UNIVERSITY OF CALIFORNIA

Santa Barbara

Wildfire Smoke in Strawberry Fields:

Evaluating Fire-Associated $PM_{2.5}$ Exposure Effects on Ventura County Farmworkers

by

Jacklyn Vo

A senior thesis submitted for the degree of

Bachelor of Arts

in

Environmental Studies

Thesis Advisor:

Dr. Helene Gardner, Lecturer, Environmental Studies

May, 2021

ABSTRACT

Wildfire Smoke in Strawberry Fields:
Evaluating Fire-Associated $PM_{2.5}$ Exposure Effects on Ventura County Farmworkers

by

Jacklyn Vo

Wildfires are predicted to increase in frequency and severity as climate change persists. While public health officials recommend staying indoors and wearing proper protective equipment during fire events, many farmworkers are rushed to crop fields to save food from falling ash. Although fire may not be nearby, smoke can be dangerous to those inhaling toxic levels of the fire's gas and particle components. Particulate matter 2.5 ($PM_{2.5}$) is of utmost public health concern because of its ability to penetrate deep into the lungs and enter the blood system. Current research suggests that $PM_{2.5}$ can detrimentally impact human respiratory, cardiovascular, and mental health. This study explores the $PM_{2.5}$ health effects on Ventura County farmworkers during 2015-2020 fire periods. A preliminary visual correlation assessment and percent change analysis were conducted using Ventura County Medical Center's (VCMC) pulmonary health records to quantify how fires affect the number of people seeking respiratory healthcare. I found that there is a weak visual correlation between fire periods, high $PM_{2.5}$ concentrations, and healthcare encounters. An average 2.06% increase in total encounters was found for all major wildfires during this time period. Farmworkers experienced increased visitations during all major fire events while non-farmworkers only had an influx for the Thomas Fire. A 91.67% increase for farmworkers. This implies that farmworker encounters approximately double during this fire, due to poor air quality irritating respiratory systems. Documenting farmworker vulnerabilities and the impacts made by natural disasters are important in developing solutions for essential and governmentally underrepresented groups, such as farmworkers.

ACKNOWLEDGEMENTS

This thesis could not have been possible without the immense support from my lovely mentors, University of California, Santa Barbara (UCSB) staff, Ventura County Medical Center (VCMC) employees, and peers. Despite our circumstances with the COVID-19 pandemic, I am beyond grateful for all the help and guidance received for this project, especially during this academically and personally challenging time.

I would first like thank Dr. Christopher Landon and Dr. Nathan Carroll for becoming my mentors, accepting me into your VCMC community, and guiding me through the research process outside of the university setting. Without you, I would not have been able to find the necessary data to explore the research questions I am curious about and complete this study. I never imagined connecting with such a supportive community, dedicated to building a welcoming environment for others. Your passion and love for helping others is truly contagious, and I will embody your compassion in my future endeavors.

I want to also express my utmost gratitude to Dr. Helene Gardner for being my thesis advisor, mentor, and friend. You have been the most understanding, kind, and badass professor I have ever been acquainted with. I appreciate you challenging me to question everything presented to me and practice my technical writing skills. I have enjoyed every meeting with you because of our fun, genuine, and honest conversations. You always bring a smile to my face and I am incredibly grateful for you being my thesis advisor.

Thank you, Heather Hodges, for guiding me through the statistical analysis process of my project. Your time, patience, and optimism has been a positive motivator for me to persevere. When we encountered a problem with the data, I admired how you always took a step back and took a different angle to approach the question. My experience, investigating my research

questions with you, is invaluable because I was able to revisit my knowledge of statistics and learn how to troubleshoot when playing with data.

To Dr. Simone Pulver, I have cherished your endless support since the end of my junior year. Thank you for being a wonderful light in my thesis process. You were empathetic to any issues I encountered during the project, assisted me with the UCSB Institutional Review Board (IRB) process, helped me brainstorm idea, and was transparent with all the necessary steps necessary to complete the thesis.

To all of IRB members and Information Technology (IT) staff that took the time to help me submit a transparent IRB protocol and develop a secure procedure to access the VCMC data. This was a learning experience for all of us and I am so appreciative of the immense support for everyone.

While this project does not contain concrete values or findings, it demonstrates the importance of supporting and documenting the experiences low-income communities and communities of color endure. As we continue learning about the interdisciplinary field of environmental studies, public health, and social equity, it's important – now more than ever – that we highlight the voices of underrepresented communities and be more inclusive when developing solutions. Thank you, everyone, for supporting this project.

It took a whole village to accomplish this thesis, but this learning process has been invaluable to my career in environmental health. I hope that you enjoy reading this thesis and thank you all from the bottom of my heart for your support.

NOTE ON MENTAL HEALTH

While 2020-2021 has been a difficult year for everyone because of the COVID-19 pandemic, I believe it's important to acknowledge the role our community has on an individual's perseverance and resilience. Many of my thesis course peers and I have embarked on an individual project that is already challenging on a normal year; however, it has been even more isolating because of COVID-19. During my senior year, I was struggling with one of the toughest years of my personal life, in addition to the pandemic. From being excited to start the project, to struggling with my depression and anxiety throughout the year, to almost quitting the thesis, and then eventually finishing the project, I would not have done this without all of my friends, family, mentors, and UCSB community. I can attribute this thesis work to people checking in with me, providing an open space to have conversations, and others going out of their way to support me. While everyone struggles with mental health to some extent, there are many people who may not have a support system, similar to mine. With this project as an example, I want to highlight the importance of being empathetic, compassionate, and kind. I also want to emphasize the need for the academic community, including UCSB staff and faculty, to take a step further to be there for students personally and academically. From my experience, I was fortunate to have a wonderful support system at home and university. Others may need a helping hand. I hope that both you and I can be a helping hand to anyone who needs it, just like how my community has been there for me.

TABLE OF CONTENTS

List of Figures vii
List of Tables vii
List of Equations vii

Chapter 1: Introduction 1
1.1 Introduction 1
1.2 Research Question 3
1.3 Rationale 4
1.3.1 Scholarly 4
1.3.2 Policy 4
1.4 Thesis Statement 5
1.5 Research Design 6
1.6 Chapter Summary 8

Chapter 2: Literature Review 9
2.1 Introduction 9
2.2 Fires & Air Quality 9
2.2.1 Particulate Matter 2.5 ($PM_{2.5}$) 10
2.2.2 Fire-Associated Particulate Matter 2.5 Health Impacts 12
2.3 Farmworker Health, Safety, & Vulnerabilities 16
2.3.1 Work Environment 17
2.3.2 Labor Laws & Regulations 17
2.3.3 Heat Exhaustion & Other Heat-Related Illnesses 18
2.3.4 Pesticides 20
2.3.5 Dust Inhalation 20
2.3.6 Fire Smoke 21
2.4 Chapter Summary 23

Chapter 3: Background 24
3.1 Introduction 24
3.2 Background on Ventura County 24
3.2.1 Healthcare in Ventura County 25
3.2.2 Agriculture in Ventura County 26
3.2.3 Farmworker Health Insurance Coverage & Access to Care 27
3.3 Major Fires & Air Quality from 2015-2020 28
3.3.1 The Thomas Fire 28
3.3.2 The Thomas Fire & Agriculture 32
3.3.3 The Thomas Fire & Farmworkers 32
3.3.4. Other Major Fires in Ventura County, 2015-2020 34
3.3.4a Woolsey & Hill Fires 35
3.3.4b Maria & Easy Fires 36
3.3.4c Lake & Holser Fires 37
3.4 Chapter Summary 38

Chapter 4: Methods 39
4.1 Introduction 39
4.2 Fire Inventory 39
4.3 Air Quality Methods 40
4.3.1 Ventura County Monitoring Sites 41
4.3.2 Rationale for EPA Daily $PM_{2.5}$ Concentration Dataset 41
4.3.3 $PM_{2.5}$ Inventory 42
4.4 Respiratory Health Methods 44
4.4.1 VCMC Health Data Description 46
4.4.2 Preliminary Visual Correlation Assessment 46
4.4.3 Farmworker vs. Non-Farmworker Percent Change Analysis 47
4.5 Chapter Summary 48

Chapter 5: Results & Discussion 50
5.1 Introduction 50
5.2 $PM_{2.5}$ Inventory Results 50
5.3 Preliminary Visual Correlation Assessment Results 53
5.4 Farmworker vs. Non-Farmworker Percent Change Analysis Results 56
5.5 Discussion 58
5.5.1 Respiratory Health & Fire-Associated $PM_{2.5}$ in Ventura County 58
5.6 Chapter Summary **..... 64**

Chapter 6: Conclusion 66
6.1 Introduction 66
6.2 Limitations 68
6.3 Future Research 69
6.4 Conclusion 71

References 72-77

LIST OF FIGURES

Figure 1: EPA Air Quality Index 12
Figure 2: Ventura County's Farm Landscape 27
Figure 3: PM2.5 Distribution During the Thomas Fire 31
Figure 4: Average Daily $PM_{2.5}$ Concentrations Across Ventura County Monitoring Sites 51
Figure 5: Daily Respiratory Encounters & Average $PM_{2.5}$ Concentrations Across All Ventura County Monitoring Stations 53
Figure 6: Daily Respiratory Encounters in Ventura County 54
Figure 7: Respiratory Hospital Admissions, Visits, & Farmworkers 55
Figure 8: Total and Mean Farmworker Respiratory Encounters in Ventura County 55

LIST OF TABLES

Table 1: Fire Inventory 40
Table 2: Percent Change of Respiratory Encounters during Ventura County Wildfires 56
Table 3: Z-Test Analysis of Percent Change 57
Table 4: Percent Change for All Encounters 58

LIST OF EQUATIONS

Equation 1: Percent Change 48

Chapter 1: Introduction

1.1 Introduction

When there's a large fire in the area, where do you run? Do you go outdoors or stay inside? According to public health and environmental agencies, minimizing your physical activity outdoors is recommended when there are unhealthy levels of air pollutants in the atmosphere; however, if you are a farmworker, you are rushed to the fields to save crops from falling ash (EPA, 2019; WHO, 2018; CAUSE, n.d.a). If you do not go to work, you may risk losing your job, housing, and meals. Proper protective equipment (PPE), such as respiratory masks, are recommended by public health officials, but are unlikely to be provided by your employers and are uncomfortable to wear. If you experience any respiratory discomfort or other health concerns, you may not be able to seek healthcare or health insurance to do so. You have no choice but to put your health at risk because you have to financially provide for yourself and your household. Working only minimum wage to provide meals for your family makes affording necessities difficult. You do not file a complaint to governmental agencies about being required to work in hazardous conditions because you fear retaliation or deportation, so you deal with the health risks and go to work.

As anthropogenic climate change persists, fires are suspected to increase in intensity and frequency. Not only are fires destructive to landscape and infrastructure, but they release harmful levels of smoke into the atmosphere. Fires emit toxic levels of air pollutants, such as carbon monoxide, ozone precursors, and particulate matter, that get dispersed throughout the surrounding region and inhaled by those exposed (Kollanus et al., 2016). The component of wildfire smoke that is of most health concern is particulate

matter 2.5 ($PM_{2.5}$). $PM_{2.5}$ is defined as liquid or solid particles with diameters of 2.5 micrometers or smaller (EPA, 2016). To put it in perspective, this is about 30 times the diameter of an average human hair strand! The inhalation of fire-specific $PM_{2.5}$ poses respiratory health concerns, such as exacerbated asthma and chronic obstructive pulmonary disease (COPD), because of its small size and ability to travel further through the lungs, into the alveoli, and bloodstream (Reid et al., 2016; EPA, 2016). Alveoli are tiny air sacs where the lungs exchange gases, like oxygen and carbon dioxide, with the blood. If $PM_{2.5}$, or any other pollutant, penetrates through the alveolar sacs and into the bloodstream, these toxicants can travel throughout the rest of the body and impair pulmonary and cardiovascular health (Aguilera et al., 2021; Nakayama Wong et al., 2011; Reid et al., 2016).

While farmworkers are not required to work if a fire is directly impacting their assigned crops, fire smoke can travel to regions that do have farmworkers present in the fields. Farmworkers are considered essential workers that help maintain the economy but harsh realities due to citizenship status, language barriers, and economic status, compared to those who are fluent in English, documented, and financially stable (Mendez, Flores-Haro, & Zucker, 2020; Riden et al., 2020). Working in hazardous air quality conditions exacerbates any pre-existing health conditions and social vulnerabilities farmworkers may have. Examining the disparities farmworkers face and how wildfires are affecting their well-being is crucial in developing climate change, public health, and disaster response planning for outdoor occupations.

1.2 Research Question

Driving through Ventura County, you can't help but notice the miles of pastures and fields. When there is a fire emergency, farmworkers rush to these fields to save crops from falling ash, if they are working in fields not directly impacted by the fire. Even though public health officials recommend staying indoors during poor air quality conditions, many farmworkers are in the fields, breathing in the harmful levels of air toxicants. Although there is substantial research on the effects of $PM_{2.5}$ on the general population, there are minimal studies on the wildfire smoke exposure health effects of farmworkers. Because farmworkers, who are primarily undocumented and of Latinx, Mexican, and/or Indigenous descent, are likely exposed to poor air quality during a fire emergency, it is crucial to evaluate how these enviornmental hazards may affect their health (CAUSE, 2015). This study investigates health records regarding the respiratory health and air quality data in Ventura County from 2015-2020 to contribute to what is known about farmworkers during fire emergencies. The following questions regarding farmworker respiratory health and vulnerabilities during fire periods between 2015-2020 are posed: (1) Is there a visual relationship between hospital encounters for a respiratory illness and fire-associated PM2.5 concentrations between 2015-2020? (2) Is there a higher prevalence of farmworkers seeking pulmonary healthcare during a fire emergency than non-farmworkers? (3) Should farmworkers be considered a 'vulnerable' demographic, needing further inclusion in disaster response, public health, and outdoor occupational fire planning?

1.2 Rationale

1.2.1 Scholarly

As wildfires intensify with climate change in the western US, exposure to air pollutants, primarily $PM_{2.5}$, is a rising concern for public health officials, environmental organizations, and government agencies. $PM_{2.5}$ from fires is associated with exacerbated asthma and COPD conditions, and research on the respiratory, cardiovascular, and mortality effects are growing (Reid et al. 2016). Many studies assess $PM_{2.5}$ exposure on the general public rather than specifically farmworkers during a short time frame. There are several qualitative analyses on how farmworkers and their employers view the associated impacts of wildfires, but there are not many quantitative papers evaluating how this demographic may be affected by short term pollution events (Corrieri et al., 2019; Mendez, Flores-Haro, & Zucker, 2020; Riden et al., 2020).

1.2.2 Policy

Ventura County's agricultural sector made a total estimated gross value of $2.1 billion in 2018, with strawberries being the number one commodity (FBVC, 2018). The revenue produced is about 10% of California's gross profit of $21.02 billion in 2018 (CDFA, 2018). Although this is only a fraction of California's income, Ventura County is the top provider for the country's strawberries, broccoli, lemons, and celery. Farmworkers are the backbone of our agricultural economy but are subjected to situations that possibly compromise their mental and physical health. For instance, farmworkers are not covered by labor laws for overtime pay, even though they are often working over 10 hours a day or 40 hours a week (CAUSE, 2015a, b). Additionally, it was only after the 2017 Thomas

Fire that agricultural employers were required to provide workers with proper personal protective equipment (PPE) when there are unhealthy air quality conditions (CAUSE, n.d.a). Recognizing that agricultural employers and governmental agencies may have lax regulations when it comes to environmental risks to farmworkers, it is necessary to further examine and evaluate the poor air quality exposed to farmworkers during fire periods and their vulnerabilities.

