Sung Ahn
Final Report

Abstract

Wildfires have been increasing in frequency of wildfires in the western United States (US) during the past decade, experiencing some of the worst wildfires in terms of air pollution that the western US has seen and California has been responsible for 88% of the total annual wildfire area in the entire US. The wildfires are causing an increase in particulate matter in the atmosphere, that lead to respiratory conditions such as asthma, from inflammation and irritation. Although growing evidence shows that during peak fire periods there is an increase in asthma hospitalization rates, significantly less is known about the impacts of wildfire occurrences on asthmatic conditions of humans. With greater wildfire rates, there will presumably be a greater number of particulate matter in the atmosphere, which may lead to greater asthmatic attacks. Using programming, we were able to create concentration maps of the wildfire occurrences in California during normal and peak recorded years, calculated the hospitalization rates related to asthma per capita, and examined the wildfire rates to the correlated years of asthma hospitalization rates per capita to determine the correlation between wildfire occurrences and asthmatic hospitalization rates. During high wildfire rate years, increase of asthmatic hospitalization rate per capita was significantly associated. A positive trend of the two variables was seen from our analysis and possible concern of air pollution resulting in varying population density was not of concern. Our work will enable further knowledge in ecology and wildlife diversity and should be built upon in future studies to analyze how wildfire severity could affect asmatic conditions.

Introduction

Asthma is a common long-term inflammatory disease of the airways of the lungs. Symptoms involve recurring episodes of wheezing, coughing, chest tightness, shortness of breath. For humans, smoke from wildfires can cause health problems, especially for children and those who already have respiratory problems (1). Asthma morbidity has been growing rapidly in certain subpopulations and different areas of the world and as a lower respiratory illness, it is ideal to question a relationship between asthma and air pollution. Several epidemiological studies have demonstrated a close association between air pollution and respiratory allergic diseases such as bronchial asthma (1-3). There are still arguments between the effect of catastrophic wildfires on long term asthmatic outcomes of individuals as there have been findings of no significant change in asthmatic hospitalization rates before and after the fires (4). However, there is some evidence that events that cause air pollution such as wildfires aggravate respiratory disease, especially asthma (5). There have been previous studies that found young children had bigger increases in hospitalization visits during the peak fire period than older age groups (1) and it has been indicated that there is a highly

significant relationship between asthma admissions and particulate matter concentrations (3).

Most wildfire investigations focus on short-term changes in hospital admissions or on segments of the population believed to be especially sensitive to respiratory stress, such as patients asthma or on those individuals especially prone to exposure, such as firefighters (6). Additionally, data that has been published by the Health *Effects Institute* indicates that a 10 μg/m3 increase in PM10, the coarse particulate fraction of air pollution is associated with approximately 3 to 6% decrease in peak expiratory flow in mildly asthmatic school children (1,7). Although the data collected and analyzed have been limited to a smaller region of San Diego, California most recent studies of wildfire smoke and morbidity/mortality take advantage of long time series data and provide growing evidence of significant increase in asthma hospitalization rates that lead to requiring treatment or in extreme cases, mortality (8). A study of 13.5 years of data including 48 days affected by wildfire smoke in Sydney, Australia, demonstrated a significant increase in mortality associated with smoke-affected days (9).

The California fires offered a unique opportunity to conduct a population-based, large-scale investigation of the health consequences of the smoke from wildfires on individual's health. At least 12 communities were either directly affected by the fire (damage) or indirectly affected (smoke) in the Southern California counties where the wildfires have been the most abundant and oppressive in the past decade (10). We thus wanted to see if the trend of wildfire rates and hospitalization due to asthma are correlated and Southern California was chosen because of its abundance in wildfires over the past decade. We hypothesized that the wildfire rate is a great predicative measure of inducing respiratory symptoms, such as asthma and would greatly affect the overall asthma hospitalization rates with increasing wildfire rate.

This study had several important advantages and findings. First, the study population of Southern California residents exposed was confined to a small geographic area, which have allowed for a better estimation of the impact of wildfires using data reported by trusted sources. Second, the analysis of the study data employed various analytical methods, which allowed an assessment of the sensitivity of the study findings through the use of different statistical methods. Third, in the study community there have been significant increases of wildfires over the past century and the data contained a relatively large number of residents with a doctor's diagnosis of asthma, which provided the study with good power to identify specific impacts on this large and potentially susceptible community. Finally, the analysis has provided thoughtful and reasonable support to believe that the asthma hospitalization rates increase with wildfire rates, which have been presumed by many previous researches done in various different regions (1-10).

