians seem to have a more positive attitude nowadays. They find advertisement informative, entertaining and fulfilling a social role. However, they are still reserved and skeptical about its social benefit (Iannacone & Green, 2014). In the difficult transition from communism to capitalism, the removal of governmental regulations that occurred with the collapse of the command economy meant that it was hard to prevent corruption in businesses and government practices. At the expense of the people, medical establishments were also subject to criticism and advertisement could be considered a form of propaganda. On the other side of the matter, the advertising industry, especially nowadays, has boomed. Competition is intense and companies are trying hard to be creative, sometimes in controversial ways. Female sexuality, materialistic and simple-minded exploitation are some of the popular approaches in the United States that are controversial and heavily criticized. Therefore, having a good understanding of the message we wanted to convey with our awareness campaign, along with the cultural and socio-economic background of citizens of Romania was beneficial in deriving an appropriate strategy.

In conclusion, the rise in pollen allergies has been causing health problems in many countries around the world. However, research on this field in Romania is relatively new and dispersed. It is important to centralize all the information so that data collection and analysis can be done effectively and integrated to the European Aeroallergen Network. Additionally, by conducting an in-depth comparative study between Romania and other countries affected, we can better understand the local pollen allergies problem in a worldwide context. Lastly, through an appropriate awareness strategy, it is necessary that the public is informed and knowledgeable about pollen allergies for better prevention and treatment methods.

## Chapter 3: Methodology

The goal of this project was to help Dr. Polliana Leru and her team at Colentina Clinical Hospital and Carol Davila University of Pharmacy and Medicine organize data and make correlations between pollen counts, pollution, climate and lifestyle choices to combat the rise in seasonal allergies. To achieve this goal, our team obtained all current data, created a software tool for data analysis, analyzed correlations in the data and compared them to other countries, examined future trends, and devised a strategy to educate the public about the rise in seasonal allergies. These steps are outlined in Figure 9. Our timeline to complete these activities can be found in Appendix B.

As mentioned in the Introduction, due to the global outbreak of COVID19, we were unable to travel to Bucharest and all work was done remotely in the United States. Fortunately, data could be sent electronically so the only change in our methodology was the implementation of the lifestyle survey, which will be further explained later in this chapter.

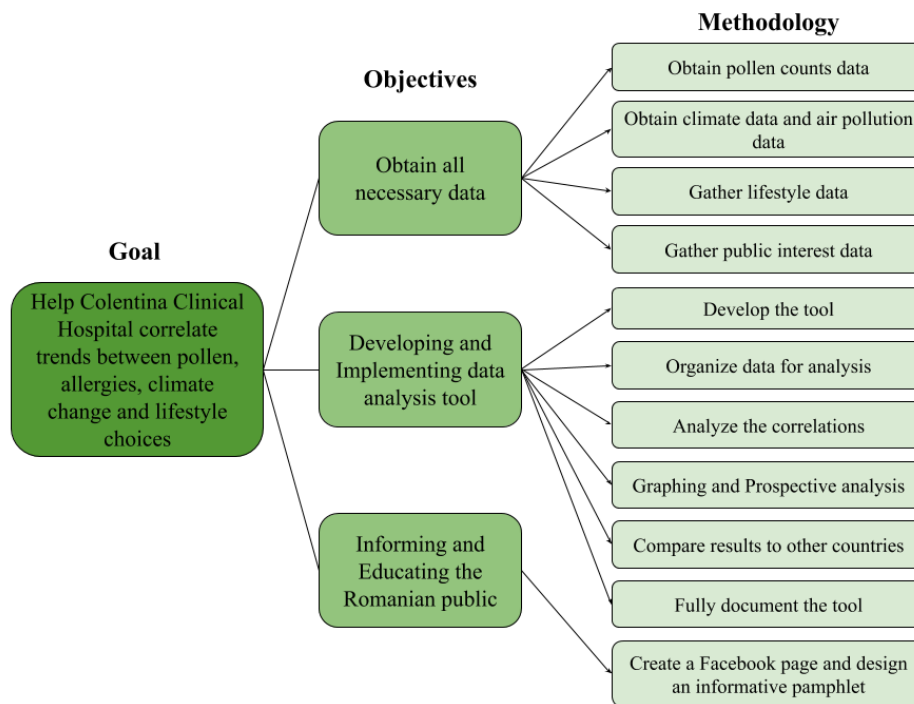


Figure 9: Project Goals, Specific Objectives and Associated Methods

### 3.1 Objective I: Compile Data on Pollen, Allergies, Climate and Lifestyle Choices

Before we started any analysis, we needed to collect all necessary data. Throughout the project, we worked with data of pollen counts, meteorological information, chemical air pollutants, and public interest. Data about pollen counts and air pollutants was sent by our collaborators, and additional meteorological data was collected by the National Meteorological Agency and the National Institute for Research and Development in Optoelectronics (INOE). There is little existing data about the types of the lifestyle choices that Dr. Leru wanted us to analyze, so we developed our own method to collect this through a survey. Additionally, we were unable to get

respiratory health data from Romania during the pandemic. We have instead collected data about the general Romanian public's interest in pollen and allergies using Google Trends.

### 3.1.1 Obtaining Pollen Data

Dr. Leru and her collaborators have been collecting pollen data using the pollen trap located at Colentina Clinical Hospital since 2014. Our team obtained this data from Dr. Leru's PhD students and made our data analysis tool compatible with their data formats. We received pollen data for 37 different species, including *Ambrosia* (ragweed), grasses and trees, consisting of a daily count of pollen particles per cubic meter of air (Leru et al., 2018). Dr. Leru informed us that the pollen trap failed to correctly capture *Ambrosia* pollen in 2015, so we removed the *Ambrosia* 2015 data to prevent it from inaccurately skewing our results.

### 3.1.2 Obtaining Climate and Chemical Air Pollution Data

Climate data was provided along with pollen data from Dr. Leru's PhD students. It was collected from the National Meteorological Agency (Global Surface Archives, 2019), consisting of measurements for temperature, dew point, relative humidity, solar radiation, wind direction, wind speed, and precipitation amount, all of which have been previously shown to affect the spread of pollen. We also received additional Bucharest climate data from her collaborators at INOE, allowing us to fill in the missing data points in our data set for the first half of 2014 and the last half of 2019.

Dr. Leru's collaborators also gave us the chemical pollution data that she has obtained from the National Air Quality Monitoring Network stations B3 and B1 since 2014, containing measurements of PM<sub>10</sub> (particulate matter with a diameter of 10 microns or less), PM<sub>2.5</sub>, ozone, toluene, benzene, butadiene, carbon monoxide, sulfur dioxide, nitrogen oxide, nitrogen dioxide, and alternative forms of nitrogen oxide species (NO<sub>x</sub>). Figure 10 below shows the location of all 6 air quality stations in Bucharest in context with the pollen trap location.

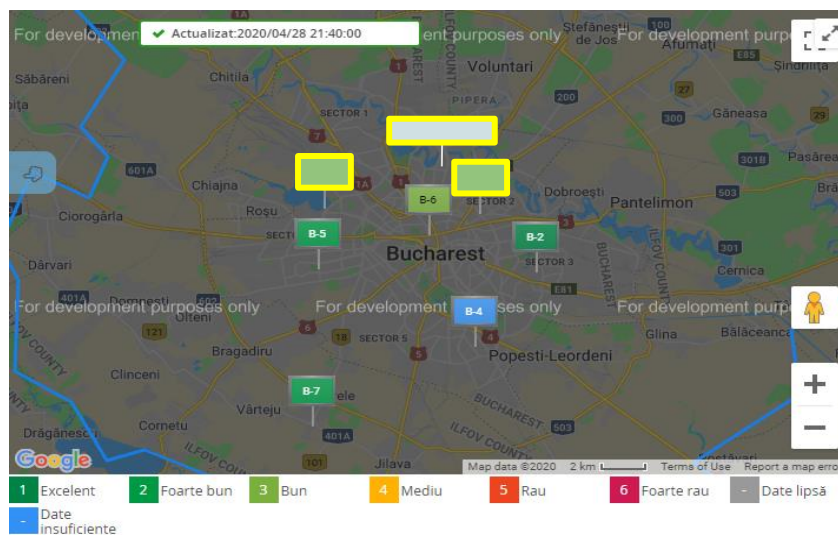


Figure 10: Air Quality Monitoring Stations in Bucharest (National Air Quality Monitoring Network)

### **3.1.3 Gathering Data on Romanian Lifestyle Choices**

As mentioned in the Background, studies from other countries have found a correlation between lifestyle choices and seasonal allergies. These correlations were shown both directly to impact the individual's health and indirectly to affect the environment and increase pollen production. However, public data about general lifestyle practices of the Romanian people are lacking. Therefore, we designed a survey to begin collecting this data and for future distribution until a large enough data set is collected. To design an effective survey, we looked at similar studies done in Romania and other European countries, and applied their methods.

### **3.1.4 Iteration of Survey Questions**

Our original plan was to conduct a focus group of 20 participants from Colentina Clinical Hospital with various backgrounds and knowledge of allergies and medicine, including doctors, administrative staff, and patients, to revise the survey questions. However, with the project having to be carried out remotely, we sent the survey to Dr. Leru, who had experience distributing surveys and is an expert in allergies (Leru et al., 2015), as well as a small group of local friends, family and classmates for feedback and sample responses for the iteration of the questions. The final version of the survey questions can be found in Appendix A. We distributed our survey to a Romanian *Ambrosia* allergy sufferers Facebook group for quantitative responses. Dr. Leru also distributed the survey to some of her patients.

### **3.1.5 Gathering Public Interest Data**

Along with the lifestyle survey, we wanted to include data on the interest in pollen allergies of the Romanian people. We did this using Google Trends, which is a feature that shows statistics on Google searches in any given location around the world. A popular term suggests that there is an interest in learning more about it. We downloaded and used this data to represent the public's level of allergy symptoms because we can connect the number of people affected by pollen and the number of people searching for information about allergies and ragweed.

## **3.2 Objective II: Developing and Implementing a Data Analysis Tool**

Dr. Leru and her team did not have a solid method for statistically analyzing their data, so we decided to develop a software tool that can analyze large sets of data and can be easily used by others with little statistics or computer science background. We then used this tool, termed the "Correlation Machine", to analyze the data on pollen, pollution, climate, and public interest by calculating correlations, predicting future trends, and then compared the results to other countries.

### **3.2.1 Developing the Correlation Machine**

To create a method for Dr. Leru and her team to easily analyze their data in the future, we designed a user interface (UI) with simple interactive features. We chose to code everything in Python due to its wide offering of libraries, widespread use, and comprehensive documentation. This allows our group and those who come after us to manage and use the program.

The data analysis features we implemented consist of compiling and managing data, calculating Spearman's correlation coefficients, producing graphs, and generating lines of regression. We

also created optional settings for the user to look at specific dates or seasons, calculate yearly or monthly averages, or extend a regression line to a future year. We chose these options based on the specific correlations Dr. Leru was interested in seeing. We also made the tool user friendly by programming it to update all correlations to a table, color coding the numbers so someone of any background can easily understand their results, and to document the correlations by saving them to Excel. See the Results section 4.1 for a description of this final deliverable.

We ensured the Correlation Machine was easy for anyone to distribute and install by tightly packaging all of the code. The user does not need to download anything other than a single executable file that they can easily open to run the program whenever they want.

### **3.2.2 Organizing the Data for Analysis**

First, we used the Correlation Machine to organize all of the data into a consistent form for easy interpretation. Since the input data can be in many different formats, we made the tool adaptable to many variations. We designed the tool to be capable of continually updating with new data, without making any modifications to the source file. We implemented this feature so our collaborator can continually collect more data and expand the results over time. Additionally, since there are many different types of data, such as pollen or climate, that may be input to the tool, it allows pollen to be manually distinguished from others and minimally processed to normalize all data.

We used these features to compile all of the data into one large “master” file with the dates shown on the leftmost side and each column representing a different category. Pollen categories were distinguished and the total pollen count per day was added to the data set.

### **3.2.3 Analysis of Correlations**

Once the data was compiled, we analyzed the correlations between pollen, climate, pollution, and public interest. We chose Spearman’s coefficient to calculate correlations because it is most commonly used in similar pollen and allergy studies as a way to statistically quantify relationships between variables. Spearman’s coefficient represents how well the data fits a monotonic function. A positive correlation means that, as the values of one variable increase, so do the values of the other variable, whereas a negative correlation means that one variable decreases as the other increases.

We used the Correlation Machine to calculate the coefficients, and considered those greater than 0.4 and less than -0.4 to be significant (Akoglu, 2018). We also calculated a p-value, which describes the probability that the correlation is accurate. A p-value of less than 0.05 was considered statistically significant. We chose these boundaries using standards for the research community.

Correlation coefficients are a computational way to indicate cause for further investigation. While this does not prove causation between the variables, a strong correlation indicates the potential to predict future trends in the relationships between factors of climate, lifestyle choices, pollen levels, and seasonal allergies. We took into consideration the nature of the data to understand what the coefficients describe. We also consulted with our collaborator for her expertise in pollen allergies and used her guidance to conduct our analysis.

### **3.2.4 Graphing and Prospective Analysis**

XY scatter plots have been used in other studies to represent the correlations of pollen symptoms to other factors, however, we designed our tool for viewing both the XY scatter plot and boxplot for any data set. A box plot with whiskers is capable of providing a year's worth of information from a glance, even factoring in uncertainty unlike a yearly average, to provide a cleaner visual. We discussed with Dr. Leru and determined that scatter plots were more relevant in this particular study for comparability with studies in other countries.

Another area where other studies are lacking is predictions of how the relationships evolve. We improved this method by adding regression as an additional level of analysis. Regression determines the relationship between variables using a single best-fit line and creates a predictive model of how they may interact in the future. We looked at three types of regression to analyze, since one may be more suited than another for any given relationship, and programmed the tool to be capable of plotting all three. We looked at linear regression, which uses a straight line, second-order polynomial, which uses a single-curved line, and LOESS, which shows a best-fit for non-linear trends. Since LOESS uses non-parametric functions for data smoothing, we could not use it to predict how the trend will continue in the far future. However, visual analysis of this type of trend was still important in understanding the relationship and predicting how the trendline might continue in the near future.

We completed a prospective analysis to predict future pollen and allergy trends based on our correlation and regression results, current climate and pollution patterns in Bucharest, and results from other studies. These regressions and projections were combined with a contextual knowledge of how pollens interact with various factors, as well as how different factors may behave over time. An example of the importance of context with climate change is if one were to create a linear regression of the last three years' weather, one might falsely assume that the average temperatures are dropping and therefore the climate is cooling. One must use the distinction between weather and climate to understand that three years of decreasing temperature does not indicate global cooling, as climate should not be measured over a matter of years, but decades or centuries. For this reason, we could make preliminary predictions, but confident projections cannot be made until much more data is gathered.

### **3.2.5 Comparing Results to Other Countries**

Models of the relationships between factors are important because they provide us with the necessary information to draw conclusions. The conclusions we drew were compared to similar studies from the United States and other European countries. We chose the studies to use for comparison based on if they used similar methods to our study, like Spearman's coefficients or linear or polynomial regressions. We also used studies that had a data set greater than 5 years to see which trends they found that were consistent over longer periods of time. The purpose was to make connections between Bucharest and other countries regarding the rise in pollen allergies and put an emphasis on the need for more research on this problem in Romania.

### **3.2.6 Documentation**

To facilitate the use of the Correlation Machine, we also created technical documentation, written as clearly and literally as possible. It provides technical information about the



development of the tool, how the internal code works, possible ways to modify the source code, and how to remake the executable file once a modification is made to the source code. See Appendix D for technical documentation of the tool. We also made sure to leave clear comments in the code itself to briefly describe the goal of the individual lines or blocks of code to help future contributors understand, replicate, or update the source code. We publicly published all of our source code to GitHub (<https://github.com/trschaeffe/PollenTool>) for anyone who wants to use it or make modifications in the future, with special care taken to not share our collaborator's data along with it.

We also created a User's Guide with step-by-step instructions and a series of YouTube video tutorials to help anyone who has limited experience with statistics or computer science using the tool. These additional documents contain annotated photos to help guide the reader and have a flexible format to allow people who are not fluent in English to learn at a pace that is comfortable for them. We made the guide and video tutorials accessible through links in a "Help" tab within the tool itself. A link to the User's Guide can be found in Appendix D.

To assess the effectiveness of our documentation, we evaluated how well we met the guidelines of Nielsen's Heuristics and adjusted the functions of the tool to satisfy them as best we could. We also sent the tool along with the User's Guide to Dr. Leru and our advisor Professor Addison to test. They assessed how easily an inexperienced user could install and use the tool to analyze a small data set based solely on the documentation. Using their feedback, we made adjustments to the appearance of the tool and wording of the guide to ensure our materials were user-friendly.

### **3.3 Objective III: Informing and Educating the Romanian Public**

In addition to analyzing the data, we wanted to inform and educate the public about pollen allergies and the related factors so people can try to reduce their effect on the population. Keeping in mind the cultural and social implications of Romania's forty-five year history of being a communist country, we believed that the most neutral and effective approach to raise awareness while avoiding any semblance of propaganda was to create a Facebook page to provide a social media presence for pollen allergies research. Additionally, we designed an informative pamphlet to be distributed to the public and a website to showcase all of our project work.