1.4 Thesis Statement

Farmworkers have a multitude of vulnerabilities affecting their chronic pulmonary health, including exposure to dust and pesticides; the addition of hazardous $PM_{2.5}$ levels during fires are suspected to only exacerbate their potential pre-existing health conditions. From 2015-2020, there were 21 fires that burned 45 acres or more in the Ventura County region. Assuming that farmworkers are exposed to higher concentrations of PM2.5 during fire periods because of their outdoor occupation, farmworkers are a population that should be investigated to better understand their working environments. Based on stories from the Thomas Fire, I believe that farmworkers are experiencing exacerbated respiratory health effects from the inhalation of unhealthy air particles during fire periods. Through an evaluation of health and air quality data, I hypothesize that there is a positive visual correlation between wildfire-associated $PM_{2.5}$ concentrations and high respiratory encounters. Furthermore, I believe that a higher incidence of respiratory healthcare visits for farmworkers will be observed, compared to non-farmworkers, possibly because of farmworkers' socioeconomic status, accessibility to healthcare, accessibility to transportation, and documentation status.

1.5 Research Design

Through a mixed-methods approach, the pulmonary health and vulnerabilities of Ventura County farmworkers will be evaluated. I will follow a three-part research approach, using pulmonary health records and$PM_{2.5}$ concentration data to relate health impacts of fire-associated pollution with the environmental conditions believed to affect the Ventura County population.

To first understand the agricultural context in Ventura County, I reviewed the 2015 Central Coast Alliance United for a Sustainable Economy (CAUSE) report and labor laws in Ventura County, enforced by the Wage and Hour Division (WHD), California State Department of Industrial Relations (DIR): Division of Labor Standards and Enforcement (DLSE), and California Occupational Safety and Health (CalOSHA) (CAUSE 2015). Reading the CAUSE reports on farmworkers developed a baseline for understanding the working conditions, vulnerabilities, and health risks farmworkers face on a daily basis. The report results are based on a survey CAUSE conducted in 2015, highlighting some of the policies violated by employers. Specifically investigating the proposed policies of CalOSHA's Protection from Wildfire Smoke" standard and Farmworker Smoke Protection Act provides a more in-depth perspective of the current legislation protecting farmworkers and gaps in regulations.

I also studied how community-based organizations, like CAUSE, Mixteco Indigena Community Organizing Project (MICOP), and California for Rural Legal Assistance (CRLA), are working to improve the protections and rights of farmworkers, during disasters and in general, to grasp a better interpretation of how farmworkers are an

underrepresented group within governmental entities. I have reached out to these organizations, asking to have a conversation about their experience during fire periods and their opinions on what could be done to further assist farmworkers during disasters; however, responses from these organizations have been sparse due to the COVID-19 pandemic. I believe reaching out to the farmworkers, directly, is currently not an appropriate approach because they are most likely unavailable to be interviewed. With these steps, in addition to the literature review, I hope to have a comprehensive perspective on farmworker health risk factors and regulations to get a contextual background of what is happening in the fields during fire periods.

To investigate the air quality in Ventura County between 2015-2020, I gathered $PM_{2.5}$ concentration data from the US Environmental Protection Agency. This data consists of daily air quality data for five monitoring sites throughout Ventura County in a .csv file. To identify fire periods and understand the magnitude of poor air quality conditions during fire periods, I created a list of major fires in this region and their associated dates from CAL FIRE. I defined major fires as one that increases the surrounding $PM_{2.5}$ concentrations and burned greater than 1,000 acres. Next, I created several line graphs showing daily average $PM_{2.5}$ concentrations, respiratory encounters, and fire periods to illustrate the changes among these variables over time.

Pulmonary health data, regarding respiratory care visits from Ventura County, were provided in a de-identified dataset by Ventura County Medical Center (VCMC). The health data consists of the number of respiratory encounters per day between 2015-2020 and number of farmworker encounters within the data. Merging health data

with air quality data, I evaluate the incidence of farmworkers and non-farmworker respiratory care visits during 2015-2020 fire periods.

1.6 Chapter Summary

In this chapter, the importance of understanding farmworker vulnerabilities and how high levels of fire-associated $PM_{2.5}$ concentrations can exacerbate pulmonary health were described. The rest of this thesis is organized as follows. Chapter 2 summarizes the literature about $PM_{2.5}$, farmworker working environments, fire smoke, and other health risk factors. Chapter 3 provides the necessary context of Ventura County farmworkers and wildfires to describe why farmworkers are of particular concern during fire emergencies. Chapter 4 describes the research collection process and methods used to investigate the aforementioned questions. Chapter 5 evaluates and discusses the results of the study regarding the pulmonary health records, $PM_{2.5}$ concentrations, and fire periods. Chapter 6 connects the results back to the three research questions and provides concluding remarks. Throughout this thesis, the health of farmworkers is of primary concern because they are essential workers that have been and continue to be a marginalized community within our society.

Chapter 2: Literature Review

2.1 Introduction

In this chapter, a summary of the literature discussing fire $PM_{2.5}$ exposure effects on human health, fire effects on farmworkers, and farmworker health risk factors are described. While there is abundant research on the relationship between fire smoke, primarily $PM_{2.5}$ exposure on general population health, there is much less data on the health of farmworkers. This may be because of farmworkers' socioeconomic status and lack of access to medical care. Through this discussion, a connection between how wildfires affect the health of the general population, specifically farmworkers, will be evident.

2.2 Fires & Air Quality

Fires can be dangerous to those near and far away. In addition to the physical devastation fires can cause, they emit toxic levels of air pollutants into the atmosphere. These pollutants, made of various gases and particles, can be dispersed throughout surrounding regions and affect ambient air quality. Meanwhile, fire flames can burn almost anything in its path and cause severe burns resulting from direct contact. People who experience major fires and have to evacuate their homes may also suffer from post-traumatic stress disorder (PTSD), depression, anxiety, and other mental illnesses (Reid et al., 2016; Marshall et al., 2007). As anthropogenic climate change is predicted to increase the incidence and intensity of fires, exploring both physical and mental health effects of fire events, and other natural disasters, are crucial in finding solutions to support potential affected communities.

The inhalation of fire smoke is associated with detrimental pulmonary and cardiovascular effects. The composition of fire smoke includes toxicants such as sulfur dioxide, hydrocarbons, nitrogen dioxide, carbon monoxide, and $PM_{2.5}$ as the main component of public health concern. Regulations regarding air quality and $PM_{2.5}$ do not differentiate between wildfire $PM_{2.5}$ and ambient $PM_{2.5}$; however, recent studies suggest that $PM_{2.5}$ in wildfire smoke may be more toxic than equal doses of ambient $PM_{2.5}$ because of the source composition (Aguilera et al., 2021). In this observational study, a 10 $\mu g/m^3$ increase in wildfire-specific $PM_{2.5}$ is linked to a 1.3-10% increase in respiratory hospitalizations, compared to a 0.6-1.3% increase for non-wildfire $PM_{2.5}$ periods. It is suspected that wildfires may pose a more threatening respiratory health effect than other fires because wildfires consist of fast-spreading and uncontrolled flames that burn a myriad of chemicals and sources. Wildfire PM is at least 50% organic carbon and 5-20% elemental carbon, suggesting that it has more oxidative potential that ambient $PM_{2.5}$ to enhance pulmonary inflammation, oxidative stress, or infection. While research is still growing on the $PM_{2.5}$ health effects, differences in $PM_{2.5}$ sources, and the relationship between human health and fires, it is well-accepted that the inhalation of fire smoke is associated with detrimental pulmonary, cardiovascular, and mental health effects. In the following subsections, the characterization $PM_{2.5}$, health effects, and standards are described.

2.2.1 Particulate Matter 2.5 ($PM_{2.5}$)

$PM_{2.5}$ is a component of fire smoke that is of most concern to pulmonary health because of its small diameter size and ability to be inhaled deeper in the lungs, compared

to other air pollutants, to provoke oxidative stress and inflammation (Nakayama Wong et al., 2011). $PM_{2.5}$ is defined as fine particles with diameters of 2.5 micrometers and smaller, including dust, dirt, soot, drops of liquid and smoke, and is about 30 times smaller than the average human hair diameter (EPA, 2016). $PM_{2.5}$ can be emitted by both natural and anthropogenic sources, including the combustion of engines and energy products, erosion of pavement, and transportation of dust (WHO, 2013).

Under the Clean Air Act, the US EPA sets National Ambient Air Quality Standards (NAAQS), monitors pollutant concentrations, and makes data publicly available to inform populations of the air quality conditions in their area (US EPA, 2014). The NAAQS are established to protect public health by setting and implementing primary and secondary air quality standards. Primary air quality standards describe standards designed to protect public health while secondary standards are made to assure public welfare from adverse effects. $PM_{2.5}$ has a NAAQS daily primary and secondary standard of 35 $\mu g/m^3$, annual primary standard of 12 $\mu g/m^3$ and annual secondary daily standard of 15 $\mu g/m^3$ (US EPA, 2014). To inform the public about local air quality, the EPA also has an Air Quality Index that categorizes air quality based on health effects that may be experienced with a certain level of pollution (US EPA, 2019; Figure 1). The greater the value, the higher the level of pollution and health concern. At daily concentrations of 35 $\mu g/m^3$, the EPA categorizes this level of $PM_{2.5}$ is "unhealthy for sensitive groups" and measures to minimize these individuals from exposure are encouraged. Interestingly, the World Health Organization has recommendations of 25 $\mu g/m^3$ for daily concentrations (WHO, n.d.). This evokes the question of whether or not the NAAQS are strict enough to

prevent daily concentrations from exceeding the levels at which may pose harmful effects to sensitive groups.

24-Hour $PM_{2.5}$ Levels ($\mu g/m^3$)

$PM_{2.5}$	Air Quality Index	$PM_{2.5}$ Health Effects	Precautionary Actions
0 to 12.0	**Good 0 to 50**	Little to no risk.	None.
12.1 to 35.4	**Moderate 51 to 100**	Unusually sensitive individuals may experience respiratory symptoms.	Unusually sensitive people should consider reducing prolonged or heavy exertion.
35.5 to 55.4	**Unhealthy for Sensitive Groups 101 to 150**	Increasing likelihood of respiratory symptoms in sensitive individuals, aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly.	People with respiratory or heart disease, the elderly and children should limit prolonged exertion.
55.5 to 150.4	**Unhealthy 151 to 200**	Increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid prolonged exertion; everyone else should limit prolonged exertion.
150.5 to 250.4	**Very Unhealthy 201 to 300**	Significant aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; significant increase in respiratory effects in general population.	People with respiratory or heart disease, the elderly and children should avoid any outdoor activity; everyone else should avoid prolonged exertion.
250.5 to 500.4	**Hazardous 301 to 500**	Serious aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in general population.	Everyone should avoid any outdoor exertion; people with respiratory or heart disease, the elderly and children should remain indoors.

Figure 1: EPA Air Quality Index
Data from the US Environmental Protection Agency (n.d.)

2.2.2 Fire-Associated Particulate Matter 2.5 Health Impacts

Exposure to wildfire-associated $PM_{2.5}$, along with other air pollutants, vary widely, depending on the fire's magnitude, spatial and temporal extent, distance from

human populations, meteorological variables, and exposure duration (Kollanus et al., 2016; Nauslar et al., 2018; Koman et al., 2019). There is a higher risk of fire smoke exposure to communities physically close to the fire source and those working outdoors during smoke wave days, defined as "≥2 consecutive days with high wildfire-specific $PM_{2.5}$, to describe episodes of high air pollution from wildfires" (Liu et al., 2015). Firefighters and agricultural workers are groups that may be exposed to unhealthy or worse air quality conditions and experience elevated health risks.

Fire-specific $PM_{2.5}$ exposure is associated with health outcomes of respiratory morbidity, specifically decreased lung function, exacerbated asthma and chronic obstructive pulmonary disease (COPD) (Reid et al., 2016; Delfino et al., 2009; Martin et al., 2013). People most at risk of health impacts from $PM_{2.5}$ include those with heart or lung disease, older adults, children, and potentially those with other chronic health conditions, such as diabetes or obesity. Multiple studies have found decreased lung function among individuals without asthma (Reid & Maestas, 2019; Kim et al., 2017). In a long-term Indonesian study on forest fires and health consequences, men and the elderly population were observed to experience higher impact on lung capacity (Kim et al., 2017). When comparing males and females, men had experienced four times the negative lung effects of smoke pollution than females. The study suggests that this is due to Indonesian men having higher levels of physical activity outdoors and Indonesian women chronically exposed to indoor pollution from wood burning cook stoves. Furthermore, consistent evidence demonstrates that exposure to wildfire $PM_{2.5}$ is correlated with increased hospitalizations and emergency department (ED) visits for asthma-related and COPD incidences (Borchers Arriagada et al., 2019; Delfino et al.,

2009; Johnston et al., 2014). In three eastern Australian cities from 1994-2007, smoke events were found to be associated with a 12% increase in asthma hospital admissions, 13% in COPD admissions, and 6% in overall respiratory admissions (Martin et al., 2013). For a study on hospital admissions and southern California fires, an average increase of 70 mg/m^3 for $PM_{2.5}$ during smoke waves, compared to non-smoke periods, a 34% increase of asthma admissions was observed (Delfino et al., 2009). Per 10 mg/m^3 increase in fire-$PM_{2.5}$ concentrations, an increase of 6.9% increase for COPD admission for ages 20-64 years old was demonstrated. In a case study in Sydney, Australia from 1996-2007, fire smoke days were associated with same day increases in ED visits for respiratory conditions, asthma, and COPD, where mean $PM_{2.5}$ concentrations were 39.1 μg/m^3 on smoke days compared to 9.9 μg/m^3 for non-smoke days (Johnston et al., 2014). This study found the greatest increase in ED visits for respiratory conditions among adults rather than children, despite children being a higher risk group for particulate pollution. This suggests that children are able to recover the best from early health issues caused by pollution (Kim et al., 2017). Although individuals with pre-existing respiratory conditions are most vulnerable to fire-$PM_{2.5}$ exposure and effects, multiple studies point to adults and elderly populations as particularly susceptible to health impacts because of their associated time outdoors and inability to recover from short-term pollution events as quickly as younger cohorts.

In a study that evaluated epidemiologic associations of modeled and measured $PM_{2.5}$ in British Columbia, Canada, medication dispensations were counted during all fire season days and extreme fire days (Yao et al., 2016). Pharmaceutical dispensations can be used to assess $PM_{2.5}$ exposures on respiratory health because the use of inhalers with

salbutamol sulfate and nitroglycerin are commonly used to relieve acute exacerbations of asthma, COPD, and angina. With an increase of 10 $\mu g/m^3$ in $PM_{2.5}$ concentrations, a 4% increase in salbutamol dispensations during all fire season days and 3% increase in nitroglycerin dispensations were found during extreme fire days. This study concludes that increases in pharmaceutical dispensations for respiratory medications suggest that there are strong correlations between $PM_{2.5}$ and disturbed pulmonary health.