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Methods:

To proceed with the analysis, data was gathered from the kaggle data publication where it contains a database of wildfires that have occurred in the United States from 1992 to 2016. The wildfire records report fire size, point location, state, county, and the class of the fire. There were about 1.8 million data values that covered the entirety of the United States. There were more than 100,000 data values for the state of California alone, which was the target state of interest in the research analysis. This data set also includes the agency that took care of the wild fire and the national wildlife coordinating group that reported data about the fire, which validated the data values that were being presented on the data set.

Additionally, asthma patients data set from the California Health and Human Services which showed the number of visits that california residents had to the hospital from years 2000 to 2016 and kept track of the county that recorded the data was used. For the purpose of simplicity and efficiency, Southern California was chosen as the target region for analysis as the 21st century wildfires have been reported as the deadliest and most destructive season on record in California (11), especially in Southern California, thus making the region ideal for studying wildfire impact on Asthma treatment.

Furthermore, population data was gathered from the United States Census Bureau to examine the population of each county in California (Figure 1). The data contained the annual estimates of the resident population by sex, race, in combination from 2010 to 2018.

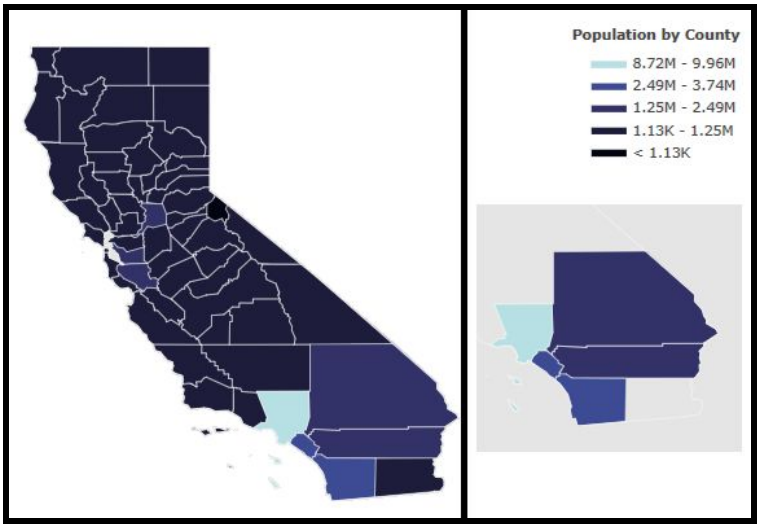

Fig. 1.

Average Population of each county in California State from 2000-2016. Only the Southern California counties were used for the continuation of this study's analysis. *On the right* is the Southern California counties. Population density is higher in the southern communities of California

The data gathered were analyzed through basic python packages such as pandas, numpy, matplotlib, and seaborn. Additional packages such as plotly and geopandas were used as well. Pandas and numpy packages allow for high-performance scientific

computing and matplotlib/seaborn allow the analyzed data to be visualized through graphs and charts. Plotly is a plotting library that allows for plotting a wide range of statistical, geographical, and scientific charts. Geopandas, an extension of pandas, was also used to assist in creating visual heat-maps as the package allows easier manipulation of geospatial data. Plotly and Geopandas were chosen as a visual heat-map, as mentioned before, would create a better visual of the data set (wildfire rates, population) and would allow for a locationalized visual that is presented on a map. The two packages' functionality works perfect for such cases and is presented in the figures.

Results:

From the asthma hospitalization data and the population data, we were able to determine the Asthma Hospitalization per Capita of each Southern California county. As the population of each county is greatly varying (I.e. Los Angeles County has an immensely greater population density than Ventura County), it was logical to proceed the analysis with an Asthma per Capita analysis. There was a sharp incline of asthma per capita starting after year 2004 to 2008 and another incline of asthma per capita until year 2012 (Figure 2). This seemed to be the case for most of the Southern California counties, especially those that were located in the most southern part of the grouping (Table 1). The increase of asthma per capita from 2004 to 2008 was significant ($p=0.0058$) and the increase of asthma per capita during 2008 to 2012 was significant as well $p=0.00709$).

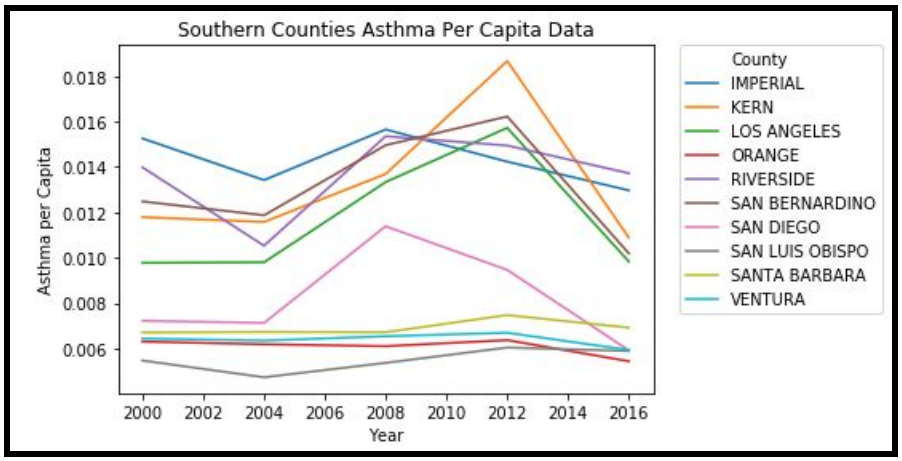

Fig. 2.