#### **3.3.1 Facebook Page**

The purpose of the Facebook page is to provide information to the public in an easy and accessible way, as well as gain more interest in research and encourage people to reach out if they have any questions. Our Facebook page provides the link to the lifestyle survey for our collaborators to collect more data. It contains posts about basic pollen and seasonal allergy information, updates on research, and has links to useful articles and news. We created this page and posted at least once a week as our project progressed to help form a strong informational basis for our visitors. We handed over the page as a deliverable at the end of the project.

#### **3.3.2 Pamphlet**

In addition to the Facebook page, we designed a pamphlet to provide basic information about pollen and seasonal allergies on a global scale, common symptoms, as well as several prevention and treatment methods in a compact format. The pamphlet can be distributed as physical or

electronic copies. It includes a link to the Facebook page and our contact information. We revised the design based on the feedback from our collaborator and advisors, making sure all information was accurate and no images infringe copyright laws. The final version was sent to Dr. Leru along with our other deliverables.

### **3.4 Desired Outcomes**

The goal of this project was to assist Dr. Leru in addressing the pollen allergy increase in Bucharest. The first step was to analyze previously collected regarding pollen, pollution, climate and public interest. Then, we streamlined analysis of future data and created an easy way to add new data to the pre-existing dataset. Additionally, comparing our findings to other countries helped us to put Romania in the global context of pollen allergies in order to find ways to decrease their negative impact in Bucharest. Finally, we created materials to raise awareness about the rise in allergies to help further educate the Romanian public. We also created a website for our project, containing all the deliverables, as well as information about our group members. We hope to prove that further support for allergy research is valuable to help the Romanian people learn more about how pollen and seasonal allergies affect their region.

## Chapter 4: Results and Discussion

Using the above methods, we were able to create a software tool with supporting documentation so that Dr. Leru and her team can easily install it and add new data in the future. Using this tool, we identified some factors that were correlated to the amount of total pollen, *Ambrosia* (ragweed) pollen, grass pollen, and allergies in Bucharest, as well as found factors that were not correlated. We were able to compare all of these results to similar studies done in other countries to determine how Bucharest is both similar and different from them in experiencing issues with pollen allergies. We were also able to provide prospective trends about how the pollen issue will evolve and assess the findings of our lifestyle survey thus far.

### 4.1 The Correlation Machine

Our data analysis tool can analyze the data our collaborators have gathered to determine what correlations exist between climate, pollution, pollen levels and allergy symptoms and provide prospective trends in the data.

Using the “Data Entry” tab (See Figure 11 below), the user can import any of their data files and compile all of their data. There are several spreadsheet formats it is capable of reading, making it possible to compile data from multiple sources with ease. It is flexible to accept data types that may be desired in the future. This tab can also be used to manually add an individual data point, designate specific pollen categories, and calculate the daily pollen counts.

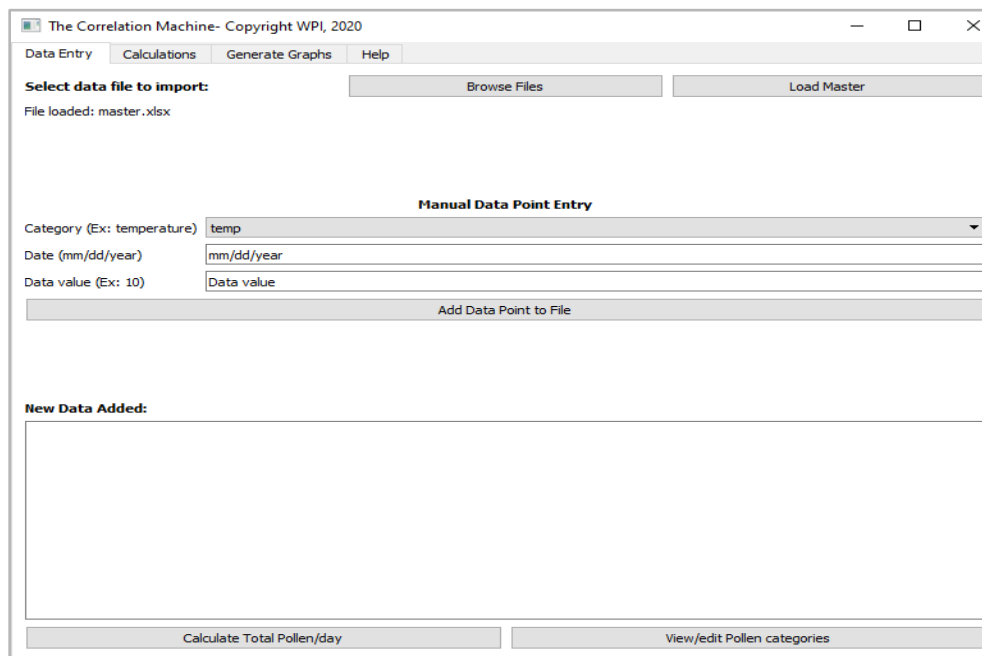


Figure 11: The Correlation Machine, Data Entry Tab

Using the “Calculations” tab (See Figure 12 below), the user can calculate the Spearman’s correlation coefficients between any two categories in their data set. There is an option to calculate based only on certain dates within the pollen season each year, monthly or yearly averages, or specific dates. The results are conditionally formatted to appear in different colors for easy interpretation. The user can also easily save all of the results to Excel using the tool.

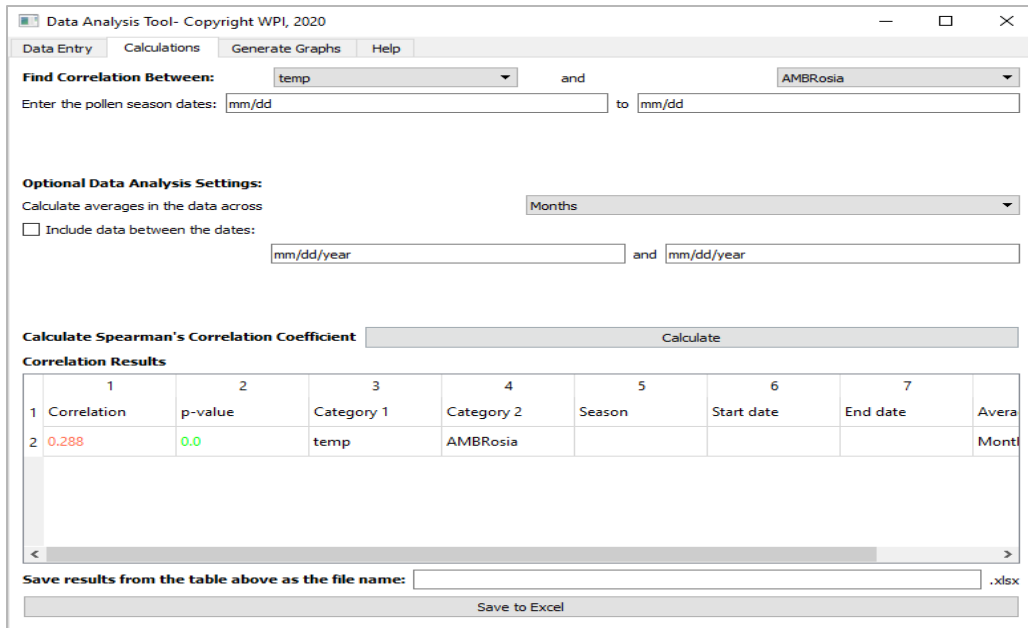


Figure 12: The Correlation Machine, Calculations Tab

Using the “Graphing” tab (See Figure 13 below), the user can generate a box plot or XY scatter plot showing up to six categories at once. The same optional settings as on the calculations tab are available for graphing as well. Additionally, three different types of regression lines may be added and extended into the future.

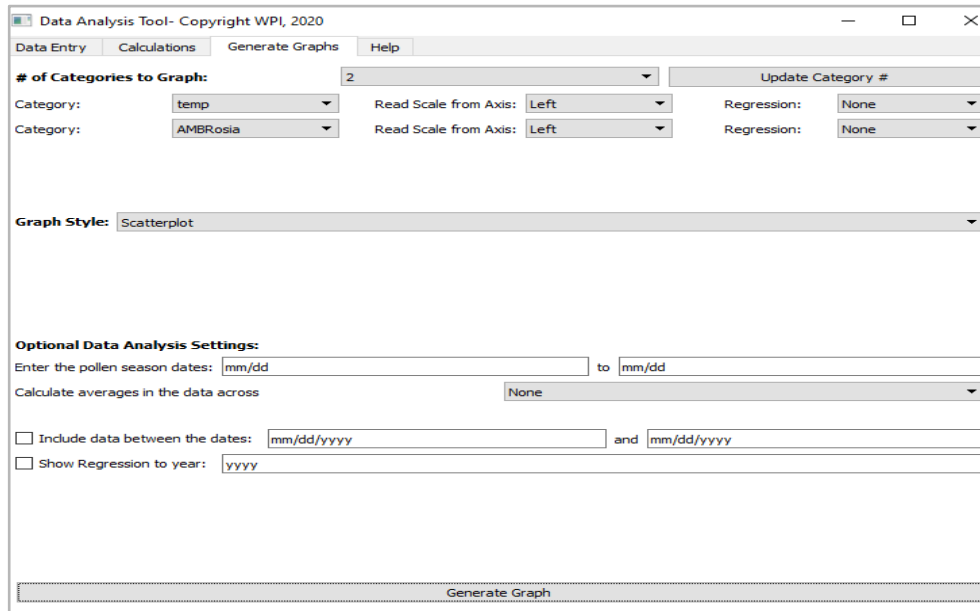


Figure 13: The Correlation Machine, Graphing Tab

We incorporated “help” links in the fourth tab of the tool to explain and troubleshoot any issues users have with these functions. These links take the user to our video tutorials and the User’s Guide, a link to which can be found in Appendix D along with our documentation.

## 4.2 Significant Correlations

We used our tool to calculate correlations between pollen, pollution, climate, and public interest data. While our tool successfully calculated the Spearman’s correlation coefficients, it was unable to produce many significant correlations between pollen counts and other factors due to the limited amount of data available. The pollen trap failed to collect *Ambrosia* pollen in 2015, so we were only able to work with five years of *Ambrosia* data (2014, 2016-2019). Additionally, there are many small gaps in the available weather and pollutant data for Bucharest.

Since the data is in relatively early stages of collection, more will be needed to fully confirm some of these correlations, especially those based on yearly averages. We are currently relying on monthly and daily averages to make correlations. Seasonal conditions affect these averages, meaning that if a factor’s level naturally becomes higher during pollen season every year, it will affect the results. Yearly averages would avoid this conundrum, but they are not currently strong enough due to the limited number of years this study examines. For this reason, context was a very important factor when determining significance. The results we deem accurate are presented in this chapter, as well as a discussion of why some may not be accurate considering the context.

The full raw correlation results can be found at this link, if you would like to view them:

[https://docs.google.com/spreadsheets/d/1rI\\_1BcpQuP0aZQcSmsAokMhGYLoNv3h2PObYdCimxP4/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1rI_1BcpQuP0aZQcSmsAokMhGYLoNv3h2PObYdCimxP4/edit?usp=sharing)

### 4.2.1 Total Pollen Level Correlations

Correlation	p-value	Category 1	Category 2	Season	Averages
-0.657	0.156175	Total Pollen	PM10	5/1 - 10/1	Years
0.107	0.610681	Total Pollen	PM10	5/1 - 10/1	Months
-0.005	0.893932	Total Pollen	PM10	5/1 - 10/1	
0.6	2.08E-01	Total Pollen	wind_spd	5/1 - 10/1	Years
0.296	0.0084	Total Pollen	wind_spd	5/1 - 10/1	Months
-0.021	0.542739	Total Pollen	wind_spd	5/1 - 10/1	
0.8	0.2	Total Pollen	Precipitation amount	5/1 - 10/1	Years
0.092	0.675593	Total Pollen	Precipitation amount	5/1 - 10/1	Months
-0.112	0.006996	Total Pollen	Precipitation amount	5/1 - 10/1	
0.2	0.704	Total Pollen	rh	5/1 - 10/1	Years
-0.321	0.0604	Total Pollen	rh	5/1 - 10/1	Months
0.104	0.002195	Total Pollen	rh	5/1 - 10/1	

Table 3: Total Pollen Correlated with PM<sub>10</sub>, Wind Speed, Precipitation, and Relative Humidity

Most of the correlations made between total pollen levels and the meteorological and pollution factors were weak and insignificant. This is likely because total pollen includes tree, grass, and

weed pollen, which respond differently to different factors, produce different pollen levels, and have different pollen seasons. Some of the notable correlations that it did create were between total pollen and wind speed ( $r=.3$ ,  $p=.008$ ) and humidity ( $r=-.321$ ,  $p=.06$ ) by monthly average. These correlations indicate that total pollen counts are greater in warm, dry months, which aligns with our knowledge of when pollen is released. Wind picks up the pollen grains and carries them further away from the plant, therefore, an increased wind speed causes a greater distribution of pollen in the air. When there is less moisture in the air, this can also increase the levels of airborne pollen because pollen grains are not being picked up by water droplets. Yearly averages indicate that precipitation may play a role in helping plants grow to full potential before releasing pollen, though as previously stated, more collection of data must be done before yearly averages can be statistically relied upon.

PM<sub>10</sub> (particulate matter) was one factor that we expected to be correlated at the daily level with total pollen. We have been told by Dr. Leru and other researchers in the field that some pollen has the potential to be smaller than 10 microns in diameter, making it considered a PM<sub>10</sub> particle. Dr. Leru has informed us that *Ambrosia* pollen is too large for this confusion to occur, except in the case of extreme weather. We did not observe this effect with our total pollen and PM<sub>10</sub> daily ( $r=-.005$ ,  $p=.89$ ) and monthly ( $r=.107$ ,  $p=.61$ ) correlations. Individually correlating each species of pollen to PM<sub>10</sub> revealed that *Artemisia* and *Ambrosia* are the only types of pollen that could potentially affect the PM<sub>10</sub> count. Results of the full test are shown below in Table 4.

Correlation	p-value	Category 1	Category 2	Season
-0.104	0.009292	ACER	PM10	5/1 - 10/1
-0.049	0.22242	AESCulus	PM10	5/1 - 10/1
-0.014	0.72096	ALNUs	PM10	5/1 - 10/1
0.256	0	AMBRosia	PM10	5/1 - 10/1
-0.083	0.038015	APIAceeae	PM10	5/1 - 10/1
0.207	0.00E+00	ARTEmisia	PM10	5/1 - 10/1
-0.02	0.621106	BETUla	PM10	5/1 - 10/1
nan	nan	CARPinus	PM10	5/1 - 10/1
-0.047	0.2416	CASTanea	PM10	5/1 - 10/1
nan	nan	CENTAurea	PM10	5/1 - 10/1
0.139	0.000498	CHENopod	PM10	5/1 - 10/1
-0.04	0.314938	CORYlus	PM10	5/1 - 10/1
-0.074	0.063833	CUPRes	PM10	5/1 - 10/1
-0.074	0.063833	CUPRes	PM10	5/1 - 10/1
nan	nan	FAGUus	PM10	5/1 - 10/1
-0.13	0.001145	FRAXinus	PM10	5/1 - 10/1

0.012	0.760622	GINKo	PM10	5/1 - 10/1
-0.183	4.00E-06	Graminee	PM10	5/1 - 10/1
-0.032	0.429313	INDE (?)	PM10	5/1 - 10/1
-0.034	0.392579	JUGLans	PM10	5/1 - 10/1
-0.043	2.85E-01	Liguliflores	PM10	5/1 - 10/1
-0.092	0.022333	MORAceae	PM10	5/1 - 10/1
-0.109	0.006499	Neidentificat	PM10	5/1 - 10/1
nan	nan	Picea	PM10	5/1 - 10/1
-0.104	0.009264	PINUs	PM10	5/1 - 10/1
-0.057	0.155002	PLANtago	PM10	5/1 - 10/1
-0.049	0.225814	PLATanus	PM10	5/1 - 10/1
-0.021	0.594115	POACeae	PM10	5/1 - 10/1
-0.088	0.029074	POPULus	PM10	5/1 - 10/1
-0.05	0.212102	QUERcus	PM10	5/1 - 10/1
0.059	0.144371	RUMEx	PM10	5/1 - 10/1
-0.031	0.439465	SALlx	PM10	5/1 - 10/1
-0.097	0.015666	SAMBucus	PM10	5/1 - 10/1
-0.156	9.20E-05	TILLa	PM10	5/1 - 10/1
nan	nan	Tubuliflores	PM10	5/1 - 10/1
-0.131	0.001121	ULMUus	PM10	5/1 - 10/1
0.046	0.25778	URTIcaceae	PM10	5/1 - 10/1
nan	nan	XANThium	PM10	5/1 - 10/1

Table 4:  $PM_{10}$  Correlated to each type of pollen

#### 4.2.2 *Ambrosia* Pollen Level Correlations

Correlation	p-value	Category 1	Category 2	Season	Averages
-0.903	0.000344	temperature	AMBRosia	8/15 - 9/22	Months
-0.821	0.088587	temperature	AMBRosia	8/15 - 9/22	Years
-0.117	0.11494	temperature	AMBRosia	8/15 - 9/22	
-0.389	0.060198	Relative humidity	AMBRosia	6/1 - 10/1	Months
-0.243	0	Relative humidity	AMBRosia	6/1 - 10/1	
-0.8	0.2	Precipitation amount	AMBRosia	6/1 - 10/1	Years
-0.229	0	Precipitation amount	AMBRosia	6/1 - 10/1	
0.2	0.019343	CO	AMBRosia	8/15 - 9/15	
0.367	0.33174	CO	AMBRosia	8/15-9/15	Months
0.5	0.391002	CO	AMBRosia	8/15-9/15	Years
0.872	0.053854	CO	AMBRosia	8/15 - 9/22	Years

Table 5: *Ambrosia* Pollen Correlated with Temperature, Relative Humidity, Precipitation, and Carbon Monoxide

As previously stated, when one observes the correlations between certain categories, one must consider the context of how they are related over time. For example, plants need time to fully grow before environmental factors have the ability to impact pollen production. Daily and monthly temperature show little to no correlation with the level of *Ambrosia* pollen, while yearly correlations are better, but have a high p-value. The *Ambrosia* plants are well suited to produce more pollen as temperature increases, as we have studied in our background. Daily and monthly correlations do not reflect this statistic because rising temperatures is not a direct trigger for the ragweed plant to release its pollen. In fact, *Ambrosia* pollen production peaks from mid-August to September as the temperatures are cooling down. Yearly correlations are the way we would find this correlation to be true, but it currently has too high of a p-value to be considered statistically significant (p= -0.821, r= 0.088). As more data is collected over years, we expect to see p-values drop and yearly correlations with temperature becoming more reliable. Additionally, we expect to see a positive correlation based on extensive research of this relationship from other studies, as opposed to the negative correlation we observed. We cannot confirm that the correlations we found with temperature are accurate due to the patching of weather data from different sources for the beginning of 2014 and the end of 2019. Based on our data, these years appear to have drastically lower yearly average temperatures compared to the rest of the data, although the pollen counts were relatively high these years, as seen in Figure 14 below.