Furthermore, there is inconsistent but growing research on the associations with cardiovascular morbidity, respiratory infections, birth outcomes, mortality, and mental health (Reid et al., 2016; Delfino et al., 2009; Johnston et al., 2007; Martin et al., 2013). These health outcomes related to fire-PM2.5 exposures are mixed due to the difficulty of associating wildfire air pollution exposure, a short-term event, to long-term health effects. In a few studies evaluating cardiovascular effects, increases in ED visits for congestive heart failure from a peat fire and ischemic heart disease were observed while many others show null associations (Rappold et al., 2011; Mott et al., 2005). Although there are many retrospective studies that investigate these potential outcomes, there are several in vivo toxicological evidence supporting potential cardiovascular health effects of fire smoke exposure. Human lung epithelial cells show increased inflammation when exposed to wildfire-associated $PM_{2.5}$, compared to ambient PM (Nakayama Wong et al., 2011). Inflammation of the epithelial cells are thought to be one of the main pathways in which $PM_{2.5}$ could affect cardiovascular health. Despite there being inconsistent findings for cardiovascular outcomes in the literature, toxicological studies support a relationship between cardiovascular health effects and fire-$PM_{2.5}$.

Wildfire-specific $PM_{2.5}$ is estimated to be 10 times more harmful on human health than other $PM_{2.5}$ sources (Aguilera et al., 2021). Susceptibility to fire-associated $PM_{2.5}$ exposure extends to those with pre-existing respiratory conditions, but further research is needed to clarify groups that are most vulnerable. Particularly for outdoor occupational settings, developing further worker protections, public health, fire disaster policies to minimize $PM_{2.5}$ exposures during a smoke event, is crucial in reducing risks to short- and long-term health.

2.3 Farmworker Health & Safety

Farmworkers experience disparities throughout their daily lives and at work due to their race, ethnicity, and citizenship status (Saxton, 2015). These factors, in addition to pre-existing health and social conditions, intertwine to exacerbate their already vulnerable situations. Natural disasters do not discriminate between who is impacted and who is not, but those of lower socioeconomic status typically do not have the means to protect their well-being, homes, and families, compared to wealthier communities (CAUSE, n.d.). Public health and government assistance have recently started included the vulnerabilities of undocumented individuals in their disaster response planning (Mendez, Flores-Haro, & Zucker, 2020). The following sections describe the literature about farmworker work environments, regulations, health risks, and how wildfire smoke contributes to the exacerbation of existing farmworker vulnerabilities.

2.3.1 Work Environment

A day in the fields consists of enduring harsh working conditions. Farmworkers, who are primarily undocumented Latino, Hispanic, and/or Indigenous folks, work long and physically demanding days to provide meals to people throughout the country. Although farmworkers are essential workers, they often receive inadequate breaks, insufficient drinking water, unsanitary restrooms, and discrepancies in paychecks (CAUSE, 2015a,b). Despite having federal and state laws that protect farmworker rights and safety, some regulations are not strictly enforced or communicated by employers to protect farmworkers from experiencing these conditions (La Cooperativa, 2017). Working about 10 hours a day, farmworkers are risking pesticide exposure, heat exhaustion and other heat-related illnesses, and dust inhalation from dry soil and/or nearby fires. If one were to get sick or injured, health care may not be accessible because of one's lack of transportation, immigration status, and health insurance (Mendez, Flores-Haro, & Zucker, 2020). About 40% of farmworkers in the U.S. have no health insurance and 20% of male farmworkers in California have risk factors of high cholesterol, high blood pressure, or obesity (Hernandez & Gabbard, 2018; Villarejo et al., 2000). Education and language barriers also make this group, along with these other existing inequalities, particularly vulnerable when it comes to disasters because emergency information is not language accessible.

2.3.2 Labor Laws & Regulations

Agricultural workers' health, safety, and wages are protected by federal and state agencies, such as the U.S. Department of Labor: Wage and Hour Division (WHD),

California State Department of Industrial Relations (DIR): Division of Labor Standards and Enforcement (DLSE), and California Occupational Safety and Health (CalOSHA). Farmworkers must be paid no less than minimum wage, time and a half for hour working over 10 hours a day or 60 hours in a week, and take breaks, as described by DLSE under the DIR (DIR, n.d.a). In a report evaluating farmworkers in Santa Barbara and Ventura Counties, 33.3% and 59.5% of farmworkers, respectively, have experienced one form of wage theft (CAUSE, 2015a,b). Workers also sometimes do not have the chance to take adequate breaks because they have to continue working, "to fulfill the order... so we have to eat while we work so that we can send the vegetables to the packing house faster" (CAUSE, 2015a,b). This is a violation of worker wage rights because agricultural employers are not enforcing regulations that require employees to get paid as promised and take breaks. Furthermore, employers must provide sanitary drinking water, washing and restroom facilities to employees (DIR, n.d.b). In the CAUSE reports, farmworkers respond to having restrooms only "cleaned every two week and often hav(ing) no toiletries or water" to wash their hands (2015a,b). Not only is there a lack of enforcement for sanitary water to protect farmworkers from disease, but this is placing those consuming these crops at risk for food-borne illnesses too.

2.3.3 Heat Exhaustion & Other Heat-Related Illnesses

Agricultural workers are doing physically demanding tasks under the sun and could experience heat exhaustion and other heat-related illnesses when dehydrated and overworked. Heat exhaustion can have individuals feeling symptoms of headache, dizziness, fainting, and rapid heart rate, where physical activity can intensify these

conditions (Corrieri et al., 2019). Especially when temperatures are high or if smoke from nearby fires make breathing difficult, these conditions strain individuals' abilities to work efficiently and contribute to their mental stress. In Santa Barbara County, 50% of farmworkers, of a sample of 275, have been sent home due to heat related issues in 2015 (CAUSE, 2015a). If an individual is sent home, they do not get to work and earn money for the time off. In addition to this, they may not be able to seek healthcare if needed because they may not have the health insurance to do so.

Wildfires only intensify their heat-related health risks because they are required to work in hot, insolated, and polluted environments where they risk the chance of experiencing heat exhaustion, stroke, or even death (Austin et al., 2020; Corrieri et al., 2019). In Austin et al.'s study, evaluating the combined burden of $PM_{2.5}$ and heat in rural Washington, the counties with the largest population of agricultural workers experienced the greatest heat and $PM_{2.5}$ exposures (2020). This informs policy makers to prioritize monitoring, prevention, and mitigation efforts in these locations to minimize the heat and respiratory health risks for the regional farmworkers during fire season.

Agricultural employers are required to have cool shade and clean water available at all times for workers, but many times, these shaded areas are too far to walk to during their short breaks and water is easily accessible. In Santa Barbara County, 10% of farmworkers found that drinking water was not easily accessible at work (CAUSE, 2015a). For Ventura County, this value is 20% (CAUSE, 2015b). The inaccessibility of water could lead to dehydration and further heat-related health concerns. The literature on the combined effects of heat stress and poor air quality, due to fires, are fairly young; but the effects of heat exposure and exhaustion are clear and immediate. With fires expected

to increase in the near future, policies to protect farmworkers during heat and smoke waves are vital in preventing them from experiencing further health concerns.

2.3.4 Pesticides

Pesticide exposure is another health concern to individuals working in the fields. Pesticides are substances used to kill, repel, or control organisms or plants harmful to the cultivation of plants; but while pesticides are meant to target pests, residue can be transported by farmworker clothes and bodies, air, water, soil, and food (Saxton, 2015; Lee et al., 2011). Pesticide exposure is linked to detrimental impacts on neurological, reproductive, endocrine, metabolic, thyroid, and respiratory health (Mamane et al., 2015; Fix et al., 2020; Curl et al., 2020). Regarding respiratory health, occupational exposure to pesticides is associated with asthma and chronic bronchitis, where the inhalation of pesticides during fumigation is the route of exposure (Mamane et al., 2015). In the CAUSE reports, farmworkers have said that sometimes employers make pesticide "sprayers stay 30 feet behind us [farmworkers] to pressure us and make us work faster" (2015a,b). This inhumane threat is not only contributing to their overall health but stresses their mental health and could lead to exhaustion.

2.3.5 Dust Inhalation

California's increasingly arid climate, drought and wildfire conditions contribute to the formation of dust and spread of infectious diseases (Pearson et al., 2019). When farmland is perturbed, soil dust particles and spores are lifted in the air and could be inhaled by individuals in the area (Schenker, 2000). Similar to how the inhalation of

$PM_{2.5}$ affects the respiratory system, dust inhalation and the pathogens in the soil spores can have detrimental impacts on health. The chronic exposure to organic and inorganic dust particles have been linked to asthma, COPD, chronic bronchitis, pneumoconiosis, farmer's lung, and interstitial fibrosis (Nordgren & Bailey, 2017; Noda et al., 2007; Schenker et al., 2009; Cormier, 2007). Additionally, exposure to pathogenic bacteria or fungi could lead to illnesses, like valley fever (Pearson et al., 2019). Even though the health effects of the chronic inhalation of dust particles are considered separate from fire smoke inhalation, both sources contain $PM_{2.5}$ and contribute to the exacerbation to respiratory illnesses. Dust inhalation is only one other health risk factor agricultural workers are exposed to and may be disproportionately affected by its pulmonary and cardiovascular health effects, opposed to non-farmworkers.

2.3.6 Fire Smoke

Black, Latinx, and Native Americans are 50 percent more vulnerable to wildfires compared to other census tracts (Davies et al., 2018). Among three agricultural regions in California (Salinas Valley, San Joaquin Valley, and Imperial Valley), agricultural employers expressed that wildfires and associated smoke are not a concern for which they have developed protocols (Riden et al., 2020). Even though smoke, stress, and respiratory issues are found to be the most common health concerns when thinking about fire health threats in the agricultural setting, a study employing an interactive webinar found that only about 45% of a group of 30 agricultural employers believed that education on wildfire health effects were effective (Corrieri et al., 2019). During the Thomas Fire, community-based organizations distributed over 15,000 N95 masks to

farmworkers because employers were not required to provide workers with PPE at the time. When employers do not enforce safety measures, like providing PPE or educating outdoor workers on the health effects of inhaling smoke, farmworkers are left to work in the hazardous smoke wave with inadequate safety gear or none at all. The immense aid and mask distribution to farmworkers during the Thomas Fire initiated the nation's first occupational safety standards for wildfires, "requiring outdoor employers to provide respirator masks when air quality is measured to be harmful" (CAUSE, n.d.a). Despite the new regulations mandated, the use of masks is not always ideal for farmworkers because they are physically active, exerting arduous energy to fulfill shipments. This results in not wearing N95 masks properly during their entire shift or resorting to bandanas or other masks to protect themselves during smoke waves. It is important to note that the use of bandanas and fabric face coverings are not sufficient enough to filter PM2.5 particles and other air pollutants. This is where education on fire smoke health effects and inclusion of medical providers and emergency centers in public health and disaster response plans could be useful in minimizing fire-smoke risks (Corrieri et al., 2019).

In a survey investigating respiratory health outcomes among global farming cohorts, women, in general, were found to have a higher prevalence of allergic asthma among farmworkers, despite differences in agricultural production (Curl et al., 2020, Fix et al., 2020). This is a concern because the inhalation of fire smoke could exacerbate existing asthma conditions and contribute to an even larger impact on female farmworkers' experiences in the field. Farmworkers suggest that the use of masks, health promotion and education on air pollution exposure, and employer encouragement would

assist in protecting their pulmonary and cardiovascular health when it comes to fire incidences (Riden et al., 2020).

2.4 Chapter Summary

Farmworkers and undocumented individuals are often excluded in disaster recovery responses, language-accessible emergency announcements, and governmental aid assistance (Mendez, Flores-Haro, & Zucker, 2020; CAUSE, n.d.a). As fires and associated air quality impacts become more frequent and intense, farmworkers are a particular group that is at risk of higher respiratory and cardiovascular health effects, compared to non-farmworker populations. The current literature on fire-associated $PM_{2.5}$ effects on human health are sufficient, whereas the health of farmworkers is sparsely studied. There are more studies on the qualitative perceptions of farmworkers during natural disasters, rather than assessments of the environmental conditions of the disaster. To my surprise, there were a few journal articles specifically discussing the Thomas Fire and the vulnerabilities of low-income communities and communities of color. Although this demographic has multiple risk factors that would consider them to be more vulnerable to wildfires than the general population, there is still a lack of data on the effects of smoke exposure on farmworkers, specifically, because health data is difficult to come by. Given what we know about PM2.5 exposure effects on the general population, we can extrapolate whether the smoke exposure from the Thomas Fire had a similar effect on Santa Barbara and Ventura County farmworkers.

Chapter 3: Background

3.1 Introduction

This chapter discussed Ventura County's health care accessibility, agricultural sector, fire and subsequent air quality between 2015-2020. To investigate how fire-associated $PM_{2.5}$ exposures impact respiratory care encounters, a review of the healthcare system in Ventura County is described. Because agriculture plays a major part of the County's economy, studying the region's agricultural sector is necessary in understanding a fire's effect on the industry. While there were over 20 fires during this time period exceeding 40 burned acres, there were only a handful that had spiked PM2.5 concentrations above the 35 $\mu g/m^3$ standard and burned over 1000 acres , including the Thomas Fire, Maria and Easy Fires, Woolsey and Hill Fires. For this reason, it is vital that we take a glimpse at the few major fires during this time to better conceptualize the fires' consequent impacts on air quality and pulmonary health.

3.2 Background on Ventura County

Ventura County is the 12th largest county in California's 58 counties, consisting of 10 incorporated cities and many unincorporated communities (County of Ventura, 2021). The population in Ventura County consists of 84.1% who identify as white, 7.9% as Asian, 2.4% as Black or African American, 1.9% as American Indian and Alaska Native, and 0.3% as Native Hawaiian and other Pacific Islander (US Census Bureau, 2019). Of this demographic, 43.2% identify as Hispanic or Latino. While the US Census Bureau defines "Hispanic" and "Latino" as an ethnicity, this method of classification contributes to a sense of confusion for those who do not identify with any of the listed races and

inaccuracies for the census. As a note, the US Census Bureau implicitly includes “all foreign born [people] who participate in its censuses and surveys, regardless of legal status” (US Census Bureau, 2019).

3.2.1 Healthcare in Ventura County

Health care refers to the prevention and treatment of disease through professional medical practices. Ventura County has 19 healthcare facilities within the region, including Ventura County Medical Center (VCMC), Santa Paula Hospital, and Oxnard Community Hospital (USGS, 2021) All of which provide the 846,000 residents access to local medical services like behavioral health, physical therapy, and mental health care.

Medical services are accessible to those who have health insurance through a public program, private company, and/or employment benefits program. In 2019, Ventura County Public Health reports having 89.2% of its adult population and 96.5% of its children’s population with health insurance, while those who are uninsured are less likely to receive medical care (VCPH, 2019). For people who are uninsured or underinsured, cost remains a large barrier to healthcare accessibility. A public insurance program that has expanded healthcare accessibility is Medicaid, under the U.S. Affordable Care Act. Medi-Cal, part of the U.S.’s national Medicaid health coverage program, is California’s program that pays for low-income people’s medical expenses (DHCS, 2021). Moreover, Covered California is the California health insurance marketplace that assists eligible individuals to purchase private insurance at a federally subsidized rate. Similarly, Health Care for All helps Ventura County families apply for health coverage from Medi-Cal, Covered California, and other low-cost programs (VCHCA, n.d.). Other health service

programs in the County include the Ventura County Health Care Plan for County employees and dependents, ACE Program for uninsured individuals, and Self-Pay Discount Program for individuals who are uninsured and ineligible for any other VCHCA program. Although there are a myriad of medical service programs in the area, there are other factors that play into an individual's utilization of healthcare facilities, such as transportation accessibility and affordability.