Graph of Asthma per Capita for years 2000-2016 in Southern California Counties. The counties that were more South out of the list above tended to have higher asthma per capita.

County	Average Population 2000-2016	2000	2004	2008	2012	2016
imperial	179,431	0.015254	0.013421	0.015650	0.014232	0.012969
kern	859,797	0.011790	0.011577	0.013690	0.018665	0.010889
los angeles	10,006,227	0.009777	0.009802	0.013334	0.015723	0.009834
orange	3,088,572	0.006310	0.006192	0.006108	0.006374	0.005445
riverside	2,256,447	0.013981	0.010531	0.015351	0.014943	0.013723
san bernardino	2,079,655	0.012481	0.011871	0.014957	0.016221	0.010195
san diego	3,179,295	0.007226	0.007132	0.011389	0.009467	0.005926
san luis obispo	273,233	0.005475	0.004739	0.005373	0.006048	0.005897
santa barbara	431,116	0.006713	0.006737	0.006722	0.007477	0.006922
ventura	837,818	0.006444	0.006354	0.006546	0.006697	0.005941

Table 1.

This table portrays the data of Southern California counties' Asthma Hospitalization rate per Capita from 2000-2016 for every 4 years. Additionally, it portrays the average population of the counties for years 2000-2016.

Severity of California wildfires have been different year to year, yet relatively constant. However, in years 2007/2008 and 2011/2012 the wildfire rate has been high across the entirety of California (Figure 3). Especially in the Southern California counties, the wildfire rates during the two timespans above were incredibly high, reaching near average of 513 wildfires in 07/08 and 414 wildfires in 11/12. The 04/05 California Wildfire rates shown in Figure 3 have been the relative wildfire frequencies that have occurred in other years within the frame of 2000-2016.

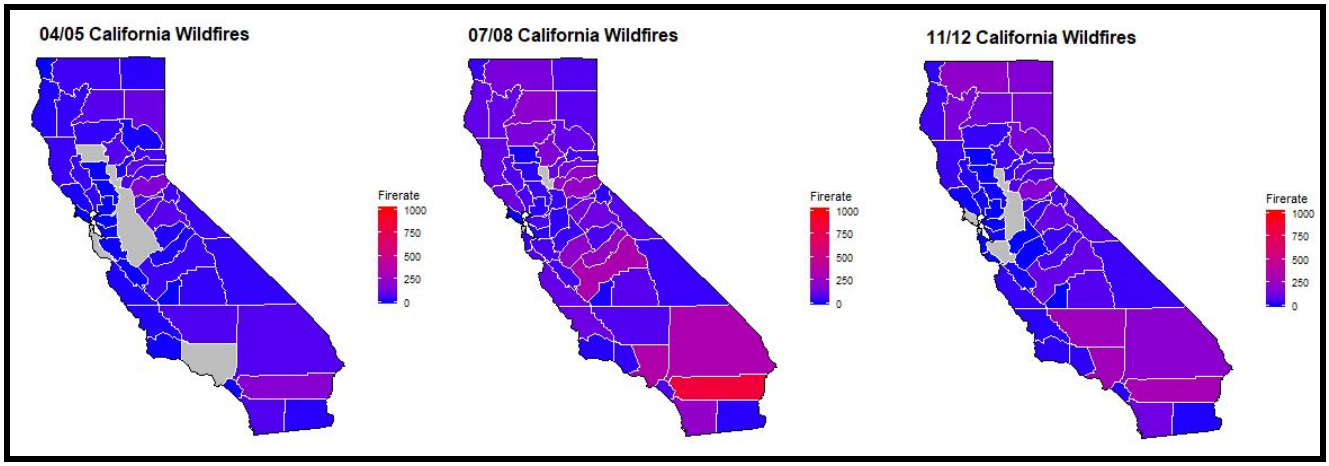

Fig. 3.
2004/2005 Wildfires, 2007/2008 Wildfires, 2011/2012 Wildfires shown respectively. Increasingly large collections of red and purple, which means high fire rate, are shown in the Southern California counties in 2007/2008 map. Although, not as severe as 07/08, still a large population of high fire rate count is present in the 2011/2012 map. 2004/2005 Wildfire map shown on the furthest left is an ideal example of other years' wildfire rates that are not shown.