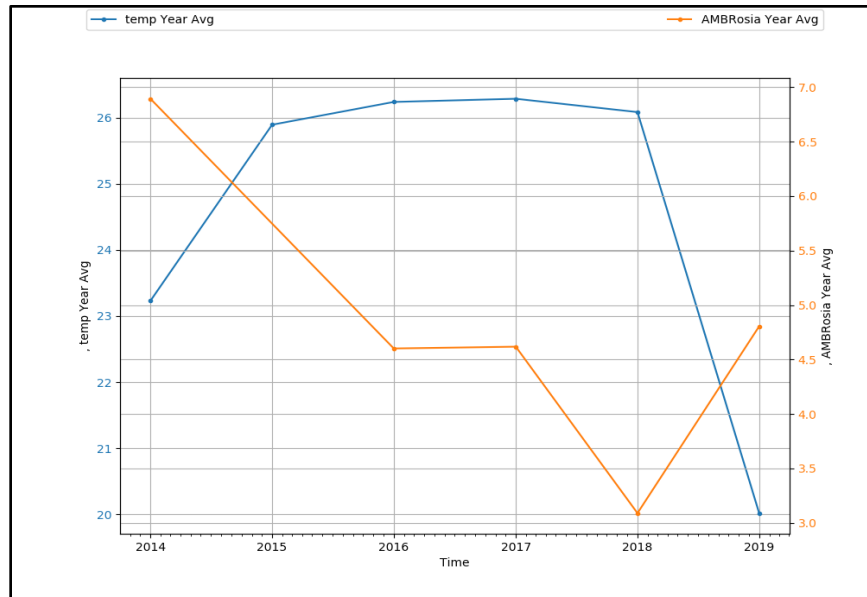


Figure 14: Yearly Averages of Temperature and Ambrosia Pollen

Since the source of our temperature data is not consistent, we cannot verify that the temperature these years were truly lower than the others, and therefore cannot confidently report the relationship between temperature and ragweed pollen.

The strongest correlations we found between ragweed pollen and meteorological factors are with relative humidity (no average:  $r = -0.243$ ,  $p = 0$ ; monthly:  $r = -0.389$ ,  $p = 0.06$ ) and precipitation (no averages:  $r = -0.229$ ,  $p = 0$ ; yearly:  $r = -0.8$ ,  $p = 0.2$ ) during the full pollen season. From these results, it is clear that there is a negative correlation with both of these factors; when there is less moisture in the air, the pollen count is higher. These correlations were not found to be very strong, although they exceeded the strength of many of the correlations with other factors. Unlike with temperature data, these results make sense in the context of daily and monthly correlations, since precipitation and humidity do not follow a defined pattern within the pollen season. This validates that we are seeing some statistically significant results that we expect, since it is known that the pollen is attracted to the water molecules, thus reducing the ambient pollen levels and the detected pollen count. On the other hand, we found no correlation between *Ambrosia* pollen counts and wind speed. Perhaps there were other factors present on windy days that had a stronger influence on reducing the pollen counts, such as precipitation, thus mitigating the increased pollen levels we expected to observe on windy days.

Of the chemical pollution factors carbon monoxide (CO) was the most strongly correlated to *Ambrosia* pollen counts, especially during the peak season of mid-August to mid-September (no averages:  $r = 0.2$ ,  $p = 0.019$ , monthly:  $r = 0.367$ ,  $p = 0.331$ , yearly:  $r = 0.872$ ,  $p = 0.053$ ). Since Bucharest is an urban area, it is exposed to higher levels of CO than rural areas due to the concentrated abundance of fossil fuel burning. While there is limited research available on how carbon monoxide may directly affect pollen production, it is possible that there is another factor that directly impacts the levels of both CO and ragweed pollen, making them linked to each other.

Other chemical pollutants appeared correlated to the ragweed pollen counts, but in context were not statistically significant and often fluctuated between positive and negative values in different situations. These inconsistencies are likely due to the small holes in the availability of the pollution data and patching of data from different stations to try and make up for this. Hopefully, the continued collection and improved consistency of data would help confirm these trends, but for now no further conclusions can be made.

### 4.2.3 Grass Pollen Level Correlations

Correlation	p-value	Category 1	Category 2	Season	Averages
-0.337	0.3403	Precipitation amount	Grasses	4/25 - 7/1	Months
-0.8	0.2	Precipitation amount	Grasses	4/25 - 7/1	Years
-0.05	0.623946	Precipitation amount	Grasses	4/25 - 7/1	
0.48	0.082356	Solar Radiation	Grasses	4/25 - 7/1	Months
0.522	0.288343	Solar Radiation	Grasses	4/25 - 7/1	Years
0.224	0.005962	Solar Radiation	Grasses	4/25 - 7/1	
0.521	0.056154	O <sub>3</sub>	Grasses	4/25 - 7/1	Months
0.6	0.208	O <sub>3</sub>	Grasses	4/25 - 7/1	Years
0.193	0.02055	O <sub>3</sub>	Grasses	4/25 - 7/1	

Table 6: Grass Pollen Correlated with Precipitation, Solar Radiation, and Ozone

Similarly to the ragweed pollen correlation results, most of the meteorological and pollution factors did not show a strong correlation with grass pollen levels when looking at the broader context. The most significant factors we found correlated to grass pollen were ozone (O<sub>3</sub>) and solar radiation, specifically during the peak grass season from April 25 until the end of June. Both showed a positive correlation; O<sub>3</sub>, solar radiation and grass pollen levels increase and decrease at similar times. While the strongest correlations with O<sub>3</sub> were found looking at yearly averages, the monthly averages were the only scenario with a strong correlation and a statistically significant p-value (yearly:  $r=0.6$ ,  $p=0.208$ ; monthly:  $r=0.521$ ,  $p=0.056$ ). While we cannot show causation between these factors and grass pollen levels, this correlation suggests that there may be some link between the O<sub>3</sub> levels or solar radiation and grass pollen over time. We can only speculate; we suspect that the link is potentially carbon dioxide (CO<sub>2</sub>), although we did not have any data on this pollutant. CO<sub>2</sub> is a significant contributor to global warming, especially in urban environments. It converts to O<sub>3</sub> in the atmosphere, and has been shown to increase pollen levels, since it serves as an energy source for plants (Schmidt, 2016).

The only meteorological factor we found correlated to grass pollen was precipitation level (monthly average:  $r= -0.337$ ,  $p=0.3403$ ; yearly:  $r=-0.8$ ,  $p=0.2$ ). However, there was no statistical significance and the negative correlation could be more related to how particles are distributed in the air than the pollen production of the plant itself. Based on our research, other studies have found that grass pollen is not strongly correlated to meteorological factors (Ariano et al., 2010)

and pollution is more related to allergy symptoms than pollen counts themselves. Therefore, our results for grass pollen were not so different from what we expected.

#### 4.2.4 Public Interest Correlations

Regarding public interest, we found from Google Trends that the terms “Ragweed” and “Allergy” in Romania became increasingly popular over the past 5 years, as shown in Figure 15 below. This is the data we used to represent public interest in pollen and seasonal allergies.

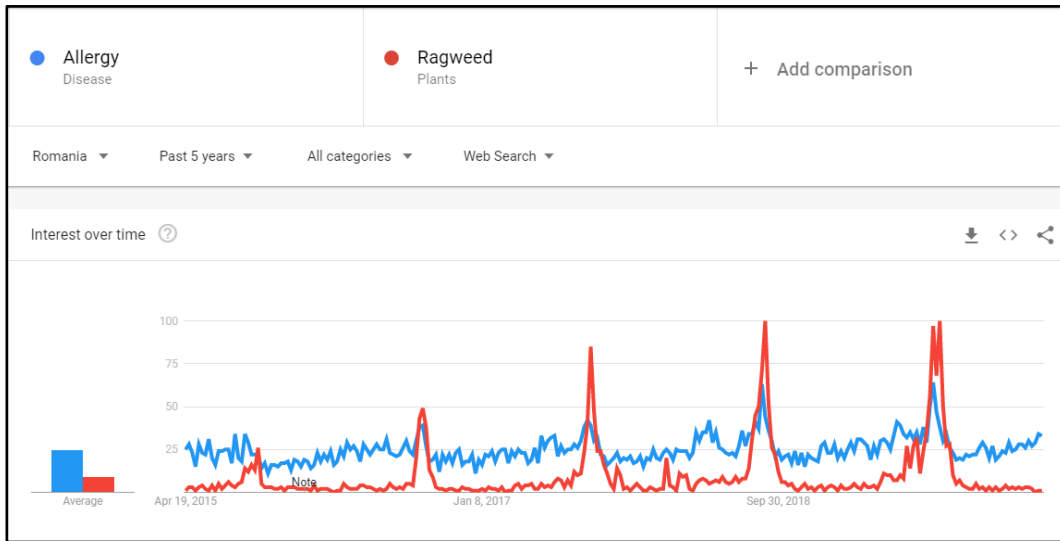


Figure 15: Interest in Allergy and Ragweed in Romania, past five years (Google Trends, <https://trends.google.com/trends/explore?date=today%205-y&geo=RO&q=%2Fm%2F0fd23,%2Fm%2F01yt1v>)

We found many correlations between public interest and climate and pollution data. We treated the interest in allergies as a measure of how many people are affected by allergies, as well as how severe their symptoms are. Both interest in the terms ‘Allergies’ and ‘Ragweed’ aligned with the total pollen levels on the daily, yearly, and monthly scale.

##### a. Climate vs Allergy Interest

Correlation	p-value	Category 1	Category 2	Averages
0.541	0	Allergy Interest	temp	
0.631	0	Allergy Interest	temp	Months
-0.9	0.037386	Allergy Interest	temp	Years
-0.415	0	Allergy Interest	rh	
-0.54	1.50E-05	Allergy Interest	rh	Months
0.3	0.623838	Allergy Interest	rh	Years
-0.197	0.002353	Allergy Interest	wind_spd	
-0.466	0.000261	Allergy Interest	wind_spd	Months

-0.3	0.623838	Allergy Interest	wind_spd	Years
0.546	0	Allergy Interest	Solar Radiation	
0.677	0	Allergy Interest	Solar Radiation	Months
0.7	0.18812	Allergy Interest	Solar Radiation	Years

Table 7: Correlations of Allergy Interest and Temperature, Relative Humidity, Wind Speed, and Solar Radiation

There are several meaningful correlations that can be drawn between climate factors and the level of pollen allergy symptoms observed by the Romanian population. The factors that positively correlate strongest with interest are solar radiation and temperature. A strong negative correlation exists between relative humidity and allergy interest as well. These three once again point to the idea that a hot, dry, sunny day will be the worst meteorological conditions for a pollen allergy sufferer. Figure 16 illustrates that the most dry, hot, and low-wind months cause the most allergy interest.

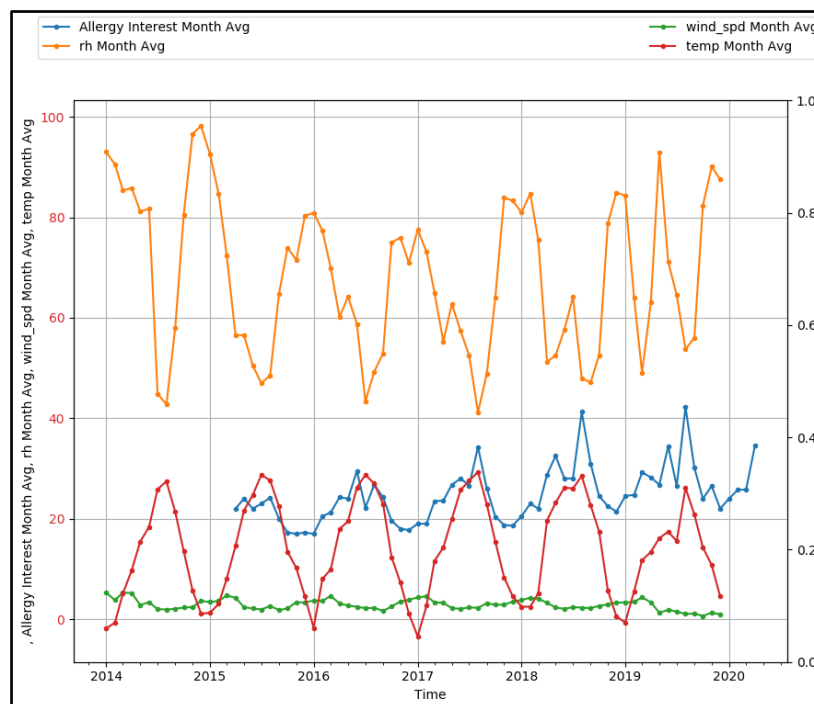


Figure 16: Monthly Averages of Allergy Interest, Relative Humidity, Temperature, and Wind Speed

Wind speed has a weak negative correlation with allergy interest. It points to the idea that the worst allergy symptoms come on days where the wind is not blowing. This effect could be due to wind in cities helping to diffuse pollutants, making the pollutants less concentrated and therefore less inflammatory during windy days. This can help explain why total pollen levels exhibited a positive correlation to wind while allergies show a negative correlation.

These results further cement the idea that pollen allergies will be worse on a hot, dry summer or fall day. Knowing this is true in Bucharest allows for better predictions to be made about what days will be the worst for allergy sufferers.

## b. Pollutants vs Allergy Interest

Correlation	p-value	Category 1	Category 2	Averages
0.5	0.391002	Allergy Interest	O3	Years
0.626	0	Allergy Interest	O3	Months
0.461	0	Allergy Interest	O3	
-0.6	0.284757	Allergy Interest	CO	Years
-0.581	6.00E-06	Allergy Interest	CO	Months
-0.343	0	Allergy Interest	CO	
-0.8	0.2	Allergy Interest	PM 2.5	Years
-0.617	1.30E-05	Allergy Interest	PM 2.5	Months
-0.34	5.00E-06	Allergy Interest	PM 2.5	
1	0	Allergy Interest	NOx	Years
-0.031	0.846846	Allergy Interest	NOx	Months
-0.025	0.757046	Allergy Interest	NOx	
-0.8	0.104088	Allergy Interest	PM10	Years
-0.262	0.093752	Allergy Interest	PM10	Months
0.0002	0.978538	Allergy Interest	PM10	

Table 8: Correlations of Allergy Interest and Ozone, CO, PM<sub>2.5</sub>, NO<sub>x</sub>, and PM<sub>10</sub>

One of the most noteworthy findings is ozone's strong correlation to the interest in allergies. While some of this correlation is due to seasonality, yearly ( $r=0.5$ ,  $p=0.39$ ), monthly ( $r=0.626$ ,  $p<0.005$ ), and daily correlations ( $r=0.461$ ,  $p<0.005$ ), O<sub>3</sub> shows positive correlations. Ozone is known to have an irritating respiratory effect similar to allergies, and is also known to amplify the effect of pollen on the lungs, similar to combustion particles. This relationship in Bucharest could be investigated as a leading cause of irritation for allergy sufferers within the city. Bucharest's ozone levels peaked at  $136\mu\text{g}/\text{m}^3$  in 2016, exceeding the World Health Organization's recommendation of  $100\mu\text{g}/\text{m}^3$  for daily ozone (Zhang, Wei, & Fang, 2019).