3.2.2 Agriculture in Ventura County

In 2019, Ventura County's agriculture produced an estimated gross value of $1.9 billion dollars, which represents a decrease of 5% from the previous year (VCAC, 2020). In 2018, the County's agriculture had an estimated gross value of $2.1 billion, a 0.2% increase over 2017 (VCAC, 2019; VCAC, 2018). Within the past five years, strawberries were the number one crop by a landslide. Strawberries are grown most commonly grown in Oxnard and Camarillo, generating a minimum of $508,471,000 to $670,716,000 between 2015-2020 (Figure 2) (FBVC, 2021). Likewise, celery was second place in 2019, grossing $243,455,000. This was a surprising increase of 23%, compared to 2018 celery crops. In third, lemons dropped by 14% over 2019, grossing $211,104,000. While strawberries are cultivated on flat pastures, lemons and avocados grow along hillsides. Row crops are predominantly in Oxnard and oranges in Fillmore, whereas other top crops include raspberries, avocados, and nursery stock.

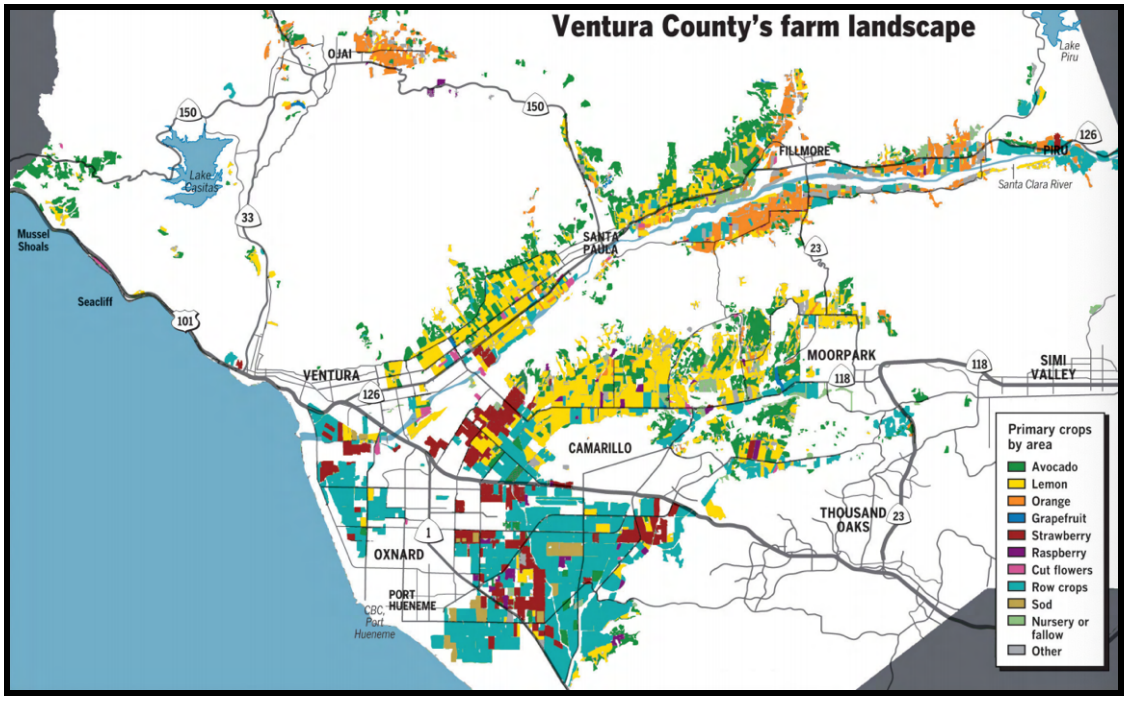

Figure 2: Ventura County's Farm Landscape, Illustrating the Distribution of Primary Crops by Area (Farm Bureau of Ventura County, 2021).

3.2.3 Farmworker Health Insurance Coverage and Access to Care

With approximately 42,000 farmworkers in Ventura County, agriculture is the backbone of the County's economy (Housefarmworker, 2021). Ventura County farmworkers, whom are 92.9% Latino and 90.5% from Mexico, are a subpopulation that struggles to achieve adequate health and safety worker rights because of their socioeconomic situation (CAUSE, 2015). Of the farmworker population, 81.5% of these individuals are undocumented immigrants. These individuals may qualify for Medi-Cal or other low-cost insurance program, but there may be other elements that impact their enrollment or utilization of medical services, including language barriers, transportation, and limited time off work (Rosenbaum & Shin, 2005).

In November 2020, Medi-Cal served 10,979 undocumented individuals out of the 234,125 total certified eligible beneficiaries in Ventura County (DHCS, 2021). According to Farmworker Justice, community health centers, such as Primary Care Associations, MHP Salud, National Center for Farmworker Health, and Migrant Clinicians Network, serve farmworkers who are ineligible for Medicaid or subsidized health insurances (2021). Paradoxically, those who do not have access to insurance also are limited in their eligibility for workers' compensation, in the case they get injured or become ill at work (Farmworker Justice, 2021; CAUSE, 2015). This disparity, in addition to misinformation and fear of employer retaliation, is also considered a farmworker barrier to healthcare.

3.3 Major Fires & Air Quality During 2015-2020

From 2015-2020, Ventura County had 21 fires exceeding 45 burned acres, including the Maria Fire, Woolsey Fire, and Thomas Fire (Table 1) (CAL FIRE, n.d.). Table 1 lists the 2015-2020 fires in Ventura County, date, and acres burned used to identify high $PM_{2.5}$ concentrations associated with fires. When matching $PM_{2.5}$ concentrations with fire periods, the fires that elevated $PM_{2.5}$ concentrations over 35 $\mu g/m^3$ were the Thomas, Woolsey, Holser, and Lake Fires. Since the Thomas Fire was the largest in California history at the time, this section takes a closer look at its impacts on Ventura and Santa Barbara communities, as well as other major fires in the region.

3.3.1 The Thomas Fire

The Thomas Fire was one of the largest fires in modern California history and the EPA air quality data demonstrates how intense the fire was (CAL FIRE, n.d.). The fire

harshly affected Ventura County's agricultural commission by causing farmers to lose years of crops, their source of income, and livelihoods, which consequently impacted the wages of farm workers as well (Faber, 2018). While there has not been a fire of this scale in the county since 2017, any wildfire can be a devastating event that could catastrophically impact a person's mental and physical health. Understanding the context of the Thomas Fire assists researchers in evaluating the impacts fires have on the well-being of farmworkers.

According to the California Department of Forestry and Fire Protection (CAL FIRE), the Thomas Fire started on December 4, 2017 and burned over 281,893 acres of land in Santa Barbara and Ventura Counties (CAL FIRE, n.d.). Years of drought and high wind conditions, fueled by the Santa Ana winds, north of Santa Paula, California, caused power lines to come into contact with each other and eject molten metal material onto dry ground vegetation (VCFD, n.d.). Santa Ana winds are strong, warm, and dry winds that blow from the Great Basin to the coast of Southern California (Garofalo, n.d.). Along with these winds, Santa Barbara Sundowners, which are gusty, nocturnal, offshore winds, helped intensify fire conditions (Cohen, 2018). Starting near Thomas Aquinas College, the Fire progressed northwest towards Ventura, Montecito, Carpinteria, and Santa Barbara until it was fully contained on January 12th, 2018. During this time, over 8,500 firefighters from all over the state came to extinguish the fire and 1,062 building structures were destroyed and 280 structures damaged (CAL FIRE, n.d.). This fire took the lives of one firefighter and one civilian. The fire had caused about $2 billion in damages (Hersky, 2018).

Not only was the fire devastating, itself, but heavy rainfall exacerbated the natural disaster on January 9th, 2018. The rain caused massive mudslides in Montecito and Carpinteria, resulting in 21 deaths and thousands of homes devastated (Guidimadjegbe et al., 2019). The debris flow had destroyed trees, powerlines, natural gas lines, sewage systems, and left numerous injured or stranded. Disaster recovery efforts, including support from the Coastguard, National Guard, and Red Cross, all assisted in responding to this emergency.

Out of the Thomas Fire's 40-day lifespan, about 13 of these days exceeded the 35 $\mu g/m^3$ daily standard in Santa Barbara and Ventura Counties. This means that concentrations, specifically in Ojai, Ventura, Carpinteria, Montecito, Santa Barbara, and Goleta, were at least "unhealthy for sensitive groups". The "unhealthy for sensitive groups" AQI category describes that older adults, children, and individuals with heart or lung disease, diabetes, and lower socio-economic status should take precautions to reduce outdoor activities and wear proper protective equipment (EPA, 2019). As concentrations increase, the effects on all exposed humans become more severe. Air quality monitoring stations in Ojai detected "hazardous" $PM_{2.5}$ concentrations as high as 557 $\mu g/m^3$ on one day, indicating an emergency situation in which everyone's health is at risk. The maximum $PM_{2.5}$ concentration during the Thomas Fire was about 16 times the EPA's $PM_{2.5}$ standard. The reason why the Ojai station showed the highest concentration of $PM_{2.5}$ was because the station was surrounded by the fire. Stations in Santa Barbara and Ventura measured the next highest concentrations, with Lompoc and Santa Maria following. Surprisingly, stations in Thousand Oaks, Pinu, and the Simi Valley showed good levels of $PM_{2.5}$ even though these stations are in close proximity to the fire

perimeter. This demonstrates that the fire smoke was moving westward towards the ocean, possibly due to the easterly Santa Ana winds.

Using Quantum Geographic Information System (QGIS), Figure 3 illustrates the $PM_{2.5}$ concentration distribution in Ventura and Santa Barbara Counties during the most hazardous day of the Thomas Fire (December 8th, 2017). Green represents good $PM_{2.5}$ concentration levels, yellow being moderate, orange is unhealthy, red is unhealthy, purple is very unhealthy, and maroon being hazardous. Because of the westward distribution of particulates, we can infer that agricultural workers east of Ventura were not affected by poor air quality conditions associated with the Thomas Fire.

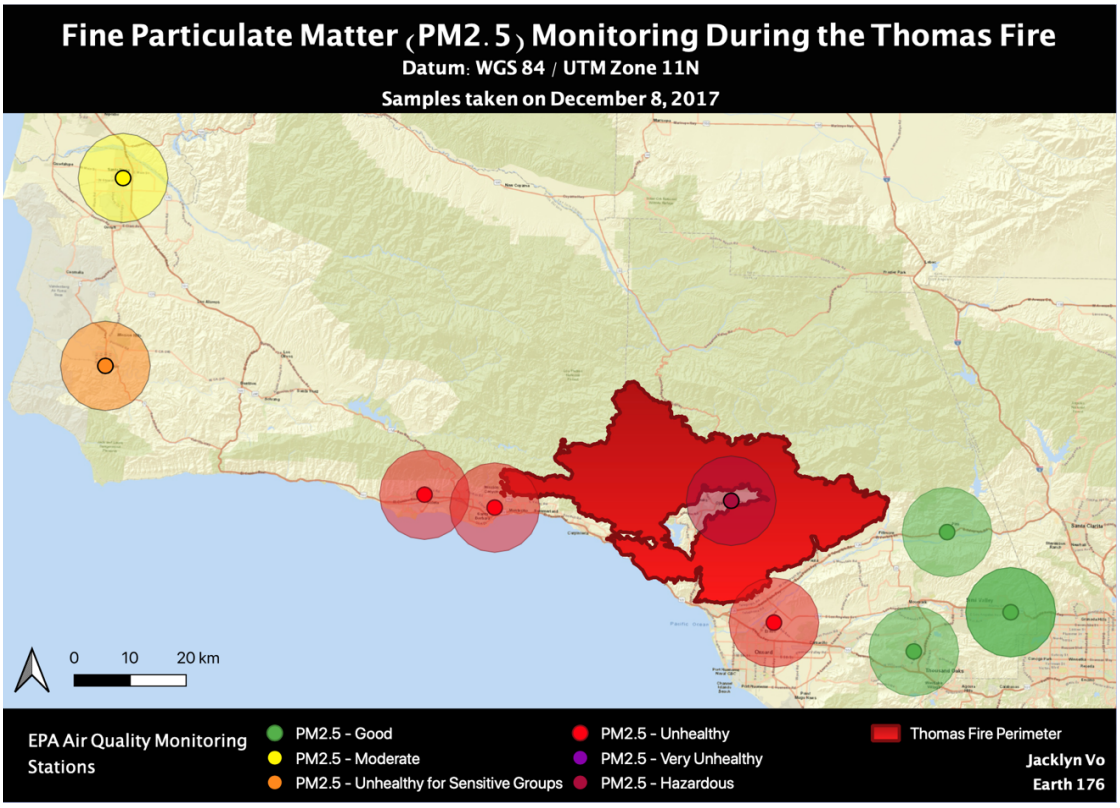

Figure 3: PM2.5 Distribution in Ventura and Santa Barbara Counties during the Thomas Fire's Most Hazardous Air Quality Conditions (December 8th, 2017)
Data from US Environmental Protection Agency

3.3.2. The Thomas Fire and Agriculture

According to the Ventura County Agricultural Commissioner, the Thomas Fire caused $171,296,703 in damages to current and future crops, agricultural machinery, and building structures (Faber, 2018). This value does not include losses in farmworker wages and farmer incomes. Many individuals lost weeks of work and some even their homes from the fire (CAUSE, n.d.a). About 10,289 acres of cropland and 60,000 acres of rangeland were affected, with avocado, lemon, and orange crops most impacted (Faber, 2018). Avocados were estimated to have $10.2 million in losses, lemons $5.8 million, and oranges $3.4 million. This harshly affected the livelihoods of farmers and farmworkers because their source of revenue had been demolished. In order to address these issues, the Santa Barbara and Ventura County Agricultural Commissioners requested financial assistance from state disaster response programs and hosting grower assistance workshops to distribute disaster recovery information (City of Ventura, n.d.).

3.3.3 The Thomas Fire & Farmworkers

Farmworkers were rushed to the fields to save crops from the Thomas Fire's falling ash. CAUSE reported that Santa Barbara and Ventura County farmworkers were left behind by disaster responses (n.d.a,b). Agricultural workers had to work in unhealthy air quality conditions, despite public health officials recommending limiting time outdoors. At first, these farmworkers were also not given proper protective gear by their employers or governmental entities, even though they are strenuously working and exerting their lungs. Many individuals experienced difficulty breathing, cough, and headaches during their shifts. Ironically, CalOSHA closed for the week due to the

disaster, leaving farmworkers unprotected and helpless in the workplace. Instead, organizations like CAUSE, MICOP, and Future Leaders of America stepped in to distribute over 15,000 N95 masks to farmworkers and pressure the CalOSHA office to reopen that following week.

Several communication issues arose when the emergency broke out. Emergency information was also only distributed in English, making information about the fire, evacuations, road closures, and health and safety information inaccessible to those who do not speak the language (CAUSE, n.d.a). Farmworkers, many of whom are Spanish speaking, were left confused and uninformed about how to keep their families safe during the emergency. As a result of this scenario and many others, California counties are now required to translate emergency notifications to the most commonly spoken language, other than English, in the county. Ensuring that all communities are receiving and can interpret emergency notifications are vital in protecting the health and safety of the public.