To provide a better perspective of the effect of wildfire rates on asthma, a regression fit was carried out to quantitatively assess the relationship. The data of asthma per capita and wildfire rates were plotted against each other (Figure 4). The data that was available was restricted to years 2000-2016, and there were a wide range of asthma per capita in the lower regions of wildfire rate values (ranging from 0.0013 - 0.0175 asthma per capita in 0-200 wildfire ranges). An increase of 0.00001 asthma per capita can be shown per an occurrence of a wildfire.

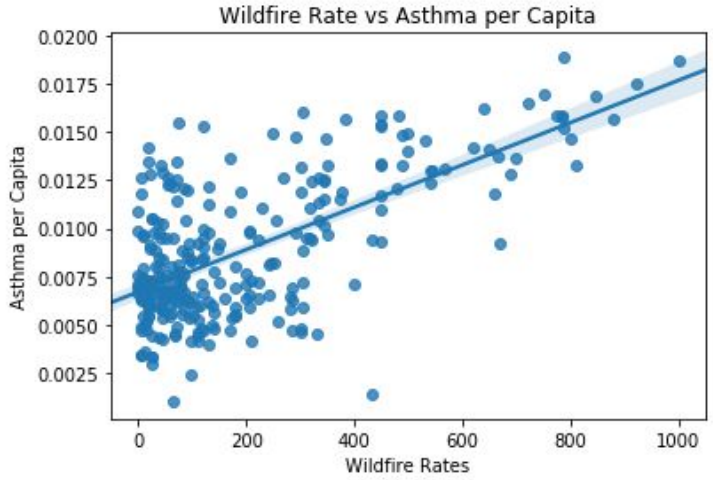

Fig. 4.

Collection of Asthma per Capita per year and Wildfire Rate per year data from 2000-2016 in Southern California Counties. Most Southern California counties' wildfire rates per year are in ranges of 0-200. Positive trend between Wildfire rates and Asthma per Capita is shown.

Discussion:

In this data-based study of Southern California residents, increases in asthma hospitalization rate per capita were associated with increase of wildfire rates. In the examination of the asthma per capita, it was quite clear that there have been increases in the years after 2004 and peaked at year 2012 for most Southern California states. This finding from data analysis is parallel with the findings of increased wildfire rates per

year after year 2004, especially in the year 2007/08 and 2011/12. A large number of studies on the adverse health effects associated with particulate matter air pollution have been identified (13,14) and a significant level of particulate matter is elevated during wildfires (15).

It seems logical to expect that those with asthmatic problems may be more susceptible to wildfire's effects of particulate air pollution as a result of sensitivity to either the irritant or inflammatory effects caused by inhaled particles. The increased wildfire rate seen in 2007 and 2012 have been recorded as the top 3 greatest amount of wildfires recorded in California history (15). As the heat-map of the data show that 2007 and 2012 have a relatively large fire rate (Figure 3), especially in the Southern region of California, there is substantial evidence that wildfires are associated with increases in Asthma hospitalization per capita.

Although the regression model (Figure 4) supports the analysis and provides the evidence that there is a positive trend between wildfire rate and asthma hospitalization per capita, the wide range of data points congregated in between wildfire rate 0-200 may bring about questions of correlation. Los Angeles County, for example, has had an average population of around 10 million during the time frame of 2000-2016 (Table 1) making Los Angeles County the county with the greatest population in California. There have been multiple studies that have provided evidence that increased population density are signs of development and increased air pollution (16, 17). However, Los Angeles County has had a relatively average or less asthma hospitalization rate per capita compared to the other counties in Southern California, which may lead to a conclusion that the increase in asthma per capita for the Southern California region in 2008 or 2012 is not due to increase in population, but due to the rate of wildfire occurrence.

Some care should nevertheless be taken in interpreting the findings of this study analysis. There are quite a lot of unavoidable biases that are caused by the unmeasured changes over time. Confounding by temperature, humidity, precipitation, and other types of biases that can be susceptible to any ecological study may have affected the data in this study as well (18). For future analyses, looking into the type of tree population that dominates the region during a wildfire and the severity of particulate matter that is released may be an approach that would be necessary. Different types of trees have different burn severity and different levels of particulate matter release (18), which may result in the fluctuating levels of asthma per capita for 0-200 ranges of wildfire rates we see in Figure 4. Additionally, although it was not analyzed in this analytical study, further analysis into wildfire size and its asmatic effect may be an ideal approach as a bigger wildfire would presumably release more particulate matter and thus cause greater asthmatic reactions.

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Data Source

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