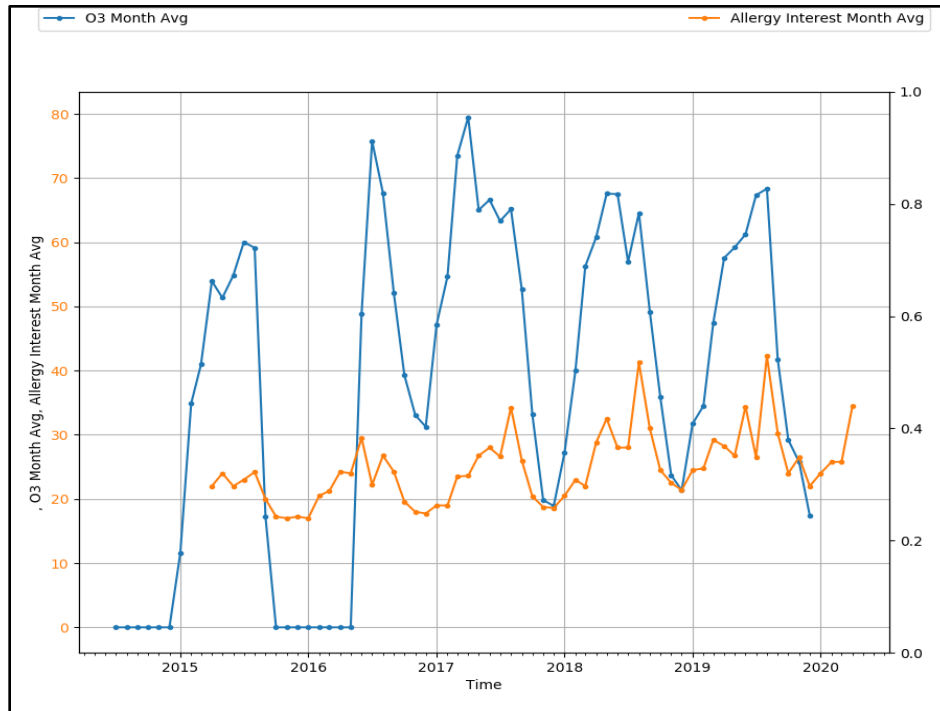


Figure 17: Monthly Averages of Ozone and Allergy Interest

Carbon monoxide, or CO, had an inverse effect: when carbon monoxide levels rise, interest in allergies falls. Again, this applies across the yearly( $r=-0.6$ ,  $p=0.28$ ), monthly( $r=-0.581$ ,  $p<0.005$ ), and daily( $r=-0.343$ ,  $p<0.005$ ) scales. Pollen seems to be uncorrelated with the levels of CO, yet it exhibits an inverse relationship with interest in allergies. There is no documented research of CO's effect on pollen symptoms.

Our research suggested that, like ozone, PM<sub>10</sub> and PM<sub>2.5</sub> are lung irritants that can lead to the development of *Ambrosia* allergies. Both PM<sub>10</sub> and PM<sub>2.5</sub> have been recorded many times above the legal limit in Bucharest. (Wall-Street, 2019). However, our PM<sub>10</sub> data returned low or negative daily, monthly, and yearly correlation coefficients for both interest in 'Ragweed' and 'Allergies'. Additionally, PM<sub>2.5</sub> had a negative correlation to the interest in 'Allergies' regarding daily( $r=-0.34$ ,  $p<0.005$ ), monthly( $-0.617$ ,  $p<0.005$ ), and yearly( $r=-0.8$ ,  $p=0.2$ ) averages. These results suggest that neither PM<sub>10</sub> or PM<sub>2.5</sub> plays a role in aggravating allergies. PM<sub>10</sub> and PM<sub>2.5</sub> also have seasonal factors which come into play, raising the levels over the cold months. This may throw off daily and monthly correlations, however yearly correlations are also showing a strong negative correlation, forcing us to look deeper into why this is happening. Additionally, our research has found that the combination of ozone and PM<sub>2.5</sub> exacerbates asthma symptoms, yet the link between pollen and the combination of these two pollutants has not been established (Gleason et al., 2014). Our results suggest that there is little synergy between ozone and PM<sub>2.5</sub>, because allergy interest is not increased by an increase in PM<sub>2.5</sub>.

We are not able to obtain data on the exact number of new people who develop an allergy. More data, including health data, is needed to obtain accurate correlations that can help to prove this connection. The correlations between the yearly average of PM<sub>10</sub>/PM<sub>2.5</sub> and new allergy patients could help describe the development of allergies as a result of the pollutants.

CO, PM<sub>2.5</sub>, NO<sub>x</sub>, NO, and NO<sub>2</sub> can all play into the creation of ozone via solar radiation, meaning that the higher levels of pollution in cities can increase ozone, thereby exacerbating allergy symptoms. This interaction could also explain why PM<sub>2.5</sub> and CO are negatively correlated to allergy interest; they are consumed in the chemical process of creating ozone (Zhang, Wei, & Fang, 2019). Knowing this, we conclude that ozone is the worst lung irritant, based on our results. The public remains largely unaffected by the raw PM<sub>2.5</sub>, CO, and NO<sub>x</sub> levels, according to our results. However, when the sun beams down and converts these volatile chemicals into ozone, the public seems to experience more severe and widespread allergy symptoms. Therefore, negative correlations found between NO<sub>x</sub>, CO, and PM<sub>2.5</sub> should not allow for the dismissal of these factors as lung irritants, because their concentrations drop when they are turned into ozone, the worst lung irritant from our findings.

### **4.3 Global Comparisons**

After compiling all of our results together, we compared our results to studies that have been done in other countries. These comparisons should be able to help us predict which correlations that we found will become stronger over time, or which correlations may not be true due to our limited amount of data.

#### **4.3.1 Northern Italy**

A study conducted in the Imperia Province of Italy by Ariano et al. examined correlations between pollen levels and temperatures in this region. They measured pollen from birch, cypress, olive, grass and *Parietaria* groups. Their data spanned over 27 years, starting in 1981 and ending in 2007. The meteorological data used in this study included yearly average values for temperature, rainfall, relative humidity, wind speed and solar radiation. The most important result from this data was that radiation and temperature both showed to linearly increase significantly over time. However, the total amount of grass pollen did not show a significant change over time, so temperature and grasses were not strongly correlated ( $r=0.02$ ,  $p=0.06$ ). There were no significant correlations between rainfall, humidity or wind speed with pollen in this data (Ariano et al., 2010).

In our project we did not find significant correlations between grass pollen with temperature, relative humidity, precipitation, wind speed or solar radiation. Our findings also showed that temperature and relative humidity increased almost linearly over time, while grass pollen remains relatively constant. The only significant factor we found correlated to grass pollen was ozone (O<sub>3</sub>) during the peak grass season. Based on this study that spans over 27 years, and how similar the findings were to our study, we would expect our data to continue this pattern in the future. This information may contribute to predicting grass pollen levels.

#### **4.3.2 Poland**

Another study which was conducted in the city of Szczecin, Poland investigated Spearman's correlation coefficients between the *Poaceae* grass family and multiple meteorological factors. Similar to our project, they analyzed the correlation between *Poaceae* with wind speed, rainfall, relative humidity, SO<sub>2</sub>, ozone and PM<sub>10</sub> and with data spanning from 2004 to 2008. Most notably

they found statistically significant correlations between *Poaceae* and relative humidity ( $p=0.00$ ,  $r=-0.39$ ), between *Poaceae* and ozone ( $p=0.00$ ,  $r=0.46$ ), and between *Poaceae* and  $PM_{10}$  ( $p=0.00$ ,  $r=0.32$ ) (Puc, 2010). In our study we consider correlation above  $r=0.4$  to be strong. Using this information, this study found the same results as we did, that only ozone correlates strongly with grasses. For the other two correlations, grasses correlated with relative humidity and grasses correlated with  $PM_{10}$ , our project findings showed correlations of the opposite sign (+/-) as this study. We found the correlation between grasses and relative humidity to be positive ( $r=0.257$ ), and the correlation between grasses and  $PM_{10}$  to be negative ( $r=-0.392$ ) and both were weak correlations. This demonstrates that more data needs to be collected both in Poland and Romania before considering these correlations as significant.

### 4.3.3 Central Europe

Matyasovszky et al. collected data from 1995-2010 from 66 pollen stations across Europe including France, Austria, Hungary and seven additional countries. This data included *Ambrosia* pollen counts, *Ambrosia* season start and end dates, as well as climate factors such as temperature and precipitations. Then, they used linear regression analysis and determined that total pollen counts depended on maximum daily ragweed pollen counts, as well as the start and the duration of the ragweed pollen season. Pollen variables did not have any significant correlations with the daily mean temperature or precipitation (Matyasovszky et al., 2018). These findings are slightly different from our project considering that we did find a strong correlation between precipitation and *Ambrosia* pollen. This difference suggests that as more data is added, this correlation may become weaker, or that geography may be a contributing factor to this correlation.

### 4.3.4 United States

A study in the United States used linear regression for data collected in 1995-2009 to calculate correlations between *Ambrosia* season duration, number of frost free days, change in days to first frost, and latitude from Georgetown, Texas, US to Saskatoon, Canada. They determined that the duration of the ragweed pollen season correlates with the number of frost free days ( $r^2=0.74$ ), and also correlates with latitude ( $r^2=0.95$ ). This finding suggested that areas at higher latitude are more affected by climate change, shown by the increase in their frost free periods over years. With longer frost free periods, these areas also have longer *Ambrosia* seasons. For latitudes above  $\sim 44^\circ N$ , the season increases as much as 13-27 days in 2009 compared to 1995. Even though analysis with temperature within our project was inconclusive, Romania has latitude of  $45.9432^\circ N$ , therefore, it is likely that over the years, with more data collected, we can also observe the increase in *Ambrosia* season duration due to climate change (Ziska et al., 2010).

Another study done on 5277 children in Southern California looking at the relationship between air pollutants ( $NO_2$ ,  $O_3$ ,  $PM_{2.5}$ ,  $PM_{10}$ ) and pollen allergies, showed that children living near major roads containing high levels of these pollutants have increased risk of respiratory disease, as well as deficits in lung function ( $p < 0.001$ ). Children living within 500m of a major freeway are 10 times more likely to develop pollen related rhinitis if they are already sensitized to at least one pollen group. The pollen types examined belong to highly allergenic species from grass, weed, and tree pollen: *Ambrosia*, *Olea europaea*, *Quercus agrifolia*, *Asteraceae*, *Phleum pratense*, and



*Cynodon dactylon* (Zhou et al., 2018). Based on the results of our project, we agree that pollutants can intensify pollen allergy symptoms, especially ozone.

#### 4.4 Prospective Trends

Dr. Leru was also interested in hearing what we might expect the future to hold for pollen allergies in Bucharest. We developed these prospective trends by observing what known events are taking place in Bucharest, understanding the implications of these events on the factors involving pollen allergies, and using our own correlations, and other researchers' correlations to tell us what the effects will be in terms of pollen levels and allergy symptoms. We have looked at two major events taking place in Bucharest, climate change and pollution awareness.

##### 4.4.1 Bucharest Climate Outlook

Based upon the correlations we have drawn above, there is research available that we may combine with our findings to produce predictions. The globe is currently warming in a widely accepted process known as climate change. Average yearly temperatures have been generally climbing as a result of global production of CO<sub>2</sub> and other greenhouse gasses. A simple linear regression of the past 30 years of climate research shows a warming of 0.08°C per year since 1990, meaning that by the year 2030 the average temperature in Bucharest could be around 11°C, if this trend were to continue. Humidity is also expected to drop according to our regressions.

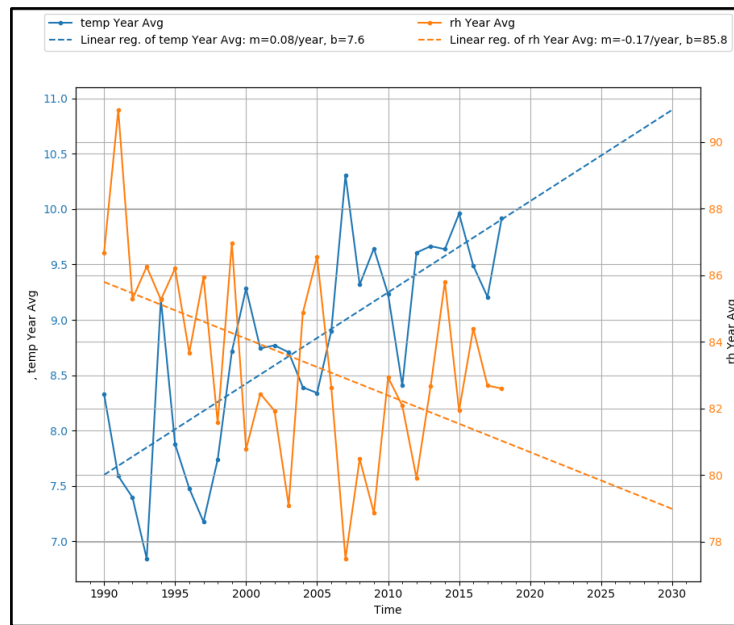


Figure 18: Yearly Average of Temperature and Relative Humidity in Bucharest, 1990-2018

Studies from the USA have not only shown that the number of frost free days correlates to the amount of pollen produced in a season, but also that *Ambrosia* is able to generate more pollen under high CO<sub>2</sub> conditions (Rogers, 2006). This link is well established and will be observable as time continues. We can therefore expect that as the climate continues to warm, more pollen will be generated. The CO<sub>2</sub> levels in Romania, as well as more data pollen levels of *Ambrosia* in Romania would help bolster this claim, as we were not able to observe it directly with the limited

*Ambrosia* data available. Global CO<sub>2</sub> levels continue to rise, meaning that the CO<sub>2</sub> in Romania will also rise. Under these conditions, *Ambrosia* will almost certainly continue to spread and grow in the Bucharest region, and we expect an increase in the amounts of pollen these plants produce.

Hot, dry days have been shown by our research to be the worst days for pollen allergy symptoms. The lower average humidity and higher average temperatures we have crudely observed will produce more of these days and therefore worsen allergy symptoms in the future.

#### **4.4.2 Bucharest Pollution Outlook**

Currently, Bucharest's levels of pollution are extremely high. As stated previously, the level of PM<sub>2.5</sub> and PM<sub>10</sub> both exceed EU legal limits. If the level of PM<sub>10</sub> and PM<sub>2.5</sub> were allowed to continue to grow, they will continue to cause lung irritation which can lead to the development of pollen allergies. Volatile PM<sub>2.5</sub> particles can also play a part in the generation of ozone, an additional lung irritant which we have correlated strongly with the public interest about allergies. While we do not have enough data to firmly claim whether PM<sub>10</sub> and PM<sub>2.5</sub> continue to rise, we are able to look to the recent interests in both. Recent action has been taken by Romania to attempt to reduce the amount of PM<sub>10</sub> and PM<sub>2.5</sub> pollution. Two independent pollutant monitoring stations have been established to better present information to the public eye, Airly and Aerlive. Both companies present a user-friendly way to view live, forecasted, and historic pollution data on a map of Romania. The Airly company provides over 30 pollutant monitoring stations in Bucharest alone, and has a network across the country.

Recent pollution activism in Bucharest has begun due to a spike in PM<sub>2.5</sub> in March, reaching a level 10 times the legal limit. Protestors argue the lack of public transportation, green spaces, and regulations on waste has led to this problem. The government has pointed to recent fires as the cause of this spike in pollution (Gherasim, 2020). Additionally, a tax on operating old cars was removed by the mayor of Bucharest. We expect that as older cars stay on the roads, larger amounts of pollution that they produce will lead to higher levels of PM<sub>2.5</sub> and other harmful pollutants such as NO<sub>x</sub>.

As pollution has been brought to the attention of the Romanian public via these independent companies, we observe legal action being taken to reduce the amount of pollution in Bucharest. The European Union has begun the process to hold Romania responsible for its pollution in Iasi, Bucharest, and Brasov (Gherasim, 2020). This may force Romania to begin working toward reducing its pollution levels. We hope the levels of air pollution will fall as Romania's public and leadership become more aware of their pollution problems and begin working together to help reduce the amount of pollution. Reducing the amount of pollution will help alleviate and reduce the yearly growth in the number of allergy patients that allergists in Romania have observed over the past years.