Continuously, undocumented folks, many who are agricultural workers, were excluded from receiving financial relief from federal aid and disaster unemployment assistance (CAUSE, n.d.a). This, along with reduced working hours due to the fire, made paying bills and feeding families more difficult for these individuals. The fire impacted the homes, wages, and transportation of the workers, making the commute to work even more challenging. Because of this disparity, the 805 Undocufund was created to assist "undocumented immigrants who have lost their homes, wages, and/or employment due to natural disasters".

From this experience, non-profit organizations have pressured California government to develop and enforce occupational safety standards for wildfires, "requiring outdoor employers to provide respirator masks when air quality is measured to be harmful" (CAUSE, n.d.a). Other legislation enacted to aid marginalized communities, since the Thomas Fire, include the Listos California Campaign, SB 160, and AB 1877 (CAUSE, n.d.a; Office of Governor Gavin Newsom, 2019). The Listos California Campaign is a $50 million grant program that aims to build community resilience in "vulnerable communities at high risk for wildfires and other natural disasters". Similarly, SB 160 requires counties to "integrate cultural competence" and "community engagement" into its emergency plans (Bill Text - SB-160 Emergency Services: Cultural Competence., 2019). Complementary, the AB 1877 holds "counties accountable for translating information into the most commonly spoken language other than English in that county". These legislatures are excellent first steps in tearing down financial and safety barriers including underrepresented communities; however, there are still accessibility obstacles for immigrants wishing to receive health care, especially during natural disasters.

3.3.4 Other Major Fires in Ventura County, 2015-2020

Major fires in Ventura County and the surrounding regions that burned over 1000 acres were the Thomas, Woolsey, Hill, Maria, Easy, Holser, and Lake Fires (Table 1). Based on the air quality dataset, the fires that increased $PM_{2.5}$ concentrations above 35 $\mu g/m^3$ in Ventura County were the Woolsey, Hill, Holser, and Lake Fires. In this section, I

briefly describe the context of these major fire periods to better understand fire events in the region.

3.3.4a Woolsey & Hill Fires

On November 8, 2018, the Hill Fire ignited in Santa Rosa Valley's Hill Canyon, 21 minutes before the Woolsey Fire started near Simi Valley (CAL FIRE, n.d.; Gabbert, 2019). Because firefighting resources immediately flooded into Hill Canyon due to the potentially greater damage to homes, fire units did not reach the Woolsey Fire until 20 minutes after it was reported. As the Hill Fire slowed down, fire units were then transferred to the Woolsey Fire.

The Hill Fire damaged four structures and burned about 4,500 acres within several days (CAL FIRE, n.d.; Gabbert, 2019). By the time the Woolsey Fire was contained on November 21, 2018, the fire had spread from Ventura County to Los Angeles County with the help of Santa Ana winds. The Woolsey Fire burned nearly 97,000 acres, destroyed over 1,600 structures, and killed three people during its 13-day span (Diskin, 2020). Although the fires were destructive to the land, its effect on Ventura County's $PM_{2.5}$ concentrations were less intense than the Thomas Fire. During the duration of the Woolsey and Hill Fires, the maximum $PM_{2.5}$ concentrations Ventura County experienced within the fire period is 41.5 $\mu g/m^3$ in Thousand Oaks and 41.2 $\mu g/m^3$ in El Rio for one day, deeming "unhealthy for sensitive groups".

3.3.4b Maria & Easy Fires

The Maria Fire started on October 31, 2019 on top of South Mountain, California, just south of Santa Paula (CAL FIRE, n.d.). The fire is thought to be caused by re-energized power lines that were shut off by Southern California Edison (SCE) for a period of strong Santa Ana Winds. Ironically, the Santa Ana Winds changed directions and played a large role in rapidly spreading the fire to neighborhoods in Santa Paula (Li & Romero, 2019). The fire threatened about 7,500 residents and was finally contained on November 6, 2019. Over five days, the Maria Fire burned 9,999 acres of land and destroyed $5.2 million in avocado and lemon orchards (Jazi, 2019). Coincidentally, the Easy Fire was burning the same time as the Maria Fire. From October 30, 2019 to November 2, 2019, the Easy Fire burned 1,806 acres in Simi Valley, California, destroyed three buildings, and was caused by a SCE electrical transmission line failure (CAL FIRE, n.d.). During the Maria and Easy Fires, $PM_{2.5}$ concentrations only reached moderate $PM_{2.5}$ conditions of about 25.5 $\mu g/m^3$ for one day, warning people who are unusually sensitive to air pollution to limit prolonged outdoor activities (EPA, 2014). According to the WHO, however, $PM_{2.5}$ concentrations above 25 $\mu g/m^3$ are considered "unhealthy to sensitive groups"; thus, requiring respiratory precautions for these groups in particular. The small $PM_{2.5}$ impact the Maria and Easy Fires had on air quality in Ventura County is shocking because the fire was massive, burning over 10,000 acres in total.

According to the Ventura County chief deputy agricultural commissioner, the Maria fire moderately to severely damaged 160 acres of avocado and 25 acres of lemons, but farmers blame SCE for shutting off the power days prior to the fire. Affected farmers found it frustrating that they had no electricity to power water wells and booster pumps

days before the fire to mitigate the fire impacts on their crops. The Farm Bureau of Ventura County's chief executive officer suggests that "the loss of avocado and citrus trees would be by far less than what it is now if Southern California Edison didn't turn off the power... Edison didn't help to prevent the fire" (Jazi, 2019). If farmers had access to electricity, their orchards would have been better protected from the fire's flames.

3.3.4c Lake & Holser Fires

From August 12, 2020 to September 28, 2020, the Lake Fire devastated 31,089 acres near Los Angeles County's Lake Hughes (CAL FIRE, n.d.). High winds, hot and dry conditions, and steep mountainous terrain contributed to the fast spread of the Lake Fire. Within a few hours, the Lake Fire grew up to 10,000 acres and prompted hundreds of people to evacuate. The Lake fire had damaged three structures, destroyed 12 structures, and injured four firefighters. A pyrocumulus cloud, known as the "fire-breathing dragon of clouds", formed due to the fire's rising heat and plume of fire smoke (Margolis, 2020). As the air rises over the fire, surrounding air gets drawn in toward the fire and develops stronger and more erratic wind and fire behaviors. During the Lake fire, PM2.5 concentrations spiked as high as 58.7 ug/m^3 in Piru and El Rio.

Around the same time as the Lake Fire, the Holser Fire was caused by a vehicle that caught on fire near a bush near Lake Piru on August 17, 2020 (CAL FIRE, n.d.). The fire burned 3,000 acres by the time it was extinguished on September 6, 2020. Considering the magnitude of the fire, it is surprising that $PM_{2.5}$ concentrations only reached about 35.1-35.7 ug/m^3 for only two days during this time period, deeming unhealthy for sensitive groups, for those in El Rio.

Elevated concentrations, deemed unhealthy for sensitive groups and unhealthy for the general population, lasted for about a week. These conditions are associated with "increased aggravation of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; increased respiratory effects in the general population" (EPA, 2014).

3.4 Chapter Summary

This chapter explains Ventura County's healthcare accessibility to farmworkers, the agricultural sector, and major fires from 2015-2020. While everyone is encouraged to stay indoors, minimize outdoor exercise, and wear protective gear during fire events, agricultural workers risk their health to complete physically demanding tasks in poor air quality conditions. The Thomas Fire is a prime example of fire that has affected a community and their health. At the time, employers were not required to provide respiratory masks for laborers, so farmworkers were intentionally placed in a situation that puts their health in danger. To assist farmworkers, non-profit organizations stepped in and distributed N95 masks during the fire event. While the other major fires in the region did not have an impact on air quality, people, and land as large as the Thomas Fire, learning the context of these fires allows us to better recognize patterns and understand the mental and physical impacts it has on people. With this context in mind, it is essential to note that although health data can inform us about how many people generally sought respiratory care, it most likely is unrepresentative of actual farmworker experiences.

Chapter 4: Methods

4.1 Introduction

This thesis is a retrospective, observational study that examines $PM_{2.5}$ concentrations and Ventura County Medical Center (VCMC) pulmonary health records from 2015-2020 to explore the fire-associated $PM_{2.5}$ exposure effects on Ventura County farmworkers. To investigate if there is a correlation between $PM_{2.5}$ during wildfire events and high respiratory encounters, I conducted a preliminary visual correlation assessment of both health and air quality data. To quantify how encounters changed during fire events, I compared the percent changes of farmworkers and non-farmworkers three weeks before and during a major fire event. Chapter 4 describes the methods and procedures I engaged in to answer my research questions.

4.2 Fire Inventory

CAL FIRE is the California Department of Forest and Fire Protection, dedicated to fire prevention, response, and stewardship (CAL FIRE, n.d.). As CAL FIRE responds to all types of emergencies, such as accidents, hazardous material spills, and earthquakes, they also conserve and manage forests. The department provides general information regarding fire events in their CAL FIRE incident database. Using this incident database, I recorded all of the fires in Ventura County and some large fires in the surrounding counties from 2015-2020 in Table 1.

Table 1: Fire Inventory (CAL FIRE, n.d.).

Fire Inventory in Ventura County 2015-2020 *Data from CAL FIRE*							
Year	**Incident Name**	**Incident Type**	**Date Start**	**Date End**	**County**	**Acres Burned**	**Did PM2.5 spike?**
2015	Solimar		12/29/15	12/29/15	Ventura	1388	No
	Potrero		11/7/15	11/7/15	Ventura	50	No
2016	Pine		6/30/16	6/30/16	Ventura	2,304	No
	Kuehner		7/1/16	7/1/16	Ventura	45	No
2017	Thomas	Wildfire	12/4/17	1/12/18	Ventura & Santa Barbara	281893	Yes
	Vista		10/24/17	10/26/17	Ventura	86	No
	Grade		7/4/17	7/6/17	Ventura	50	No
2018	Woolsey	Wildfire	11/8/18	1/9/19	Los Angeles and Ventura	96,949	Yes
	Hill	Wildfire	11/8/18	11/15/18	Ventura	4,531	Yes
	Briggs		11/15/18	1/4/19	Ventura	150	No
	Peak	Wildfire	11/12/18	1/4/19	Ventura	186	No
2019	Maria	Wildfire	10/31/19	11/6/19	Ventura	9999	Yes
	Easy	Wildfire	10/30/19	11/2/19	Ventura	1,806	Yes
	Snail	Wildfire	9/1/19	9/5/19	Ventura	279	No
	Olivas	Wildfire	10/11/19	10/12/19	Ventura	200	No
	South	Wildfire	7/14/19	7/15/19	Ventura	131	No
	Wendy	Wildfire	10/14/19	10/10/19	Ventura	91	No
2020	Holser	Wildfire	8/17/20	9/6/20	Ventura	3,000	Yes
	Lake	Wildfire	8/12/20	9/28/20	Los Angeles	31,089	Yes
	Lime	Wildfire	6/10/20	6/17/20	Ventura	803	No
	Elizabeth	Wildfire	6/10/20	6/12/20	Ventura	289	No
	Cornell		12/7/20	12/8/20	Ventura	174	No

The purpose of having a fire inventory is to find if any fire events coincide with elevated $PM_{2.5}$ concentrations. For each fire, I searched the $PM_{2.5}$ dataset to see if concentrations spiked, compared to before or after the fire events. If $PM_{2.5}$ concentrations spiked, I recorded a "yes" under the "affected $PM_{2.5}$?" column in the fire inventory. These fires are considered "major fires" in this study. Once the fire inventory was complete, I labeled major fires on the health and air quality plots.

4.3 Air Quality Methods

Before evaluating the pulmonary health effects of inhaling fire-associated $PM_{2.5}$, I first examined the air quality in Ventura County from 2015-2020 to get a broader perspective of the impact fires have on the atmosphere. This resulted in the development of a fire and $PM_{2.5}$ inventory to organize the data. Using CAL FIRE's fire data and the Environmental Protection Agency's (EPA) daily $PM_{2.5}$ data, I created graphs of what the

air quality looked like from 2015-2020. In this section, the tools, methods, and procedure rationales used to investigate air quality for this study's scope are explained.

4.3.1 Ventura County Monitoring Sites

Monitoring stations are sparsely located throughout Ventura County, based on the region's meteorology, population density, and pollution levels (EPA, 1974). Stations are typically located in urban areas because the purpose of monitoring is to protect humans from potentially dangerous levels of air pollutants. In contrast, rural areas lack monitoring stations and therefore do not typically have an accurate measurement of the associated air quality; however, interpolation can be done to estimate the air quality of a certain area, outside the breadth of the stations. Further research could investigate ideal rural locations to install monitoring sites for more accurate air quality measurement. For this project, I explored the air quality data from the following five EPA monitoring sites in Ventura County: El Rio-Rio Mesa School #2, Ojai – East Ojai Ave, Piru – Pacific, Simi Valley-Cochran Street, and Thousand Oaks (Table 2).

4.3.2 Rationale for EPA Daily $PM_{2.5}$ Concentration Dataset

I derived the $PM_{2.5}$ concentration data from the EPA Air Data website to examine the $PM_{2.5}$ concentrations during fire periods. The EPA has multiple datasets available, including the pre-generated Air Quality System (AQS) data, AirNow daily data, and raw data. The pre-generated AQS dataset contains the most accurate daily $PM_{2.5}$ and air quality index (AQI) samples in all U.S. EPA monitoring sites within a year while the others are organized by county and year. The pre-generated AQS data goes through a

monitoring verification process to check measurements for precision, whereas the daily and raw data have yet to be verified and entered into the AQS. The EPA does not recommend using the AirNow daily dataset because of the following reason:

> The AirNow data are not fully verified and validated through the quality assurance procedures monitoring organizations used to officially submit and certify data on the EPA AQS and, therefore, cannot be used to formulate or support regulation, guidance or any other Agency decision or position" (EPA, 2018).

Despite being unverified, I chose to utilize the EPA Air Now daily $PM_{2.5}$ dataset instead of the pre-generated AQS dataset because it contains all of daily samples for 2015-2020, unlike the the AQS data. The AQS dataset has yet to include data since September 2020 because these samples have yet to be checked. Although the last few months of 2020 are not included in the pre-generated AQS, I checked the AirNow daily dataset with the pre-generated AQS to see if $PM_{2.5}$ concentrations differed for dates prior to September 2020, or if the sample source was from the AQS or AirNow. From my search, the AQS and AirNow datasets matched, with the exception of the pre-generated data's missing samples from September 2020 to December 2020. Additionally, the AirNow dataset lists the source in which the samples came from (AQS or AirNow), so I was able to verify PM2.5 concentration values for January 2020 to September 2020 with the AQS dataset. Because most of the AirNow daily dataset contains the most complete data for my desired study period, I chose to work with this dataset rather than the pre-generated data.