#### **4.4.3 COVID-19 and Pollution**

The correlation between pollution and pollen allergies is a trend that must be mapped over decades. The COVID-19 pandemic is a rapid development in comparison. Airly has conducted studies comparing air quality to the areas of outbreak of the COVID-19 virus and found that

average annual  $PM_{2.5}$  was highest in the most infected areas in Europe, especially Northern Italy. It is believed that  $PM_{2.5}$  may increase the infectivity and death rate of the COVID-19 virus, as the related SARS virus exhibited similar characteristics of being more severe for people in polluted regions (Airly, 2020). Figure 19 below shows the annual averages of  $PM_{2.5}$  data from the B-1 air quality measuring station in Bucharest. It aligns with the map data presented in the study which demonstrates that while relatively speaking, the annual pollution in Bucharest is not nearly as bad as Northern Italy, it is still categorized as moderate to severe. It has not been clearly stated whether chronic or acute  $PM_{2.5}$  exposure is responsible for making the lungs more vulnerable to a COVID-19 infection. This distinction is important because  $PM_{2.5}$  counts will decrease over the summer and have decreased annually, yet  $PM_{2.5}$  spikes can come at any time due to fires or excessive traffic. Regardless, ensuring that there are measures in place to protect the population from pollution spikes and continuing to decrease the average amounts of  $PM_{2.5}$  would certainly be an action to protect against COVID-19.

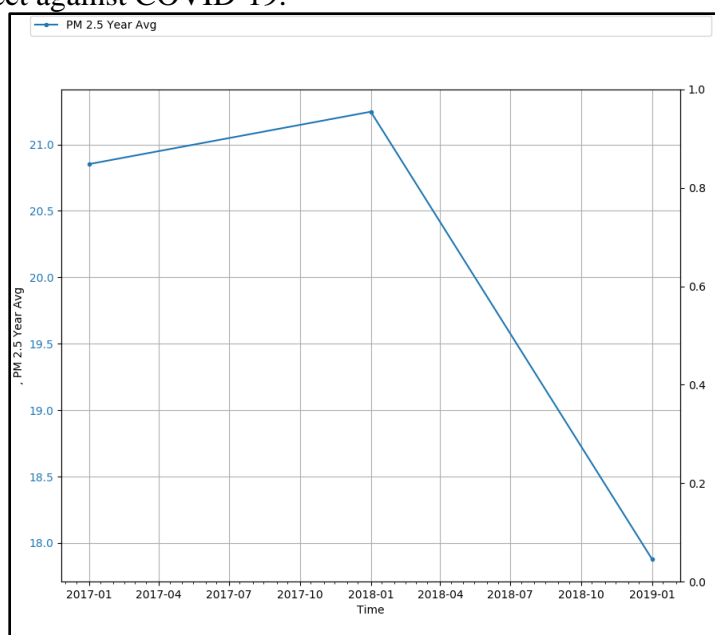


Figure 19: Yearly average of  $PM_{2.5}$  in Bucharest

#### 4.5 Lifestyle Survey and Google Trends

As mentioned in the Methodology, we distributed the survey to the Romanian *Ambrosia* allergy sufferers Facebook group. We received 92 responses and all participants are from different parts of Romania, mostly the Muntenia region where Bucharest is located. The age of participants ranges from 18 to 74, with 74% being female. The majority (93%) of the participants are allergy sufferers, among which 87% are affected by pollen (including ragweed, trees, and grasses), 28% are affected by dust mites, and the rest are affected by other allergens such as animals, chemicals, food, metals and histamine intolerance. Many people have more than one type of allergies. Full survey results can be found in Appendix E.

Sneezing, ocular itching, and nasal conditions such as runny nose, nasal congestion, and itchy nose are the most common symptoms, with a few sufferers experiencing rashes or hives. They reported to experience these symptoms mainly from August to October (Figure 20), which is the *Ambrosia* season, suggesting that allergy to *Ambrosia* is the most common. This finding is biased

because our respondents are from the *Ambrosia* sufferer group. However, seeing that people have their symptoms even outside of the ragweed season suggests that many are affected by more than just ragweed alone. Additionally, coping with these symptoms in Romania is largely done by visiting a doctor, followed by over-the-counter medicine (Figure 21).

When do you usually experience your symptoms? Check all that apply

84 responses

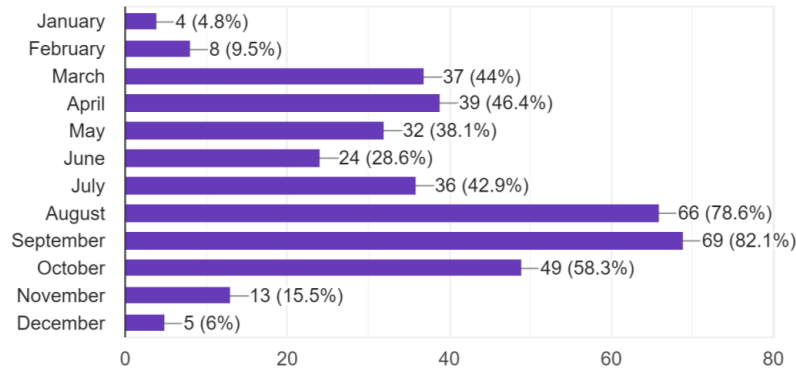


Figure 20: Reported Months when Participants Experience Allergy Symptoms

How do you treat your allergy symptoms?

89 responses

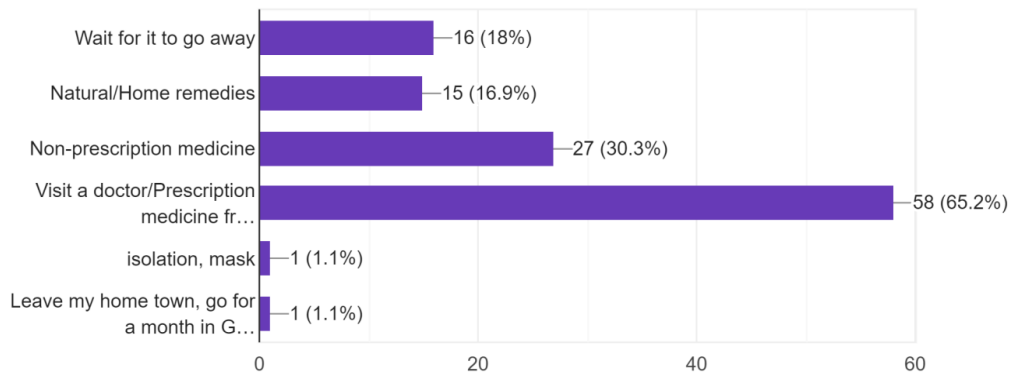


Figure 21: Common Treatment Methods

The majority reported no history of allergy from personal or parental records (Figure 22). Instead, our respondents developed their allergies within their lifetimes. 68.5% have been suffering from their symptoms for over 3 years (up to survey time). Even though genetics and family history plays a role, the exact numbers and biomechanics for this is still uncertain (Agnew et al., 2018). Our collaborator, Dr. Leru, also mentioned that personal atopy is more typical in grass pollen, not so much for *Ambrosia*, and sensitization to *Ambrosia* usually happens after childhood. As the majority of the respondents are *Ambrosia* sufferers, this might be a biased result.

### Medical history of pollen allergies, hay fever, or asthma

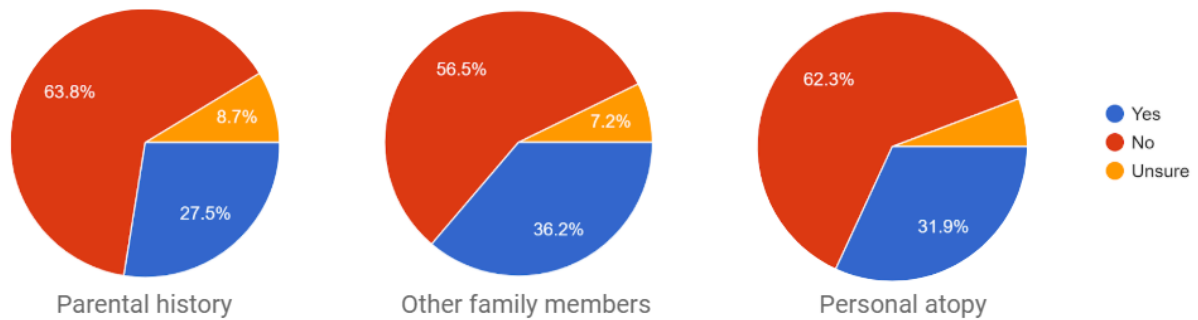


Figure 22: Medical History of Respiratory Diseases

Instead of genetic causes, there has been more evidence linking allergies to environment factors, including household conditions and outdoor exposure to chemical pollutants. Our survey showed that 30% of allergy sufferers reported that they smoke tobacco products, 25% have lived in a space with mold (Figure 23), 52% have or used to have pets, and 63% lived in an urban area during the age of 0-6.

Check all of the statements below that apply:

73 responses

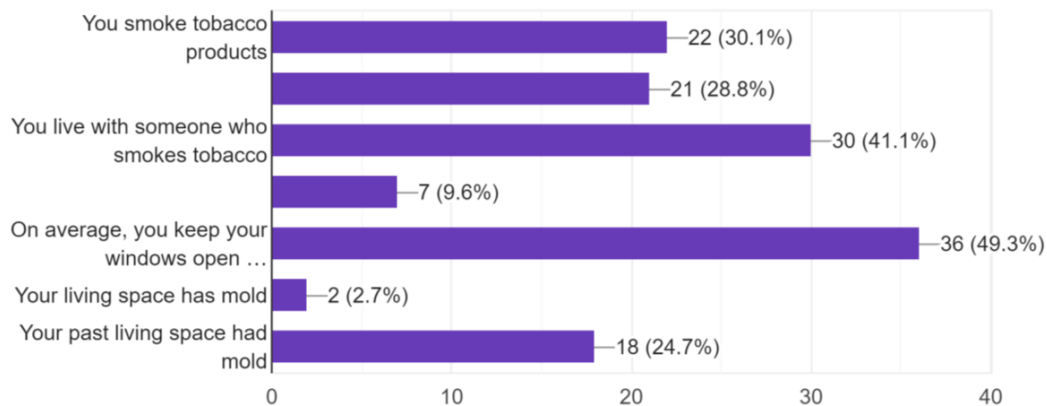


Figure 23: Household and Living Conditions

We also found that 52% choose cars as their primary mode of transportation. However, 54% of them only spend on average less than 1 hour driving per day (Figure 24), so it is unclear whether Romanians' car usage has an impact on pollution level.

What mode of transportation do you use most?  
92 responses

How much time do you spend in a car each day (on average)?  
92 responses

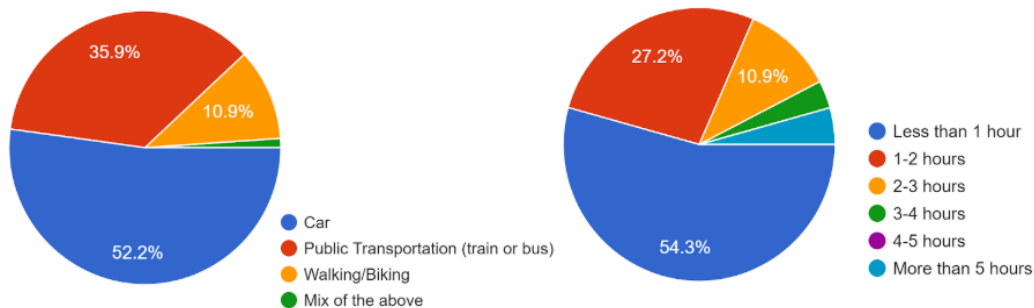


Figure 24: Romanians' Car Usage

Bucharest is a highly congested city with abundant air pollutants that are harmful to allergy sufferers (Wall-Street, 2019). The suburbs directly surrounding cities are most affected due to their combination of unmaintained growing space, urban pollution, and higher amount of plant life than the densely populated city. This is further evidenced by Google Trends data, where Ragweed was searched in Ilfov county, which surrounds Bucharest, more than anywhere else in Romania in the past 5 years (Figure 25).

What region of Romania are you from?  
92 responses

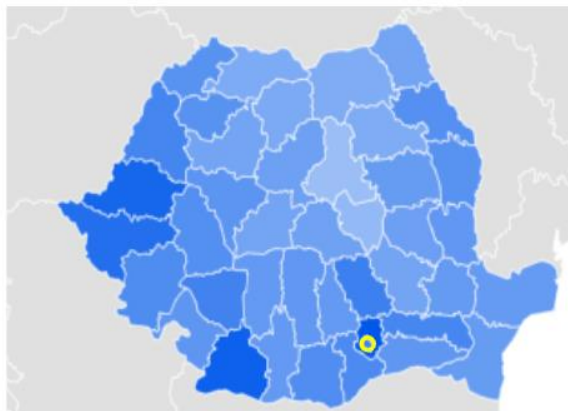
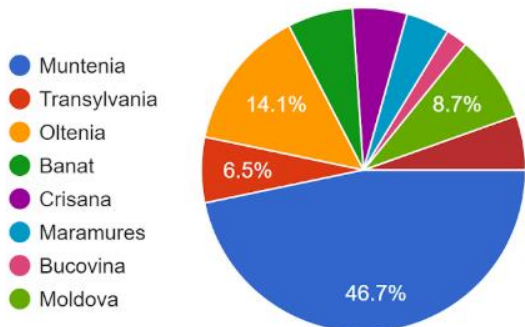


Figure 25: People in urban areas are more affected by pollen allergies  
(<https://trends.google.com/trends/explore?date=today%205-y&geo=RO&q=%2Fm%2F01yt1v>)

The interest in allergy symptoms align with the height of ragweed season, with a secondary peak in March, indicating allergies to other pollens such as trees and grasses. Transportation statistics, however, did not provide conclusive data to link vehicles with allergies. To be able to make a concrete correlation, a more thorough study about vehicle usage over time compared to chemical emissions and allergy symptoms will need to be conducted.

Another aspect in our survey is diet. Studies in our Background linked a poor diet to the likelihood of developing an allergy. However, our findings regarding diet did not align with those studies. Of the allergy sufferers surveyed, 90% reported to not have a poor diet (Figure 26), with food choices from 6 categories (Vegetable, Fruit, Grains, Protein, Dairy, and Oils/Butter). A

few reasons that perhaps explain this mismatch could be the inaccuracy in self-evaluation, the broad definitions for each food category (which do not specify elements of a poor diet), and perhaps focus on diet during the period of the development of allergies rather than current diet.

There are 6 food categories from the US Department of Health and Human Services: Vegetable, Fruit, Grains, Protein,...5, how diverse are your daily food choices?

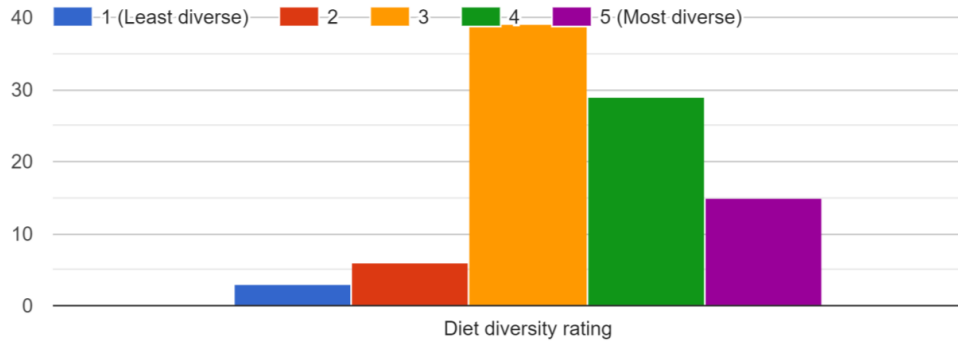


Figure 26: Diet diversity self-evaluation

Another important finding is that 75% of Romanians experience their symptoms at work (Figure 27). This finding is significant because it means allergies can affect their productivity, the quality of their work, as the symptoms can be disruptive or may cause them to leave work for doctor visits, and sometimes even their own safety. It especially stresses the importance of more research to help people cope with the effects of seasonal allergies.

Do you experience allergy symptoms at work?  
91 responses

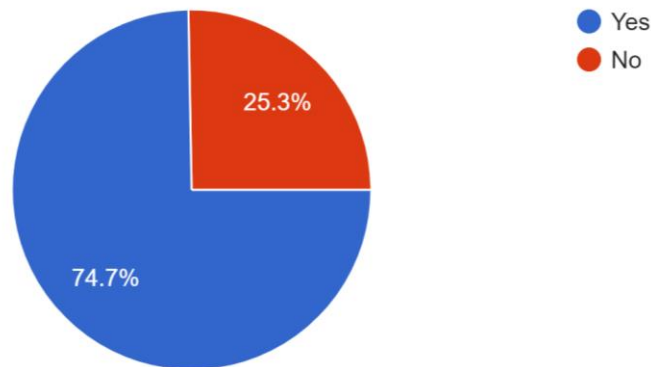


Figure 27: Romanians experience allergy symptoms at work

These findings give us an insight into what Romanian allergy sufferers are facing, however, the amount of responses we received was minimal and targeted to *Ambrosia* sufferers, making our results somewhat biased towards those types of respondents. Therefore, more studies are necessary to have results that are representative of the Romanian population, especially for different sub-groups of *Ambrosia* and Grass allergy sufferers.

## 4.5 Final Deliverables

To summarize the deliverables of this project: we have created (1) a data analysis tool, allowing users to find correlations between pollen counts, meteorological factors, and air pollutants, including full documentation of how to use the tool, (2) a website for our project that contains everything about our research, including all of our deliverables and presentation (<https://sites.google.com/view/wpi-iqp/home>), (3) a pollen allergies Facebook page on which we uploaded weekly posts about pollen allergies (<https://www.facebook.com/polleninromania/>), (4) an educational pamphlet (Appendix C) as a compact way to inform the public about allergies, and (5) a lifestyle survey (Appendix A) designed to be given to the public about pollen allergies.



## **Chapter 5: Recommendations**

With the completion of our project, there are a few things we believe could be added or expanded in the future. Our biggest recommendation is for the continuation of data collection, as this will strengthen the confidence in our results, allow more trends in Bucharest to be determined, and help find more correlations in places where our current data set is limited. Additionally, we believe that calculating and publishing pollen forecasts in Bucharest, adding health data as a factor, collecting more survey results to reach a statistically significant level, and investigating whether there is a link between COVID-19 and pollen allergies would be future work worth investigating.

### **5.1 Publishing Forecast Data**

In order to further raise public awareness, another function could be added to our data analysis tool to automatically or semi-automatically send present data entries to a website that reports the data to the public. Polleninfo.org is the best platform for this because it is the most widely used, has been advocated by our collaborators, and performs its own mapping functions on the data it receives from its pollen collectors across Europe. It publishes forecasted data for select regions to the public, so our group investigated what would be required to get live pollen counts and forecasts for Bucharest published. We had additionally hoped to publish this information to Facebook to reach more of the public. Continuation of this preliminary work would help allergy sufferers cope with their symptoms.

We met with the polleninfo.org team in an attempt to establish pollen forecasting in the Romanian polleninfo webpage. The researchers personally believed that the most useful features for Bucharest's pollen monitoring system would be short term and medium term forecasting, which could then lead to the development of other features such as personalized pollen forecasting, as described in section 2.3.3. In order to have any feature enabled on the polleninfo website, a one-time fee would be required. Additionally, to get features such as short and medium term or personalized forecasting, our Romanian collaborators would need to regularly create their own forecasts and maintain the webpages. It would be helpful to lessen the required manpower by creating a neural network (advanced computing algorithm) to predict pollen counts, similar to the one Dr. Leru has participated in creating for the Pannonian Basin of Hungary. Carrying out this research could be combined with finding ways to advertise the forecasting system in Bucharest to create a future WPI IQP.

### **5.2 Correlation between health data and pollen**

Since the COVID-19 virus attacks the lungs of those who are infected, it has become more important than ever to seek out a correlation between the inflammation caused by pollen and other health conditions such as COPD, viruses, and more. Our report covers the factors that affect the raw pollen counts, and can only estimate the perceived effect on the public using Google Trends. Documented links to true health data would provide a very strong argument towards Romania developing a National Aerobiology Network. Medical data, such as the rate of cardiac death and rate of new allergy patients, could potentially be correlated to pollen or pollutant levels. The Correlation Machine has been designed to easily import new categories of data and will be able to process this data whenever it is available.

### 5.3 Future Survey Distribution Methods

Distributing surveys for data collection was difficult, since a large number of responses is required for the results to be statistically significant. Despite the restrictions from COVID-19, we received 92 responses. Since lifestyle data is an important aspect in this study, we came up with several ways to help gather a larger number of responses in the future. First, we suggest the survey can be handed to the people in the waiting room at Colentina Hospital. It can be accessed electronically or as a paper flyer. If the hospital database has the email address of allergy patients, Dr. Leru can also send the survey to them via email. To reach an even broader audience, Dr. Leru can share the survey to other hospitals or allergists in Romania, or to the members of the Romanian Society of Allergology and Clinical Immunology (RSACI). Additionally, another way to encourage people to take the survey is to create an incentive, usually in monetary form, depending on the budget of the research. <https://www.prolific.co/> is a survey distribution platform that allows an organization to give out payments to participants for their time taking the survey. In the future, with more responses, results from the survey can be integrated into the analysis tool to determine any correlation between people's lifestyle and pollen allergies.

### 5.4 COVID-19 and Pollen Interaction

As mentioned previously, there is a link between COVID-19 infection and PM<sub>2.5</sub>. Like PM<sub>2.5</sub>, pollen is a lung irritant and causes an immune response. It is possible that pollen could have a similar effect as PM<sub>2.5</sub> regarding COVID-19.

Comparing a graph of the historic grass pollen counts with the current COVID-19 map shown in Figure 28, the hotspots for pollen including Northern Italy, Spain, Istanbul and the United Kingdom are also hotspots for COVID-19. The high number of infected people in these areas is concerning, because those with asthma are among the high risk groups for having more severe COVID-19 infections, and we may therefore expect the death rate to be higher in these pollinated areas (CDC,2020). These relationships merit further and more intense studying as the global scientific community tries to understand COVID-19. If it were studied and confirmed that pollen symptoms increase the spread and death rate of COVID-19, knowing beforehand could help prepare allergy sufferers to keep their symptoms managed through reducing exposure and medication, reducing the number of new cases and deaths.

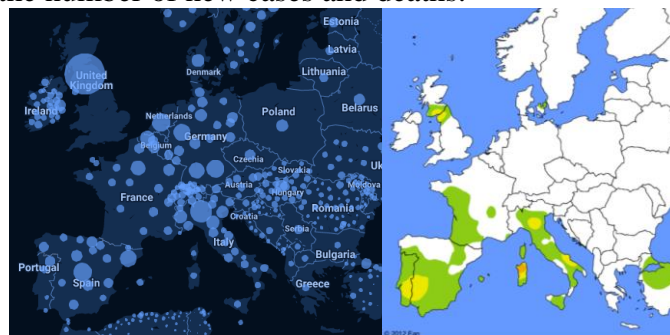


Figure 28: April 21, 2020 COVID-19 Infection Map (Coronavirus (COVID-19), n.d) (left), March 23-31 Poaceae Pollen Map (Pollen Info, n.d) (right)

## Chapter 6: Conclusions

Pollen allergies in Romania are rising rapidly and causing problems for many people, especially those living in urban areas. This rise is largely caused by an increase in pollen, which is affected by climate change, air pollution, and lifestyle choices of the public. There have been many studies on this issue done in other countries, as well as efforts to learn more about pollen allergies and coping methods for the public. However, this research is still premature and sporadic in Romania, which highlights the importance of our project and Dr. Leru's work to study this phenomenon in Bucharest.

Throughout this project, we identified factors that correlate to pollen counts and streamlined this process for Dr. Leru and her team. From our results, we concluded that pollen levels are highest on warm dry days for all types of pollen. This information can be used to make daily predictions of symptom severity. We also concluded that increased ragweed pollen levels have sparked an increase in public interest in learning more about allergies. We identified the strongest correlating factors to *Ambrosia* pollen as humidity and precipitation, which decreased the pollen levels, and CO levels, which had a positive correlation especially at the yearly level. We conclude that ozone is the largest contributing chemical pollutant to pollen allergies, as it was found to increase both grass pollen counts and allergy symptoms. Our findings were consistent with other studies around the world, particularly regarding grass pollen and climate in Poland and Northern Italy and pollutants worsening symptoms in the US. Even though our analysis only yielded a handful of strong correlations, we could see more trends for other factors with further data collection in the future.

Unfortunately, we were unable to make our own conclusions regarding the effect of temperature on pollen counts, but were able to use background knowledge to make some tentative predictions. We identified a significant increase in the temperature of Bucharest over the past 30 years, which we predict will continue. We also predict that humidity will decrease over time. Based on these prospectations, we think that ragweed pollen levels and seasonal allergies will continue to increase over the years. Regarding pollution, we hope the recent increased awareness of the exceedingly high PM<sub>2.5</sub> and PM<sub>10</sub> levels in Bucharest along with more regulations to limit air pollutants will help reduce the levels of air particles that can worsen the symptoms of pollen allergy sufferers.

Our survey revealed interesting discoveries about the lifestyle of Romanian people, and posed potential research topics to be further explored. We found most allergy sufferers in Romania are from urban areas and experience symptoms at work, suggesting that public measures to reduce pollen levels will benefit the productivity and overall health of the Romanian public. With the collection of more survey results, we hope to see a further investigation of car usage in Romania and how it may impact air pollution and pollen allergies.

At the completion of our project, we compiled and presented all relevant information about pollen allergies from global and local sources, developed a "Correlation Machine" for ease of analysis, and proved that Romania is observing a similar trend to other countries that are heavily impacted by pollen. Our project team, along with our collaborator, Dr. Leru and her research team believe that with climate change, urbanization, and the immediate threat of COVID-19, it is more important now than ever before to gather more research in Romania regarding pollen

allergies in order to protect the health of the public. Dr. Leru has advocated for the establishment of a national allergy network in Romania, and we support this suggestion as the best way to advance research that can be used to help the public cope with increased pollen allergies.

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## Appendices

### Appendix A: Survey Questions

# Pollen Allergy and Lifestyle Survey

We, students from Worcester Polytechnic Institute, and the Research and Development Department of Colentina Clinical Hospital, would like to invite you to participate in a quick survey. The survey should take around 5 minutes, and your responses are completely anonymous. Your participation is voluntary and you can skip any question that you rather not answer.

We are collecting information about lifestyle practices and pollen allergy symptoms. Think about your symptoms as well as what you do everyday, and try to answer each question as accurately as you can. The responses will be analyzed to determine which lifestyle practices of the people of Bucharest affect allergies, if any, and help allergy patients by making suggestions for prevention methods. The research will be published for educational purposes.

Before we begin the survey, please let us know if you have any questions about the survey or research. After the survey, if you have any follow up questions, feel free to email us at: [trschaeffe@wpi.edu](mailto:trschaeffe@wpi.edu)

For more information about this research or about the rights of research participants, or in case of research-related injury, contact the email listed above. In addition, you may contact the WPI IRB Chair Professor Kent Rissmiller, Tel. 508-831-5019, Email: [kjr@wpi.edu](mailto:kjr@wpi.edu) and the Human Protection Administrator Gabriel Johnson, Tel. 508-831-4989, Email: [gjohnson@wpi.edu](mailto:gjohnson@wpi.edu) for further concerns.

\* Required

1. I accept the terms of this survey \*

If you do not accept the terms of this survey, please exit the survey

*Mark only one oval.*

Yes

## Background information

2. How old are you?

---

3. What is your gender?

*Mark only one oval.*

- Female
- Male
- Other: \_\_\_\_\_

4. What region of Romania are you from?

*Mark only one oval.*

- Muntenia
- Transylvania
- Oltenia
- Banat
- Crisana
- Maramures
- Bucovina
- Moldova
- Dobrogea
- Not from Romania

5. Do your parents have a history of pollen allergies, hay fever, or asthma?

*Mark only one oval.*

- Yes
- No
- Unsure

6. Do any of your other family members have a history of pollen allergies, hay fever, or asthma?

*Mark only one oval.*

- Yes  
 No  
 Unsure

7. Do you have personal history of atopy (allergy in early life)?

*Mark only one oval.*

- Yes  
 No  
 Unsure

### Allergy information

What type of allergies do you have?

- Weed/Herb Pollen (Ambrosia, Artemisia, Apiaceae, Centaurea, etc.)  
 Grass Pollen (Graminea, Poaceae, etc.)  
 Tree Pollen (Aceraceae, Aesculus, Cupressus, Fraxinus, etc.)  
 Dust mites  
 Animals  
 Drugs/Medications  
 Food  
 None  
 Other: \_\_\_\_\_

9. How long have you had the condition(s) listed above?

*Check all that apply.*

- Less than 6 months
- 6 months - 1 year
- 1 year - 2 years
- 2 years - 3 years
- Over 3 years

10. From a scale of 0-5, how severe are your allergy symptoms on average?

*Mark only one oval per row.*

	0 (No symptoms)	1 (Least severe)	2	3	4	5 (Most severe)
Sneezing:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Coughing:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rhinorrhea (runny nose):	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nasal congestion (congested nose):	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nasal itching (itchy nose):	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ocular itching (itchy eyes):	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mouth and Throat itching	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rash/Hives:	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. When do you usually experience your symptoms? Check all that apply

*Check all that apply.*

- January
- February
- March
- April
- May
- June
- July
- August
- September
- October
- November
- December

12. Do you experience allergy symptoms at work?

*Mark only one oval.*

- Yes
- No

13. How do you treat your allergy symptoms?

*Check all that apply.*

- Wait for it to go away
- Natural/Home remedies
- Non-prescription medicine
- Visit a doctor/Prescription medicine from a doctor

Other:  \_\_\_\_\_

**Household conditions**

14. During the age of 0-6, did you live in an urban or rural area?

*Mark only one oval.*

- Rural
- Urban
- Suburban

15. Do you have (or use to have) pets in your home?

*Mark only one oval.*

- Yes
- No

16. Check all of the statements below that apply:

*Check all that apply.*

- You smoke tobacco products
- You used to smoke tobacco products
- You live with someone who smokes tobacco
- You experienced maternal smoking
- On average, you keep your windows open more than 12 hours/day from May to November
- Your living space has mold
- Your past living space had mold

## Diet

17. There are 6 food categories from the US Department of Health and Human Services: Vegetable, Fruit, Grains, Protein, Dairy, and Oils/Butter. A balanced diet includes a wide variety of food from these categories. From a scale of 1-5, how diverse are your daily food choices?

*Mark only one oval per row.*

	1 (Least diverse)	2	3	4	5 (Most diverse)
Diet diversity rating	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

## Transportation

18. What mode of transportation do you use most?

*Mark only one oval.*

- Car
- Public Transportation (train or bus)
- Walking/Biking
- Other: \_\_\_\_\_

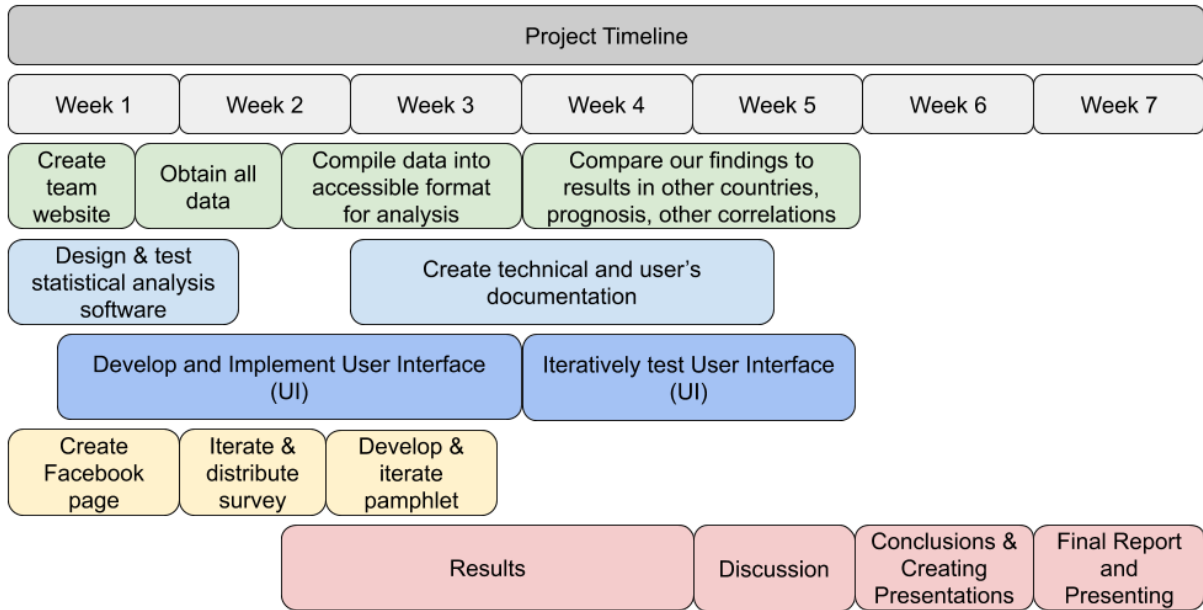
19. How much time do you spend in a car each day (on average)?

*Mark only one oval.*

- Less than 1 hour
- 1-2 hours
- 2-3 hours
- 3-4 hours
- 4-5 hours
- More than 5 hours



## Appendix B: Project Timeline



## Appendix C: Pamphlet

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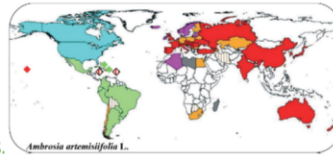
# Pollen Allergies

## About Pollen Allergies

Pollen Allergies is a global chronic respiratory disease. It became prevailing around the 1990s, affecting millions of people each year and having a negative impact on the economy. As of 2016, approximately 10-30% of the global population have hay fever and 4% have asthma due to pollen allergies. In the United States alone, it cost approximately \$11.2 billion on the country's economy in 2005.

## Quick Facts

*Ambrosia artemisiifolia*, commonly known as ragweed, is the main allergen, native in North America and spread to the rest of the world through war supplies. It became invasive in Europe, parts of Asia, and Australia. Other common pollen sources are trees and grasses.