4.3.3 $PM_{2.5}$ Inventory

To analyze and plot the $PM_{2.5}$ concentrations in Ventura County from 2015-2020, I first had to organize the EPA Air Now Data on Matlab and Excel. MatLab is a visualization, numerical computation, and programming language that enables users to

explore engineering and scientific problems. A code in MatLab was written to eliminate inessential columns and sort out inconsistencies in the EPA's raw air quality dataset. Unnecessary data in the EPA raw data included "Site ID", "POC", "UNITS", "Daily_OBS_Count", and "AQS_Parameter_Code" columns, and inconsistencies in the raw data included missing samples for various dates or double samples per day. To best capture Ventura County's overall air quality, the code took daily averages across all monitoring sites to present a single average $PM_{2.5}$ concentration per day. The benefit and drawback of having an average across all stations is that it simplifies the data and generalizes the air quality of the entire region. While an average across all stations can represent all of Ventura County, air pollutants are not distributed evenly throughout the air. During the Thomas Fire, for example, only regions west of the fire experienced "hazardous" air quality while the areas east had "good" air quality (Figure 3). For this study, a simplification of the $PM_{2.5}$ concentrations was done to better visualize the impacts fires have on the region. Once the EPA $PM_{2.5}$ concentrations were organized and simplified, I plotted this information on Excel to be consistent across both air quality and health data analyses and abide by my IRB protocols. Despite the tedious sorting process, the resulting data is easier to comprehend and digest for assessments.

Next, I labeled the dates in which fire events occurred on the $PM_{2.5}$ plots by referring to the fire inventory (Figure 4). Because $PM_{2.5}$ concentrations depend on external factors like meteorological, topographic, and emission factors, we cannot necessarily attribute a spike in $PM_{2.5}$ concentrations to a fire; however, we can infer that if $PM_{2.5}$ concentrations are elevated to unhealthy levels during a fire event, the fire most likely contributed to the increase in atmospheric $PM_{2.5}$ concentrations.

4.4 Respiratory Health Methods

I explain the research process of collaborating with Ventura County Medical Center (VCMC) to obtain respiratory health records, submitting two Institutional Resource Board (IRB) applications, and meeting with many supportive UCSB staff to troubleshoot data accessibility and analysis issues. I conducted a preliminary visual correlation analysis to see if there is a correlation between high $PM_{2.5}$ concentrations and elevated respiratory visits among farmworkers and non-farmworkers during fire periods. I also calculated the percent change of respiratory health encounters three weeks before a fire period and three weeks from their start dates to investigate how the number of encounters for farmworkers and non-farmworkers changed. The purpose of the calculating percent change is to investigate how the number of people who sought healthcare changed with wildfire conditions.

Early in the project, I reached out to Santa Barbara and Ventura County Public Health Departments, searching for any data regarding farmworker health. After months of empty email inboxes, I got in touch with two phenomenal professionals: Dr. Nathan Carroll, the VCHCA Assistant Chief Medical Informatics Officer and a VCMC Family Medicine Hospitalist Physician, and Dr. Christopher Landon, a Pediatric Pulmonology Specialist and founder of the VCMC Pediatric Diagnostic Center. Meeting Dr. Carroll and Dr. Landon changed the entire course of my project because VCMC has records of how many of its patients are farmworkers. Each healthcare facility is required to record patient farmworker statuses, according to the Health Resources & Services Administration's (HRSA) (NCFH, n.d.). The US Department of Health and Human services developed a National Advisory Council on Migrant Health, who mandated the

recording of "patient percentages - migrant farmworkers" for all physicians included in each state's database (Privacy Act of 1974, 2010). In order to do so, the Bureau of Primary Health Care (BPHC) "expects every health center grantee to develop a policy and procedure for verifying 'Special Population' designation of its users, including agricultural workers" (NCFH, n.d.). Using a de-identified dataset, I was able to investigate my research questions: (1) Is there a visual relationship between hospital encounters for a respiratory illness and fire-associated PM2.5 concentrations between 2015-2020? (2) Is there a higher prevalence of farmworkers seeking pulmonary healthcare during a fire emergency than non-farmworkers?

Maintaining Health Insurance Portability and Accountability Act (HIPAA) compliance was the main concern for data accessibility and security. HIPAA mandates standards to protect sensitive patient health information from being disclosed without patient consent or knowledge (DHCS, 2019). To protect the privacy of subjects, I completed the National Drug Abuse Treatment Clinical Trials Network's (NDAT CTN) Good Clinical Practice Training, submitted IRB applications to both UCSB and VCMC, and met with members of UCSB Human Subjects and Office of Technology & Industry Alliances to establish security procedures. After getting approved by both IRBs, I was able to access and explore the data at VCMC.

To assist me in the statistical analyses, Dr. Heather Hodges, a Postdoctoral Scholar in the UCSB Bren School of Environmental Science & Management, guided me through the process of finding the best methods to test my research questions. Without her expertise, developing concrete results would not have been possible.

4.4.1 VCMC Health Data Description

The health data consists of unidentifiable, aggregate values of daily VCMC respiratory encounters from 2015-2020. Each date has the number of total respiratory encounters, non-farmworker hospital admissions, non-farmworker visits, farmworker encounters, and the means for each category. Hospital admissions describe people who have been admitted into a healthcare facility for a respiratory illness. Healthcare visits represent people who have sought medical attention for a respiratory concern but were not admitted for treatment. Lastly, healthcare encounters sum both admissions and visits. The farmworker status is recorded by VCMC, required by the HRSA. While each date contained values for total encounters, admissions, and visits, the values for farmworker status were sparse. In this study, the number of farmworker encounters per day did not start being recorded until January 2017, even though the HRSA updated the System of Records (SOR) in 2010 (Privacy Act of 1974, 2010).

4.4.2 Preliminary Visual Correlation Assessment of the Pulmonary Health & Fire

Using the VCMC records, EPA data, and fire inventory, I plotted respiratory encounters against time with $PM_{2.5}$ concentrations and identified the periods in which major fires occurred to see if there is a visual relationship between fire events and respiratory encounters (Figure 5). This allows me to intersect all of these variables to determine their relationship with one another. I also plotted respiratory encounters over time in several different ways to get different perspectives of the data.

Figure 6 shows the number of encounters split between all encounters and the number of total farmworkers within these encounters. The orange line represents non-farmworker healthcare encounters while the green line represents farmworkers within the data. Breaking the data down like this allows me to see the difference between the number of farmworker and non-farmworker encounters. Figure 7 demonstrates all of the encounters, split up by hospital admission, visitations, and number of farmworkers within these categories. Evaluating the data this way allows me to see if people are getting admitted to the hospital for treatment or simply visiting a clinic to get checked up. Continuously, Figure 8 displays the total and mean number of farmworker encounters there are from 2015-2020 to get a better glimpse of how farmworker encounters fluctuate over time.

4.4.3 Farmworker vs. Non-Farmworker Percent Change Analysis

My second research question asks if there is a higher prevalence of farmworkers visiting a health facility for a respiratory concern during a fire event than non-farmworkers? To test this question, a proportions percent change and z-test analysis was conducted. A percent change calculation measures the amount of change over time and allows for comparisons between farmworkers and non-farmworker, despite having a low farmworker prevalence. The percent change of farmworker and non-farmworker encounters were calculated, comparing three weeks before and after the start of the Thomas Fire, Woolsey and Hill Fires, Maria and Easy Fires, and Lake and Holser Fires using Equation 1 (Table 2). The reason why I chose three weeks before and three weeks from the start of the fires is because this time frame encompasses any fluctuations in

smoke emissions throughout the fire event. Once the percent changes for each fire period were calculated, a z-test on these values assessed the validity or repeatability of a scenario by determining whether two sample means are different when variances are known and the population sample greater than 30 (Table 4). A z-score represents how many standard deviations above or below the mean population the value is, and a p-value measures the probability that an observed difference could occur by random chance. The lower the p-value, the greater the statistical significance of the observed difference.

Equation 1: Percent change equation to quantify the change in respiratory encounters three weeks before and three weeks starting a fire event

Percent Change Equation
% Change = ((New Average - Old Average)/ Old Average)*100

To test the repeatability and validity of the percent changes, z-tests were employed. The null hypothesis (H_o) states that the percent change of non-farmworker respiratory encounters will be higher than farmworkers before and after a fire event. The alternative hypothesis (H_1) states that the percent change of farmworkers will be higher than non-farmworkers before and after a fire event. If the p-value is less than the significance level of 0.05, then we reject the null. If the p-value is greater than 0.05, then we fail to reject the null hypothesis.

4.5 Chapter Summary

This chapter describes the rationale and procedure in organizing the EPA $PM_{2.5}$ and VCMC pulmonary health data for my analyses. As I explored the fire events that occurred in Ventura County between 2015-2020, I found that there were only a handful of

fire events that contributed to elevating $PM_{2.5}$ concentrations above “unhealthy levels”. For this study, fires that spiked $PM_{2.5}$ concentrations and burned greater than 1,000 acres are considered “major fires ", and comprise the Thomas, Woolsey, Hill, Maria, Easy, Lake, and Holser Fires. Data from CAL FIRE, EPA, and VCMC were employed throughout this project to better understand how fire-associated $PM_{2.5}$ affect the respiratory health of farmworkers and the general population in Ventura County.

Chapter 5: Results & Discussion

5.1 Introduction

In this chapter, I describe the results from plotting the average $PM_{2.5}$ concentrations across all of the Ventura County monitoring stations, preliminary visual correlation assessment, and percent change analysis. Following the results is a discussion about the finding's implications for farmworkers and non-farmworkers, and an in-depth look at the health and air quality data during the Thomas Fire, since it was the largest fire in California at the time. While the results and discussion are a simplified interpretation of the people's experiences during wildfires, this study is an attempt to bridge gaps in knowledge regarding the pulmonary health of farmworkers during these times of poor air quality and uncertainty.

5.2 $PM_{2.5}$ Inventory Results

From matching the fire inventory with raw air quality data, fire periods that corresponded with elevated $PM_{2.5}$ concentrations above 35 $\mu g/m^3$ include the Thomas, Woolsey, Hill, Lake, and Holser Fires. For the Easy and Maria fire periods, a moderate air quality index and $PM_{2.5}$ concentrations were observed despite both fires burning over 10,000 acres in total (Table 1). Because the Easy and Maria fires were so large, I decided to include them in the percent change analysis even though the $PM_{2.5}$ concentrations did not exceed EPA's 35 $\mu g/m^3$ standard for this time period and only reached about 25.5 $\mu g/m^3$ in El Rio. Besides, the $PM_{2.5}$ concentrations did reach the WHO's $PM_{2.5}$ standard. This sparked curiosity for if other components of fire smoke could have been impacting the air quality at a larger extent for this fire period. When looking at the AQI for the

Maria and Easy Fire events, AQI spiked up to 79 a few days after the fires started. This supports the idea that $PM_{2.5}$ is only one component of fire smoke that could contribute to poor air quality; therefore, to better understand how fires can affect human health, researchers must evaluate as many components of fire smoke as possible to get the most comprehensive analysis. Other spikes in $PM_{2.5}$ were unrelated to fire events.

Figure 4 illustrates the average daily $PM_{2.5}$ concentrations across all monitoring stations and major fire events in Ventura County between 2015-2020. The Thomas Fire was the largest fire in the region's modern history, and we can see that a $PM_{2.5}$ concentration average across all sites reached over 115 $\mu g/m^3$.

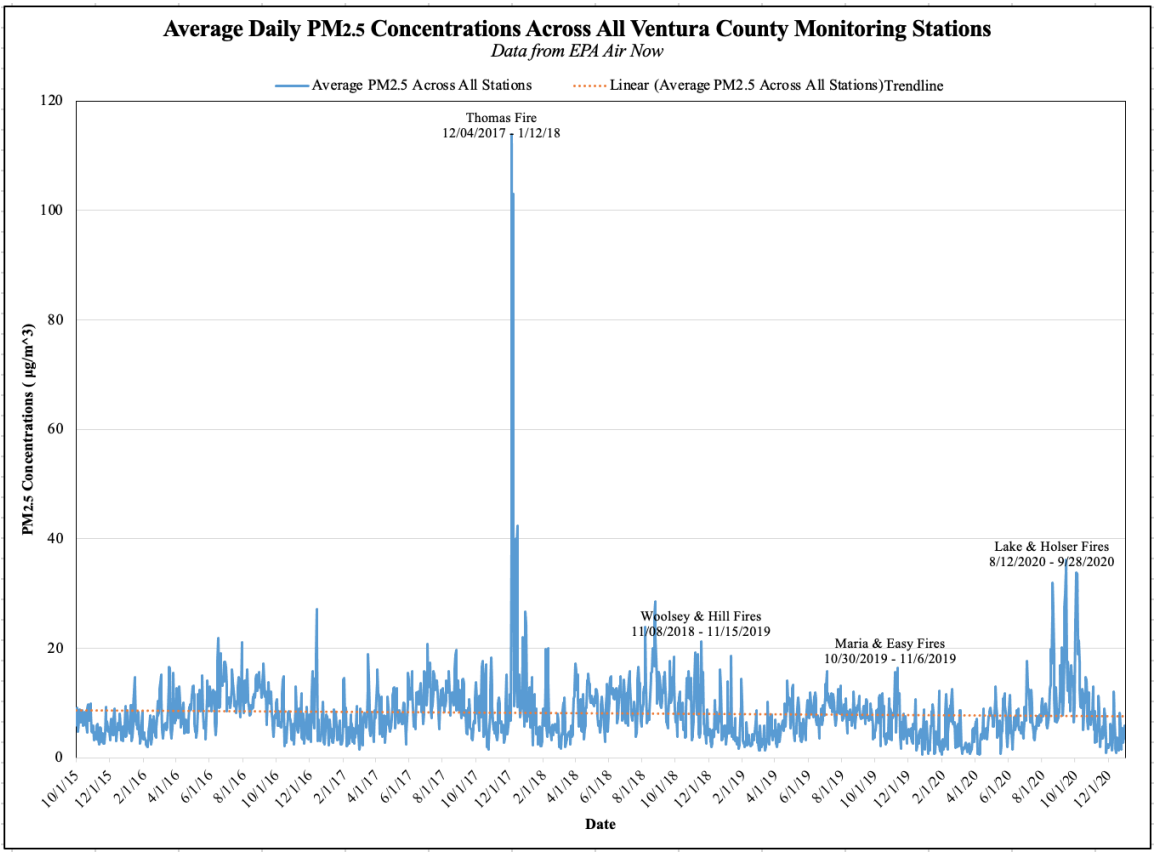

Figure 4: Average Daily $PM_{2.5}$ Concentrations Across Ventura County Monitoring Sites, 2015-2020

Even though this is three times the EPA's $PM_{2.5}$ standard, not all of Ventura County experienced high levels of $PM_{2.5}$. If average $PM_{2.5}$ concentrations across all monitoring sites showed a big deviation from the normal 8 $\mu g/m^3$ and was during a wildfire event, the data implies that either the fire was extremely large and therefore emitted a massive amount of $PM_{2.5}$, the composition of the fire smoke is $PM_{2.5}$ rich, and/or the fire smoke got more dispersed throughout the county than anywhere else.

Referring to Figure 3, we can see that on the most hazardous day of the Thomas Fire, Santa Barbara County and the western Ventura County cities experienced the worst air quality while cities to the east of the fire experienced good air quality. This reiterates how the concentration of air pollutants depends on its atmospheric distribution, emission source, and meteorological factors. If we evaluate the average daily $PM_{2.5}$ for all monitoring stations, small spikes occurred for the Woolsey and Hill Fires and Lake and Holser Fires. During the Woolsey and Hill Fires, average $PM_{2.5}$ jumped to about 18.9 $\mu g/m^3$. For the Lake and Holser Fires, average $PM_{2.5}$ concentrations spiked to 36.18 $\mu g/m^3$.