Factors affecting allergies:

### 1. Climate Change

Climate change and global warming increase the temperature and lengthen pollen seasons

### 2. Air Pollution

Pollutants cause inflammation of the respiratory system, making us more susceptible to pollen allergies

### 3. Lifestyle & Exposure to Allergens

Your daily activities and exposure to allergens at a young age were proven to increase the chances of having pollen allergies

## Common Symptoms



Inflammation & Watery Eyes



Runny Nose



Sneezing



Coughing



Itchy skin

Hay fever  
Asthma



QR Code to our website

## Quick Links

Our website: <https://sites.google.com/view/wpi-igp/home>

Facebook: <https://www.facebook.com/polleninromania/>

Contacts: [polianaleru@yahoo.com](mailto:polianaleru@yahoo.com) [gr-bucharest-pollen-d20@wpi.edu](mailto:gr-bucharest-pollen-d20@wpi.edu)

## Prevention

1. Use public transportation or carpool to reduce emissions



2. Maintain a balanced diet



3. Exercise regularly



4. Keep household clean and ventilated



5. Avoid smoking and passive smoking



## Treatment

Depending on the severity of the symptoms  
Please consult with a doctor or allergist

1. Medicine (antihistamines)



2. Immunotherapy



3. Maintain a healthy lifestyle



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## **Appendix D: Data Analysis Tool Development**

The tool that we created is a data analysis program coded in Python to determine the relationships between airborne pollen counts and environmental factors such as climate and air pollution. The full code can be found on Github: <https://github.com/trschaeffer/PollenTool>

We have also written a detailed User's Guide including video tutorials so that anyone can learn how to use the tool. It can be accessed from this link: <https://docs.google.com/document/d/1AO7KPz4ybl1cILyjgckGVQ38X49zzYsnGo60tWddggA/edit?usp=sharing>

The development process of the tool is covered in this appendix, including the descriptions of the code for data processing and analysis.

### **D.1 Development of the Data Analysis Tool**

The development of the pollen tool began as a segmented process where the individual functions were written before implementation into the user interface (UI). The three main tabs of the UI: Data Entry, Correlation, and Plotting, became three separate python files which are imported into the main UI file. The goal of the data entry file is reading and merging data that the user inputs to the master Excel file using the openpyxl library. The correlation functions are able to filter the data into a format that can be analyzed using Spearman's correlation methods. The plotting functions are able to process the data and generate plots using the python library Matplotlib, including plotting of various forms of regression.

### **D.2 Development of the User Interface**

Our data analysis tool was built with a set of robust logic so that it would be flexible and applicable to as many situations as possible. Below are some of the decisions that we made to ensure that the tool could be used for all of our collaborator's data.

We have created flexibility in the user's ability to import data. The tool will accept .xls and .xlsx files, and the format in which data is stored in these files can range. Additionally, the user has the option to import a new data file that they have created and add it to their master data set, or load in the master data set. The master data set consists of all of the data they have imported in the past. This allows all of the different types of data, such as pollution, climate, and pollen, to be stored all in one place for easy access by the tool. Since the daily pollen counts are currently collected manually, we have also created the option to enter individual data points to the master data set using the tool and calculate the total pollen per day.

The tool is also able to calculate correlations and generate graphs based on various conditions the user can opt to use. The user may filter the data to include only certain dates, specify the pollen season, calculate monthly or yearly averages, and plot and extend regression lines into the future.

#### **D.2.1 Data entry Logic**

One of the innovative features of our tool is its ability to continually be updated with data over time, allowing more accuracy in its data processing over time. The challenge lies in the variance

of formatting styles, thus, our tool must be flexible to receive and understand these differences. We received files with three different formats and two different file types. While these different formats initially provided a challenge, it allowed us to enhance the adaptability of our program. A .xlsx format with the dates in mm/dd/yyyy format was used in the spreadsheet that will contain all data, a spreadsheet we refer to as the “mastersheet”. When importing data to the mastersheet, the tool tries to identify the format of the data file by checking cells ‘A2’, ‘A3’, and ‘B1’ for a date, whether it be a written out month or a formatted date. If written-out months are given, the year is extracted from ‘A1’. The program will then use the orientation of the dates to continue to extract the category information and data out of the file. With this, as well as several functions to merge, and filter data by date and category, we were able to get all data into a single format and onto the mastersheet. This mastersheet is loaded and updated whenever a new file is merged into it.

### **D.2.2 Merging, filtering, and maintaining data integrity**

When a spreadsheet is created it contains three key elements that our program must be able to handle. It contains categories, data, and dates. These categories are filled using the above techniques. Categories will be a list N long, dates will be a list M long, and data will be a list of lists, N lists of M length.

The first operation performed on this dataset is to remove any categories and dates with no data in them. Any cells that are blank, contain a “-”, “--”, or “nan” are considered to be empty and are turned into NoneType. It is best to remove these empty sets so the user will not be able to select an empty category to be analyzed, which would result in absence of results. The dates containing no data were also removed so that the program could run faster and not increase file sizes unnecessarily. Whenever a date or category is deleted from the two lists, special care is taken that the main data list is also resized so that it can continue to align its index values to the indexes of the dates and the categories. Whenever a category or date is deleted, a string is generated describing this action and can be reported to the user.

The second main operation that is performed after selecting a file to browse is to merge this file into the master data set. The idea behind this is it will give the user the ability to interface with all available data at once. Similar categories are brought together, as well as similar dates. To properly merge categories together the category with the shorter name is compared against the longer category, concatenated to the same length. Any data within these categories is also merged, with the data from the new file overwriting the data from the masterfile. This is done so that if there were to be a mistake in the master spreadsheet, one could simply fix the original spreadsheet then import the data once again, as opposed to manually editing the mastersheet as well as the original file. “Total pollen” is a special category that will always overwrite all data in its category. This is done so that if a former pollen category were made a non-pollen category it would not allow any prior data to remain.

If a new category must be added, it is simply put on the end of the list of categories. While this process could be done alphabetically, for us it makes more sense this way because pollen allergies can be loaded into the master sheet first, followed by other factors, allowing the most important data to always appear first in drop-down menus. Upon merging files, the interface will

generate a prompt asking the user if the new categories are pollen categories. This is done so that total pollen per day can be calculated based on the pollen count of any given day. To note a pollen category, a marker, “(p)” is added to the end of its name. The marker is always filtered out before presenting data to the user. To view and edit what is a pollen category, the user is able to list all categories along with their status as a pollen category. Dates are merged chronologically, and future dates are appended to the ends of the categories. Special care is taken throughout these processes to ensure that the data is kept associated with the correct dates and categories. This process is shown below.

How can we merge these two datasets together?

New SS	Category 2	Category 4
Date 3	Data 23	Data 43
Date 4	Data 24	Data 44

Master SS	Category1	Category 2	Category 3
Date 1	Data 11	Data 21	Data 31
Date 2	Data 12	Data 22	Data 32
Date 4	Data 14	Data 24	Data 34

Step 1: Insert dates and blank data to align lengths

New SS	Category 2	Category 4
Date 1	Data 21	Data 41
Date 2	Data 22	Data 42
Date 3	Data 23	Data 43
Date 4	Data 24	Data 44

Master SS	Category1	Category 2	Category 3
Date 1	Data 11	Data 21	Data 31
Date 2	Data 12	Data 22	Data 32
Date 3	Data 13	Data 23	Data 33
Date 4	Data 14	Data 24	Data 34

Step 2: Find like categories



Step 3: Merge like categories

Category 2
Data 21
Data 22
Data 23
Data 24

Master SS	Category1	Category 2	Category 3
Date 1	Data 11	Data 21	Data 31
Date 2	Data 12	Data 22	Data 32
Date 3	Data 13	Data 23	Data 33
Date 4	Data 14	Data 24	Data 34

Master SS	Category1	Category 2	Category 3
Date 1	Data 11	Data 21	Data 31
Date 2	Data 12	Data 22	Data 32
Date 3	Data 13	Data 23	Data 33
Date 4	Data 14	Data 24	Data 34

Step 4: Append new Categories

Category 4
Data 41
Data 42
Data 43
Data 44

Master SS	Category1	Category 2	Category 3
Date 1	Data 11	Data 21	Data 31
Date 2	Data 12	Data 22	Data 32
Date 3	Data 13	Data 23	Data 33
Date 4	Data 14	Data 24	Data 34

Master SS	Category1	Category 2	Category 3	Category 4
Date 1	Data 11	Data 21	Data 31	Data 41
Date 2	Data 12	Data 22	Data 32	Data 42
Date 3	Data 13	Data 23	Data 33	Data 43
Date 4	Data 14	Data 24	Data 34	Data 44

### D.2.3 Special treatment of “Pollen Categories”

There are several differences in the way that data is represented between our collaborator and the other institutes whose data we used. When the pollen count is zero, that category is left blank. When weather data is not taken, the cell is left blank or with a ‘-’. This would cause some issues for the tool because it raises the question, “how should a blank or ‘-’ be dealt with to keep the

data honest?” The resolution our group created was by making a distinction between the treatment of pollen and non-pollen categories.

When the user merges a file, just before the new categories are appended to the end of the master data set, the user is given a checklist of the new categories, and asked to check off which are pollen types. This begins the special treatment of the pollen category. A ‘(p)’ is added to the end of the category’s name to mark it as a pollen category, and -10000 is added in every blank slot of the data. The -10000 is treated as zero by the UI, and simply marks that the data was added artificially. This allows the removal of pollen categories, along with any zeros the tool has added to the data. There is a button in the Data entry section of the UI allowing the user to switch categories between being a pollen or non-pollen category using the same dialog as before. Having the user perform this task also allows the creation of a total pollen category, which is the sum of all pollen categories. There is a separate button to calculate this category initially, and whenever a pollen category is modified, it will automatically be recalculated.

### **D.3 Correlation and graphing**

The program creates an array for each variable using “numpy.array”, then uses the function “spearmanr”, available from the SciPy library in Python, to calculate Spearman’s correlation coefficients. We used the “polyfit” function of the in the numpy library to create linear regression for each relationship. Polynomial regression applies the same “polyfit” function with some different parameters. LOESS regression is done using the “loess” function of the statsmodel library.

### **D.4 Advanced Data Analysis Settings**

In order to make the data analysis functions of the tool more flexible, we decided to implement some optional advanced settings for organizing the data. Since there is such a large number of data points available to cover the many years of data collection, the graphs can easily become very messy and difficult to interpret. As a means of simplifying the analysis process, we have made it an option for the user to graph the averages of the data across years or months and to graph these averages. This option is also available for the correlation calculations so the user can determine the appropriate spearman’s correlation coefficient values for the data they wish to analyze. If used, when the user prompts for the correlation calculation or creation of the graph, the data is read in by the tool and it calculates averages of the data points. The tool goes through every date in the file, unless a specific date range is specified (see section below), groups the dates and corresponding data point for each time period, calculates the average for each group of data, and reports them in a chronological array used for the graphing function or correlation calculation. This makes it much easier to visualize and analyze the data over a period of several years. Simplifying the data in this way may also bring to light some patterns in yearly or monthly meteorological or pollution trends that influence the pollen season.

Other options available to the user are selecting to correlate or graph data within only certain dates in the pollen season or a certain date range. If the user chooses to select these options, then only data within the specified date range will be included in the calculations or graphs. To do this, the tool reads in each date, determines if it is within the specified date range, makes arrays of only the corresponding data points within that range, and then completes the calculations and

graphing functions using these filtered arrays. Any combination of optional settings is able to be processed by the tool. These features are useful because the user may want to look at only certain dates within the pollen season, or a certain month, week, or year.

### **D.5 Delivery of the Data Analysis Tool**

Python is not a language that is made to produce deliverable products to those with little technical experience. This shortcoming is exasperated by our remote presence, meaning that our team could not be present to assist any installation or technical guidance. Any user loading python packages is typically expected to install Python, collect dependencies from the Python terminal, and finally launch the file through the same terminal. As an alternative to this, we use the Pyinstaller package, a tool that is made to create a single executable file with all dependencies, even Python, included. While it creates a large file that may take a while to load and be scanned by antivirus softwares, this is the best option for our work, as this file can be run on any computer with a single click.

Getting Pyinstaller to properly work was challenging. The process involved finding all of the missing “hidden” imports. The steps taken to get the pyinstaller tool to work were documented and put into a text file so that this process may be repeated in the future. Unfortunately, we found pyinstaller to be extremely unreliable in transferring from computer to computer, so results may vary with our process of using it to successfully create a .exe.

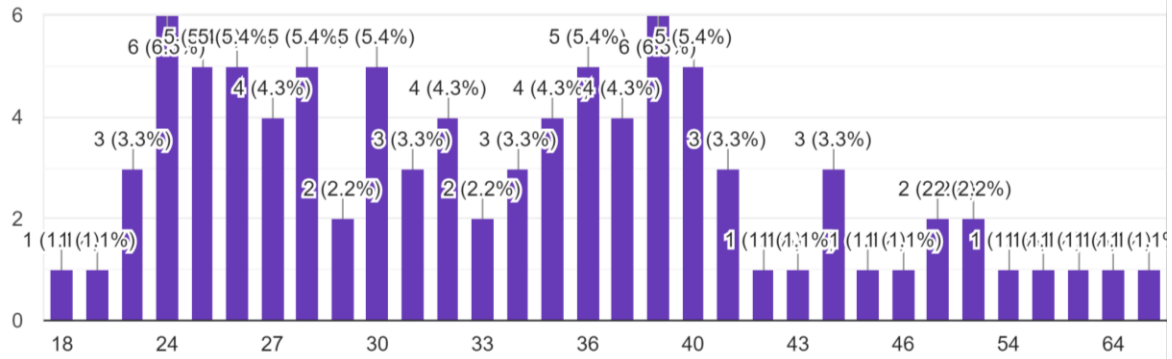
## Appendix E: Full Survey Results

Full responses can be found here:

[https://docs.google.com/spreadsheets/d/1Uz006amzXgDYhebPIFsI1P-A7xcQ21FSuYZek\\_bERhM/edit?usp=sharing](https://docs.google.com/spreadsheets/d/1Uz006amzXgDYhebPIFsI1P-A7xcQ21FSuYZek_bERhM/edit?usp=sharing)

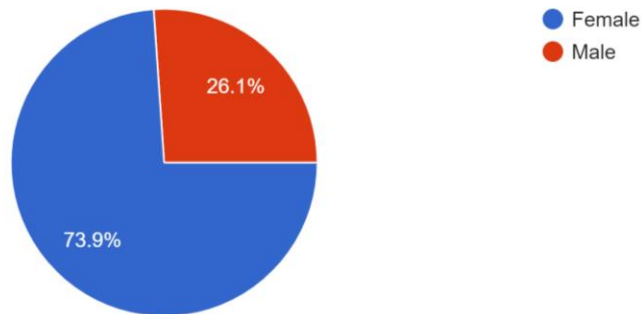
How old are you?

92 responses



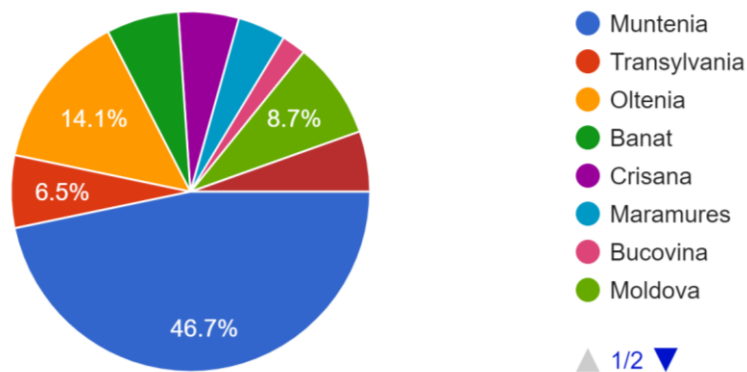
What is your gender?

92 responses



What region of Romania are you from?

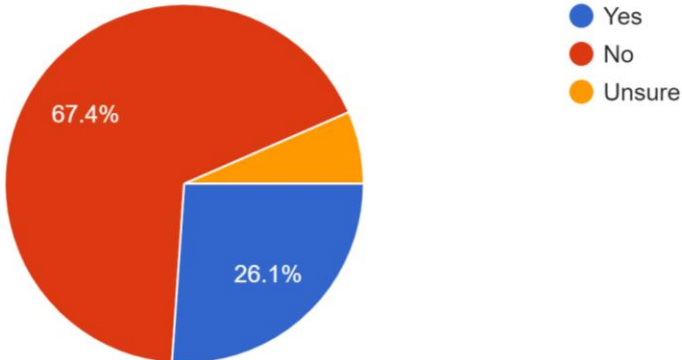
92 responses





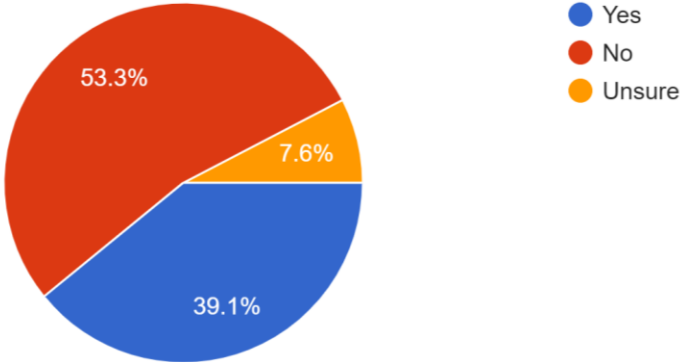
Do your parents have a history of pollen allergies, hay fever, or asthma?

92 responses



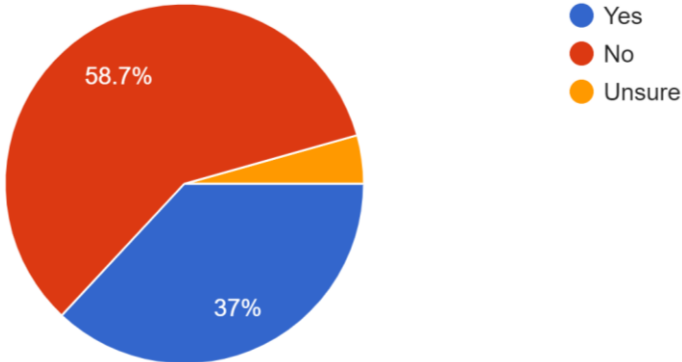
Do any of your other family members have a history of pollen allergies, hay fever, or asthma?

92 responses



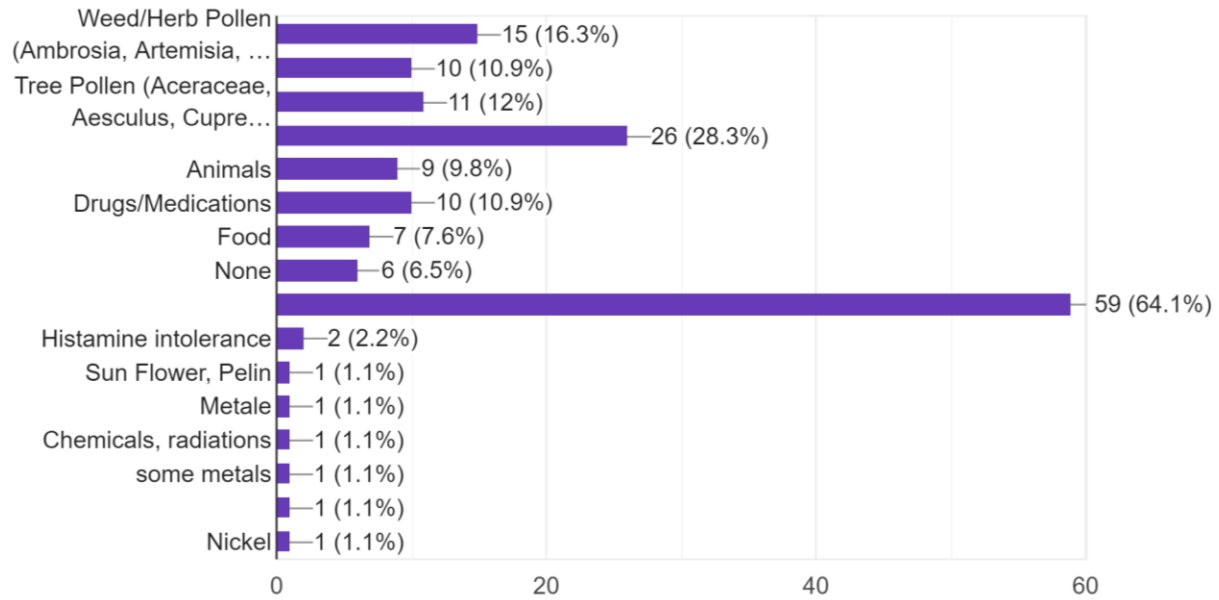
Do you have personal history of atopy (allergy in early life)?

92 responses



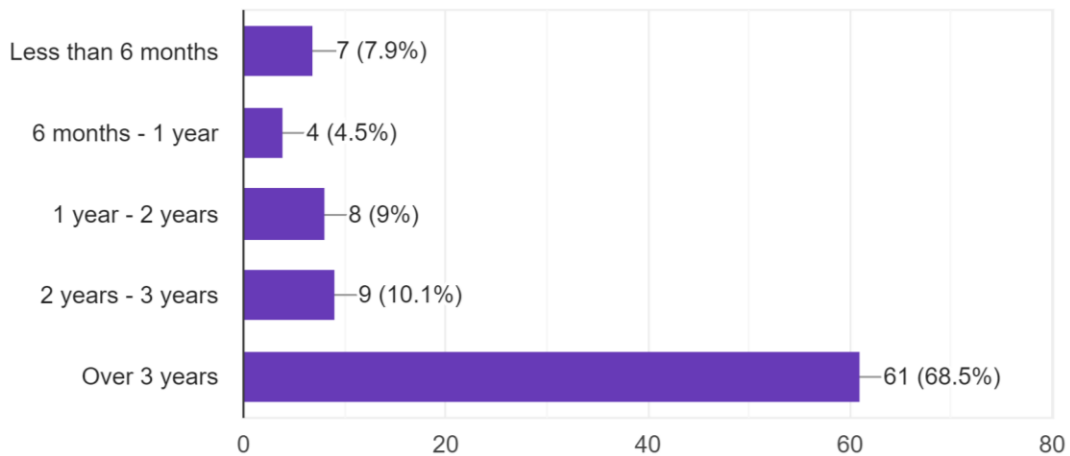
## What type of allergies do you have?

92 responses

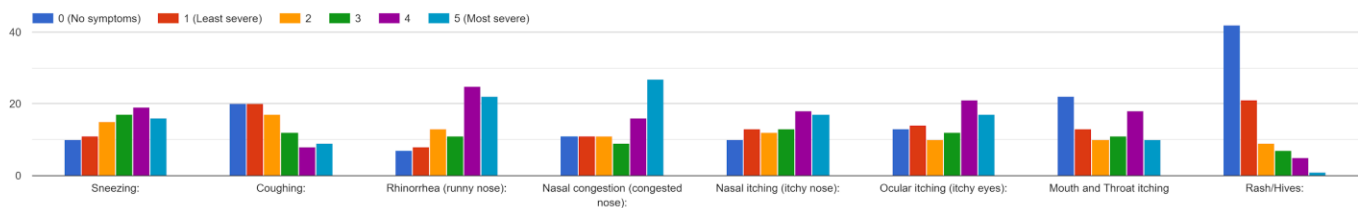


## How long have you had the condition(s) listed above?

89 responses

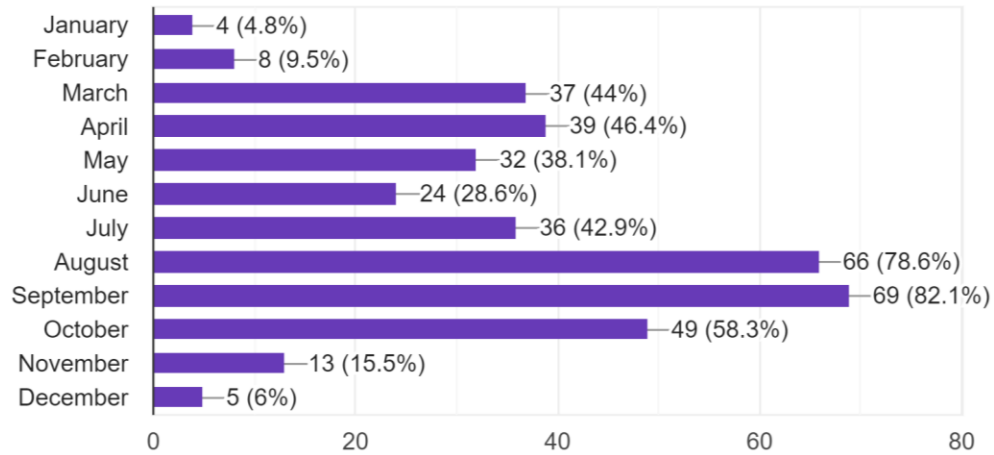


From a scale of 0-5, how severe are your allergy symptoms on average?



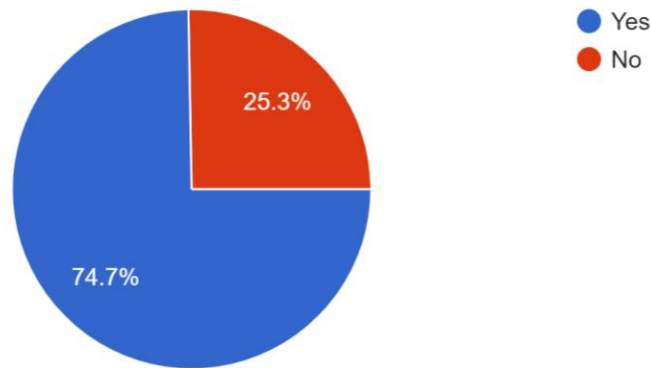
### When do you usually experience your symptoms? Check all that apply

84 responses



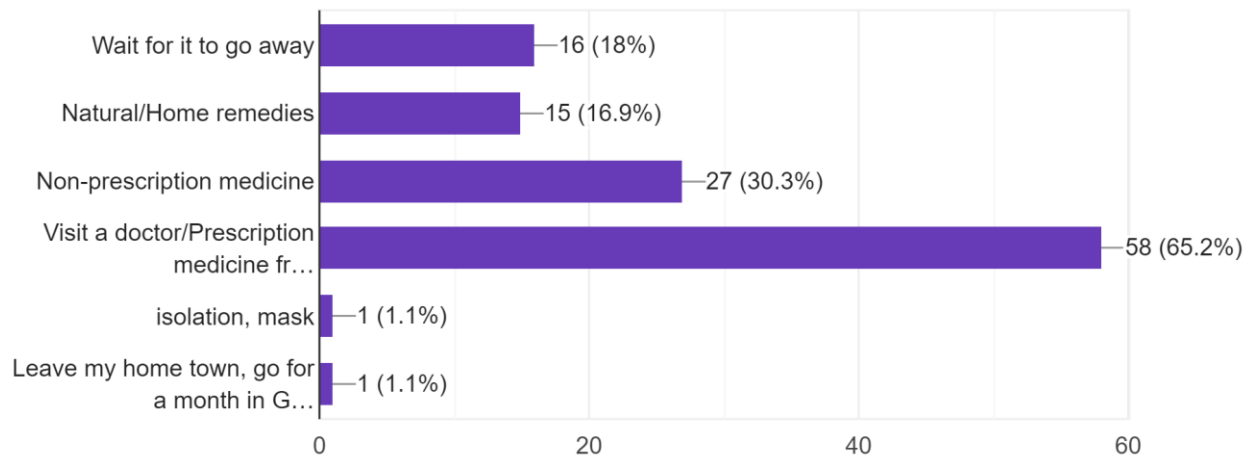
### Do you experience allergy symptoms at work?

91 responses



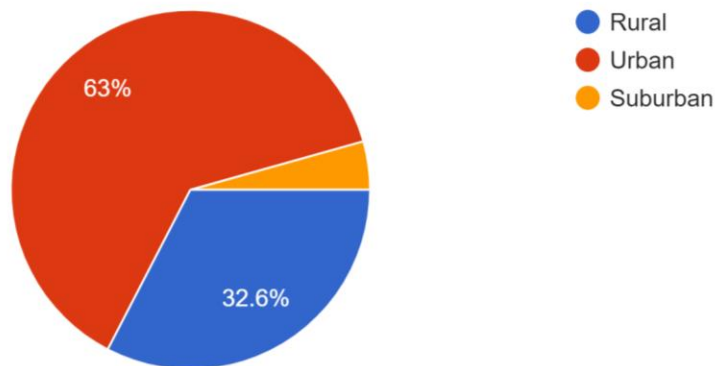
### How do you treat your allergy symptoms?

89 responses



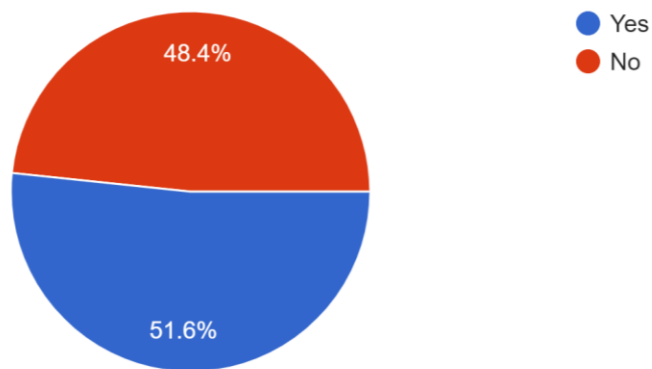
During the age of 0-6, did you live in an urban or rural area?

92 responses



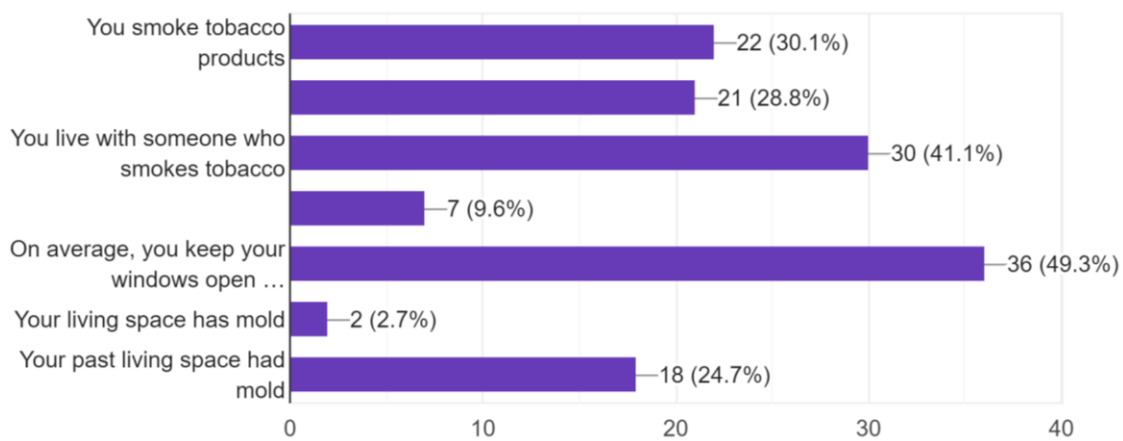
Do you have (or use to have) pets in your home?

91 responses

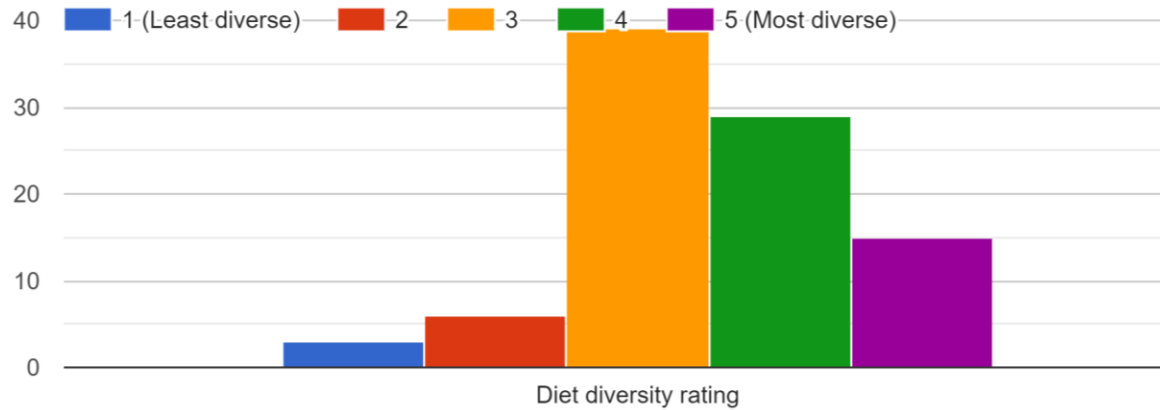


Check all of the statements below that apply:

73 responses

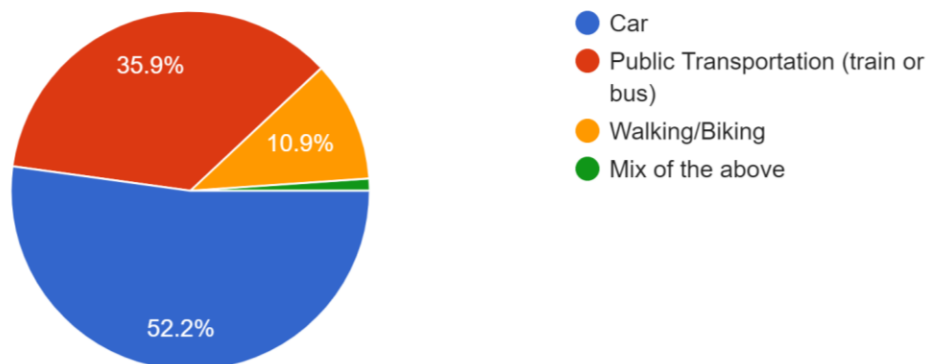


There are 6 food categories from the US Department of Health and Human Services: Vegetable, Fruit, Grains, Protein,...5, how diverse are your daily food choices?



What mode of transportation do you use most?

92 responses



How much time do you spend in a car each day (on average)?

92 responses