Diving deeper into the raw air quality data for the Thomas Fire, $PM_{2.5}$ concentrations actually reached a startling 557 $\mu g/m^3$ in Ojai on the most hazardous day of the fire. This level of $PM_{2.5}$ is about 16 times the EPA $PM_{2.5}$ standard and could pose "serious aggravations of heart or lung disease and premature mortality in persons with cardiopulmonary disease and the elderly; serious risk of respiratory effects in the general population" (EPA, 2014). When evaluating the Woolsey and Hill Fires, $PM_{2.5}$ concentrations maxed at 41.2-41.5 $\mu g/m^3$ in within two days of the start of the fire. Furthermore, the Lake and Holser Fires had a peak of 35.7 $\mu g/m^3$ in Piru. Although both

maximum concentrations are not considered “hazardous”, the $PM_{2.5}$ concentration indicates that the air quality is “unhealthy for sensitive groups " in the region.

5.3 Preliminary Visual Correlation Assessment Results

For the preliminary visual correlation assessment, I plotted respiratory encounters and fire-associated $PM_{2.5}$, concentrations over time and identified the major fire periods. Based on this analysis, I observed that pulmonary health encounters do not reflect the $PM_{2.5}$ concentrations associated with the Thomas, Woolsey, Hill, Maria, Easy, Lake, and Holser Fires very well (Figure 5).

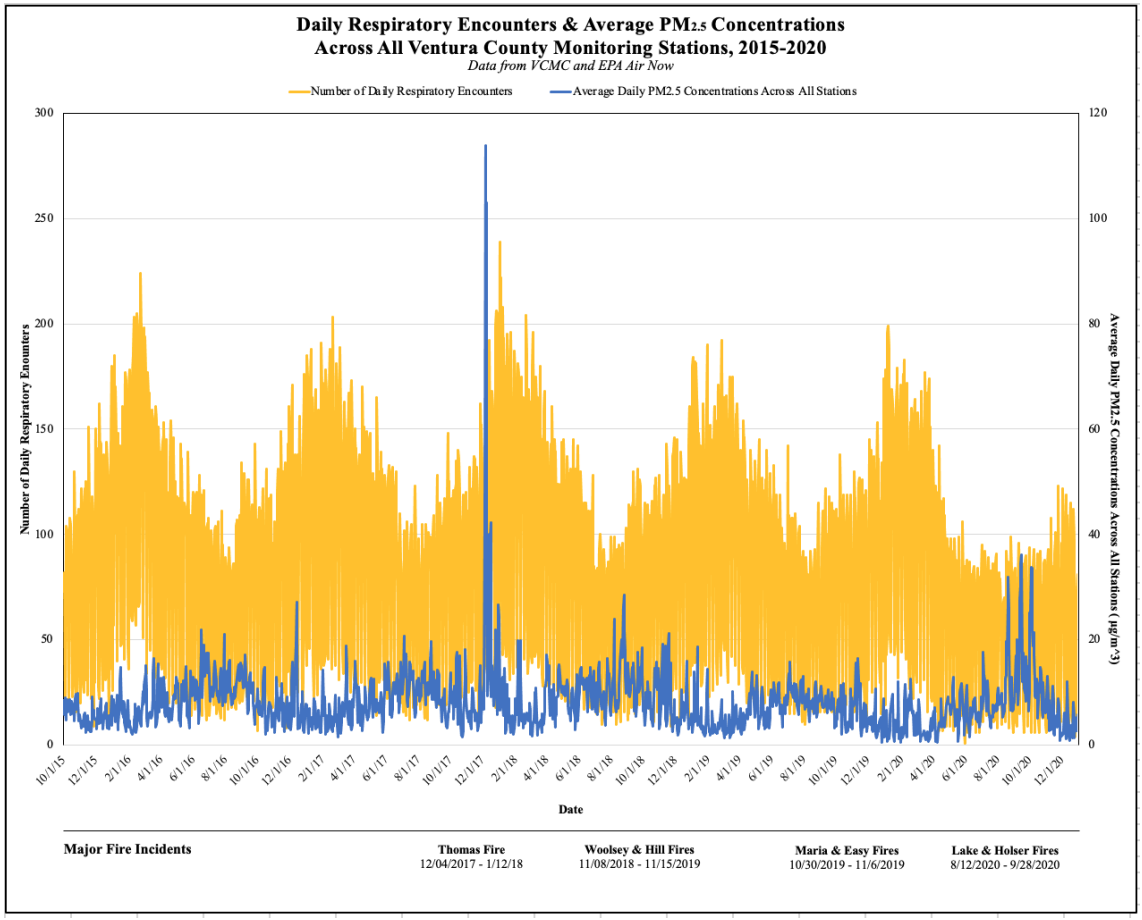

Figure 5: Daily Respiratory Encounters & Average $PM_{2.5}$ Concentrations Across All Ventura County Monitoring Stations

From the data, we examine a huge spike in $PM_{2.5}$ concentration averages across all monitoring stations from the Thomas, Woolsey, Hill, Lake, and Holser Fires; however, the total respiratory encounters do not reflect these declines in air quality (Figure 5). I observe oscillations in the respiratory encounters that parallel influenza seasons, but not much deviation from normal cycles when a fire event occurs. This makes me question what the data would look like if we were to plot the respiratory encounters against AQI values to encompass more air pollutants, rather than just $PM_{2.5}$.

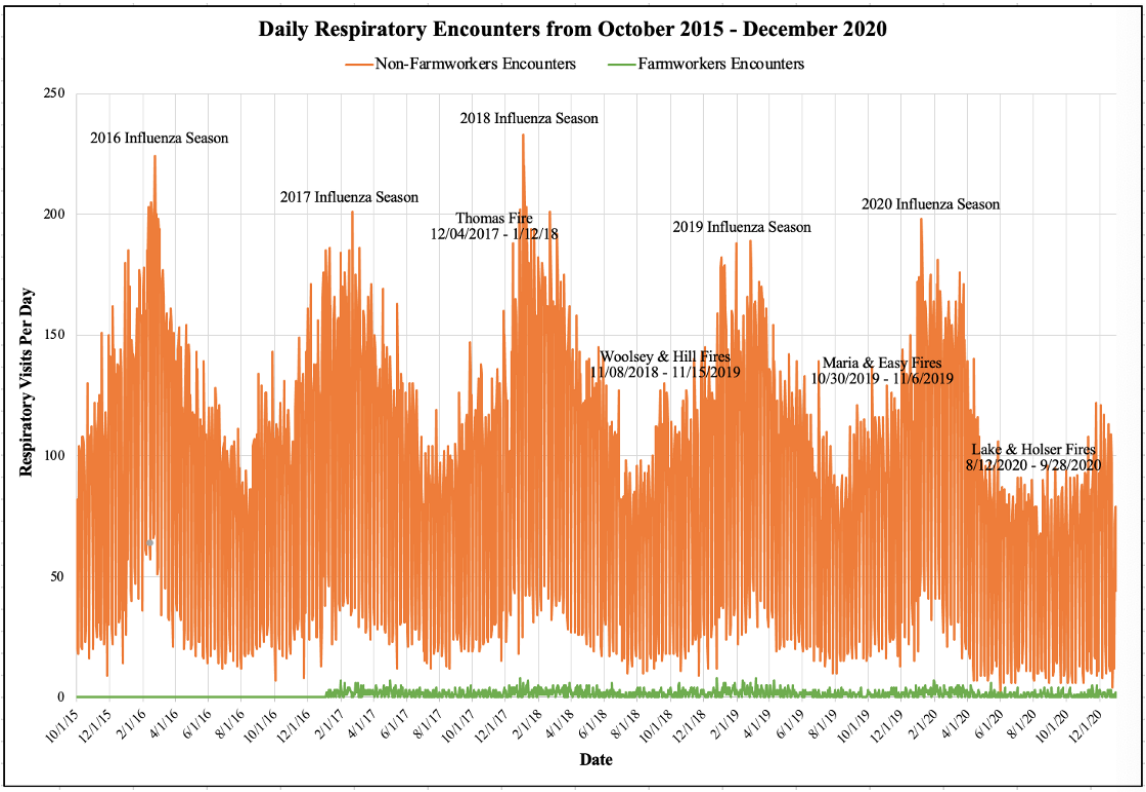

Figure 6: Daily Respiratory Encounters in Ventura County

For the purpose of this thesis, it was not worthwhile to fully conduct a correlation regression analysis for respiratory encounters and fire-associated $PM_{2.5}$. The preliminary visual correlation assessment demonstrated a weak relationship between respiratory encounters and fire periods; therefore, there is not substantial data to warrant further

correlation calculations. Additionally, there is a time limitation that also encouraged me to focus my analysis on the percent change and z-test, testing if farmworkers or non-farmworkers experience a higher flux in healthcare encounters during fire periods.

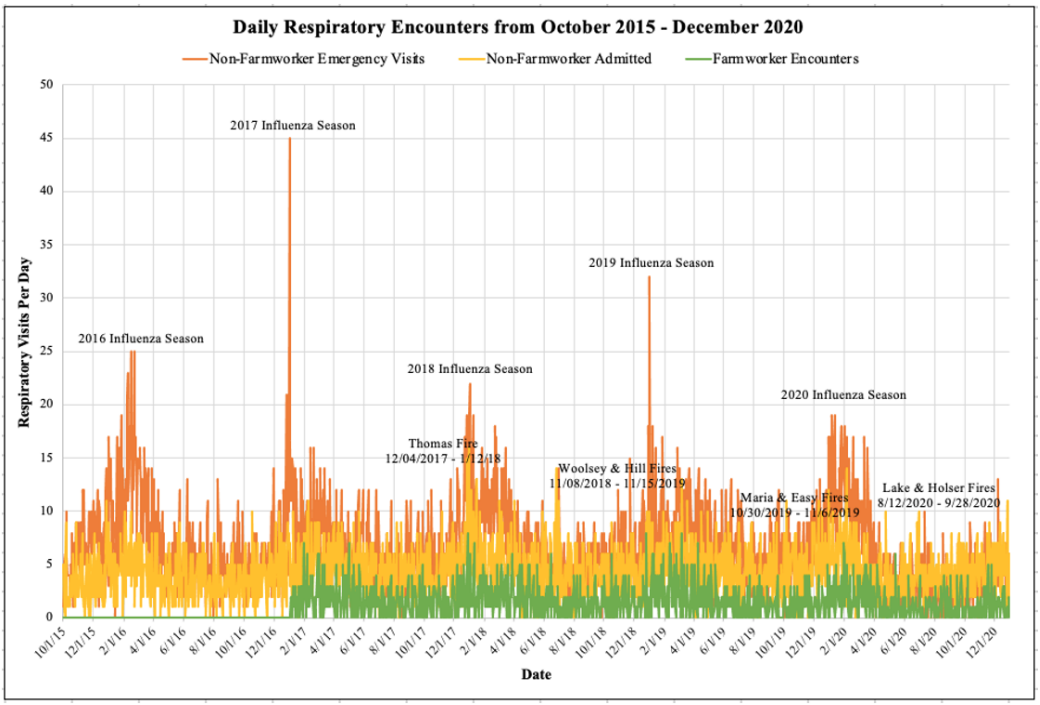

Figure 7: Respiratory Hospital Admissions, Visits, & Farmworkers

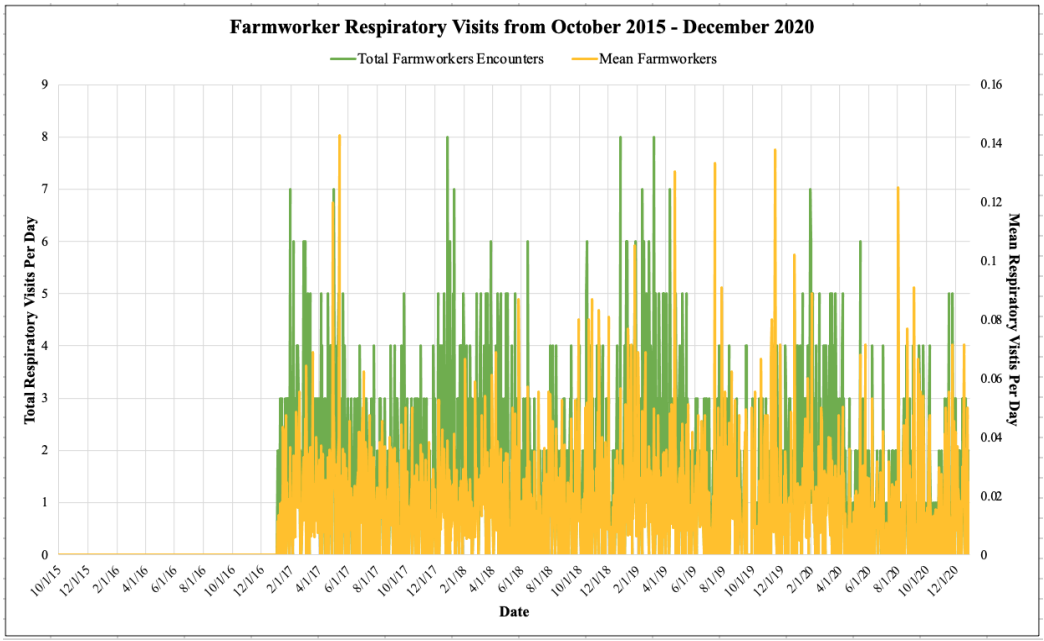

Figure 8: Total and Mean Farmworker Respiratory Encounters in Ventura County

5.4 Farmworker vs. Non-Farmworker Percent Change Analysis Results

Table 2 represents the calculated percent change of the healthcare encounters during the Thomas Fire, Woolsey and Hill Fires, Maria and Easy Fires, and Lake and Holser Fires. Overall, we see an average of 1.32% increase in non-farmworker encounters during fire periods and a 53.78% increase for farmworkers. During the Thomas Fire, a 91.67% increase in farmworker respiratory encounters were observed during a fire event, compared to the non-farmworkers' 13.62% increase. Based on these values, a z-score of 18.18 and p-value of 0 was calculated (Table 3). Because the p-value is less than the significance level of 0.05, we reject the null hypothesis and conclude that the percent change of farmworker respiratory encounters before and during the start of the Thomas Fire is higher than the percent change of non-farmworkers.

Table 2: Percent Change of Respiratory Encounters during Ventura County Wildfires, 2015-2020

Percent Change of Respiratory Encounters During Ventura County Wildfires, 2015-2020								
3 weeks before and 3 weeks after a fire event								
		All Encounters	Non-Farmworkers			Farmworkers		
Incident_Name	Time_Period	Avg_Encounters	Sample_Size	Avg_Encounters	%_Change	Sample_Size	Avg_Encounters	%_Change
Thomas Fire	11/13/2017 - 12/03/2017	94.1429	4172	93	13.6201	70	1.1429	91.6667
	12/04/2017 - 12/24/2017	107.8571		105.6667			2.1905	
Woolsey & Hill Fires	10/18/2018 - 10/07/2018	80.8571	3317	79.4762	-1.2582	66	1.381	27.5862
	11/08/2018 - 11/28/2018	80.2381		78.4762			1.7619	
Maria & Easy Fires	10/09/2019 - 10/29/2019	83.1905	3360	82.381	-5.7803	44	0.8095	58.8235
	10/30/2019 - 11/19/2019	78.9048		77.619			1.2857	
Lake & Holser Fires	07/22/2020 - 09/11/2020	56.8571	1117	56.0476	-1.2909	17	0.8095	37.037
	08/12/2020 - 9/01/2020	56.619		55.3333			1.2856	
Average percent change for all fire periods					1.322675			53.77835

For the Woolsey and Hill Fires, a 27.59% increase in farmworker encounters was found while non-farmworkers experienced a 1.26% reduction in respiratory visits. A z-score of 16.05 and p-value of 0 were estimated to test the significance of the percent changes, so the alternative hypothesis was accepted. For the Maria and Easy Fires, farmworkers had a 58.82% increase in encounters and non-farmworker had a 5.78%

decrease from three weeks before the fire period. When the z-test was calculated, a z-score of 14.21 and p-value of 0 was measured, warranting the acceptance of the alternative hypothesis. For the Lake and Holser Fires, a 37.04% increase in farmworker encounters was found while non-farmworkers experienced a 1.29% reduction in respiratory visits. A z-score of 10.93 and p-value of 0 were estimated to test the significance of the percent changes, so the alternative hypothesis was accepted.

Table 3: Z-Test Analysis of Percent Change
Testing whether the percent change of non-farmworker encounters are higher than farmworker encounters before and after fire periods

Z-Test Analysis

Testing whether the percent change of non-farmworker encounters are higher than farmworkers before and during a fire event

H_0 = the percent change of non-farmworker respiratory encounters before and during a fire event will be higher than the percent change of farmworker respiratory encounters before and during a fire event

H_1 = the percent change of farmworker respiratory encounters before and during a fire event will be higher than the percent change of non-farmworkers respiratory encounters before and during a fire event

$\alpha = 0.05$ | if $p < \alpha$: reject H_0 | if $p > \alpha$: fail to reject H_0

Incident Name	%_Change_Non-Farmworker	%_Change_Farmworker	Z-Score	P-Value	Significance (p<0.05)	Difference (B-A)
Thomas Fire	13.6201	91.6667	18.1826	0	Yes	0.7805
Woolsey Fire	-1.2582	27.5862	16.047	0	Yes	0.2633
Maria & Easy Fires	-5.7803	58.8235	14.214	0	Yes	0.5304
Lake & Holser Fires	-1.2909	37.037	10.926	0	Yes	0.3575

Because there was such a startling difference in non-farmworker and farmworker percent changes, I calculated the percent change for all encounters and fire incidents, merging both populations (Table 4). I observed an overall increase of 2.06% of respiratory encounters from the start of a fire event in Ventura County during 2015-2020. While the latest three fire periods experienced slight decreases in healthcare encounters, the Thomas Fire had a large increase of 14.57%. This indicates that the Thomas Fire played a major role in encouraging people to seek pulmonary healthcare, possibly due to

air pollutants associated with the fire irritating the respiratory systems of many people in the region.

Table 4: Percent Change for All Encounters

Percent Change for All Encounters	
Testing all encounters 3 weeks before and after fire periods	
Incident_Name	**%_Change_All_Encounters**
Thomas Fire	14.5675
Woolsey & Hill	-0.7656
Maria & Easy Fires	-5.1517
Lake & Holser Fires	-0.4188
Average percent change for all fire periods	2.0579

5.5 Discussion

5.5.1 Respiratory Health & Fire-Associated $PM_{2.5}$ in Ventura County

Based on the US Census Bureau, there are 846,006 individuals in Ventura County, 5%, or 42,300, of whom represents farmworkers (2019). According to a survey of Ventura County farmworkers, 57% of 989 farmworker respondents reported having access to healthcare (Maxwell et al., 2015). If we extend this proportion to all 42,300 farmworkers in Ventura County, approximately 18,300 individuals are estimated to lack access to healthcare. While 57% of farmworkers are suspected to be recorded in VCMC's healthcare system, what is the health of the other 43% that do not have healthcare?

Over the course of five years, there was a total of 2,206 VCMC farmworker respiratory encounters and 169,550 non-farmworker respiratory encounters, for a total of 171,756 for all encounters. Based on these values, farmworkers only make up 1.3% of the VCMC pulmonary health data. The maximum number of average daily farmworker

encounters is eight and maximum average daily mean is 0.14 encounters (Figure 8). The low prevalence of farmworkers, compared to the non-farmworkers, suggests that further investigation of whether the number of farmworkers for respiratory health care encounters is representative of reality. Some possible explanations for the low respiratory encounters include the idea that VCMC farmworkers are not concerned with their pulmonary health to get checked out, they have barriers to healthcare, and/or there are reporting errors. These implications are consistent with findings from Maxwell et al. and Mendez, Flores-Haro, & Zucker's observations regarding farmworker vulnerabilities and natural disaster responses (2015; 2020). These studies argue that given the social status of Latinx and Indigenous immigrant farmworkers, they are particularly vulnerable to disasters and require special consideration in disaster planning. With the fear of deportation, economic hardships, language barriers, and exposure to other health hazards in their outdoor work environment, farmworkers are in a challenging position to receive the aid they may need in an emergency.

To address my first research question regarding the relationship between respiratory encounters, $PM_{2.5}$ concentrations, and fire periods, Figure 5 was created to visually see if there's a correlation between these variables. Based on the preliminary visual correlation assessment, there is not a significant visual difference between non-fire and fire periods in the respiratory health encounters; therefore, I conclude there is not a strong relationship between pulmonary encounters and fire-associated $PM_{2.5}$. This entails that, across all of the wildfires in Ventura County from 2015-2020, there is not a large response in healthcare encounters, in response to high $PM_{2.5}$ concentrations in the atmosphere.

Even though the VCMC data does not clearly demonstrate the effects in which wildfire $PM_{2.5}$ concentrations affect the pulmonary health of farmworkers, there are still suspected respiratory and cardiovascular health impacts associated with the inhalation of the toxicant. In a study examining fire-specific $PM_{2.5}$ and respiratory hospitalizations, a 10 $\mu g/m^3$ increase in fire-specific $PM_{2.5}$ is associated with a 1.3-10% increase in respiratory hospitalizations and 4% increase in salbutamol dispensations during all fire season days and 3% increase in nitroglycerin dispensation during extreme fire days (Aguilera et al., 2021; Yao et al., 2016). Although the respiratory encounters in this study cannot be directly attributed to fire-specific $PM_{2.5}$ concentrations, there is an average 2.06% increase in all respiratory encounters during fire periods in Ventura County. Particularly with the Thomas Fire, there was a maximum of 239 encounters on January 2, 2017, following the fire. Shortly thereafter was the 2018 influenza season, where Ventura County experienced the highest number of encounters. This could be attributed to the fire exacerbating asthma or other respiratory illnesses, so when flu season came around, more people needed health care for a pulmonary health concern.

Furthermore, Figure 6 demonstrates a significant difference between farmworker and non-farmworker encounters. This is potentially due to the fact that non-farmworkers encompass a myriad of demographics from varying economic statuses and occupations while farmworkers are a specific cohort of individuals. The majority of Ventura County farmworkers are low-income, immigrants from Mexico, and/or of Latinx, Hispanic, Mixteco, and/or Indigenous descent. Additionally, only about 24,000 out 42,300, or 57%, of Ventura County farmworkers have access to healthcare (Maxwell et al., 2015). This brings up the question of how many of these 24,000 farmworkers have a pulmonary

health complication and do not have access to health care are concerned for their respiratory health. In contrast, a mean of 88.35 non-farmworkers are seeking pulmonary healthcare on a daily basis. Annual averages for non-farmworkers ranged from 74 encounters in 2020 to 94 in 2017 whereas farmworkers ranged from 1.26 encounters in 2020 to 1.64 in 2017.

In Figure 6, large fluctuations in respiratory encounters for non-farmworkers are observed whereas a relatively stagnant succession is seen for farmworker encounters. The main influence observed in the non-farmworker encounters is the impact flu season has on the pulmonary health. According to the CDC, influenza season in the United States occurs in the fall and winter, with peaks between December and February (2021). Based on VCMC records, flu season peaks in February in Ventura County, as seen in Figure 5-7. The flu is a contagious respiratory illness, caused by influenza viruses that infect the nose, throat, and sometimes lungs. Influenza can complicate chronic medical conditions, such as asthma, if high risk individuals develop serious cases of the flu. These individuals include the elderly with chronic medical conditions, pregnant women, and children younger than 5 years old. While children are not included in the VCMC pulmonary health data, those who are 65 years and older and pregnant women are included in the non-farmworker encounters. Although these individuals are high risk of getting the flu, people who are unvaccinated are able to become sick and weaken immune systems; therefore, we see these large oscillations in non-farmworker encounters over time.

In Figure 7, respiratory encounters are broken down by the number of hospital admissions, clinic visitations, and farmworker encounters within these encounters. Based

on these breakdowns, it is clear that influenza seasons dominate the occurrence of admissions with the Thomas Fire, following this influence.

My second research question asks if farmworkers experience a higher incidence of encounters during a fire emergency than non-farmworkers. Based on the percent change and z-test calculations, a larger increase in farmworker encounters over all fire periods were observed than non-farmworkers. The reason why a large percent change increase in farmworker encounters is possibly due to the small number of average farmworker encounters. If we look at the number of encounters, average farmworker encounters jumped from approximately 1.14 encounters three weeks before the fire to 2.19 encounters three weeks after the start of the Thomas Fire (Table 3). This is approximately doubling the number of farmworkers entering a healthcare facility for a pulmonary concern when the Thomas Fire began. If we examine the raw average encounters, as is, the 91.67% increase and p-value of 0 is reasonable and consistent with the observed average encounters. For the Woolsey and Hill Fires, a 27.59% increase in farmworker encounters and 1.26% decrease in non-farmworker encounters were observed. This suggests that the number of farmworkers seeking respiratory care increased by 27.59% when the fire began. In contrast, the incidence of non-farmworkers decreased by 1.26% since the Woolsey and Hill Fires began.

During the Maria and Easy Fires in October 2019, a 58.82% increase in farmworker encounters and 5.78% decrease in non-farmworkers occurred when the fire started in Ventura County. The Maria and Easy Fires affected the pulmonary health encounters of Ventura County farmworkers and non-farmworkers at a higher magnitude than the Woolsey and Hill Fires. The difference is possibly due to the fires' locations and

weather patterns affecting the distribution of pollutants. While the Maria and Easy Fires burned 11,805 acres in Ventura County, the Woolsey and Hill Fires burned 101,480 acres in both Los Angeles and Ventura Counties (Table 1).

Because of the relatively small farmworker sample size, we cannot conclude that there are more farmworkers entering a healthcare facility for a respiratory concern than non-farmworkers. Instead, we can conclude that there is a larger percent change for farmworkers than non-farmworkers when a fire breaks out. When sheerly looking at average encounters, the number of farmworkers doubled during the Thomas Fire compared to non-farmworkers increasing by 13.62%. To put it in perspective, on an average day, there is about one farmworker walking into a healthcare facility for a respiratory health concern. When the Thomas Fire hit, the number of farmworkers nearly doubled, possibly due to poor air quality. Although the data may be overleveraged, there is a lack of farmworker respiratory health data, in general. This suggests that there are either reporting errors or socioeconomic factors affecting a farmworker's ability to seek healthcare. A Ventura County survey found that 57% of 989 farmworker respondents reported having access to healthcare, 41% reported access to transportation, and 26% reported being able to work enough to support their family (Maxwell et al., 2015). This survey supports the implication that farmworkers have barriers to healthcare. Ventura County has about 20,000 indigenous migrants, many that work in agriculture, that should have the basic needs to care for their well-being (MICOP, 2021). The sparse records on farmworker health indicates that healthcare services could improve monitoring and reporting procedures to improve the accuracy of health records.

Based on this study and literature, I conclude that farmworkers are, indeed, a population that needs prioritization and inclusion when it comes to fire and other natural disaster response plans. The percent change analysis demonstrates that farmworkers experience an overall incline in respiratory encounters during a fire period than non-farmworkers. As a result, government entities, and agencies that have the means to, should develop strategies to incorporate farmworkers in emergency responses and stricter enforcements to farmworker rights legislation.

5.6 Chapter Summary

Chapter 5 describes the results and discussion of the analyses conducted, comparing $PM_{2.5}$ concentrations, respiratory encounters, and major fire events. While there is no significant visual correlation between $PM_{2.5}$ and pulmonary healthcare encounters, a correlation regression analysis could be employed in the future to quantify this relationship, despite the potentially positive or negative correlation outcome. Conducting a percent change analysis and testing the significance of it, using a z-test, addresses my second research question of whether farmworkers of non-farmworkers seek healthcare more during a fire event. As a result, the percent change analysis indicates that farmworkers experience a higher influx of pulmonary health encounters than non-farmworkers during the four fire periods in Ventura County. Although the number of farmworker encounters are sparse, this study highlights a few possible conclusions: how the health of farmworker populations is poorly documented, how there may be reporting errors in the records, and/or socioeconomic factors that impact a farmworker's ability or desire to seek healthcare.

Based on the percent change analyses, comparing farmworkers, non-farmworkers, and all encounters, an overarching conclusion that the only fire that significantly impacted Ventura County population's respiratory health was the Thomas Fire. In contrast, farmworkers experienced increases in respiratory encounters for all fire incidents while non-farmworkers had declinations for the Woolsey, Hill, Easy, Maria, Lake, and Holser Fires. In regards to if farmworkers or non-farmworkers have more serious health effects from the inhalation of fire-associated $PM_{2.5}$, it is suspected that farmworkers experienced harsher pulmonary health effects from the fires than non-farmworkers.

Chapter 6: Conclusion

6.1 Introduction

This study aims to demonstrate that farmworkers are especially vulnerable during fire disasters due to their pre-existing vulnerabilities, lack of government aid because of their immigration status, and need to work during smokewave days. While California governments, public health departments, and environmental agencies are adapting to the increasing severity of wildfires, it is necessary that we attempt to better understand the disproportionate impacts natural disasters, in response to climate change, have on marginalized people.

In this paper, an evaluation of Ventura County Medical Center's pulmonary health records, Environmental Protection Agency's $PM_{2.5}$ data, and CAL FIRE's fire incident information was conducted to document the impacts wildfires have on farmworkers and the general public. First, I completed a preliminary visual correlation assessment of respiratory encounters, $PM_{2.5}$, and fire events, and determined that the data did not warrant further correlation regression calculation. Next, I calculated the percent change of farmworkers and non-farmworkers to compare the magnitude of healthcare encounters in response to fire events. Through this analysis, I concluded that farmworkers experienced a more intense pulmonary health response to fire events than non-farmworkers. I suspect that this is due to their outdoor physical activities while there are smokewave days. Based on this study's analyses and literature on farmworker health, I determined that farmworkers are, indeed, a vulnerable population that need official legislative protection and stricter enforcements when it comes to labor laws, climate planning, and natural disaster responses. This is because farmworkers, in particular, are

engaging in arduous labor when there are unhealthy air quality conditions. When doing physical activity outdoors, individuals are inhaling more air and breathing at a faster rate as they are exerting energy to complete tasks. This, in turn, leads to the increased inhalation of unhealthy or hazardous concentrations of $PM_{2.5}$ or other air pollutants in the atmosphere that could potentially exacerbate pre-existing pulmonary and cardiovascular health conditions.

In addition to wildfire smoke effects on pulmonary and cardiovascular health, fires can affect both the mental and physical health of those exposed by destroying livelihoods and triggering traumatic experiences. While this paper did not inspect the mental health impacts of Ventura County farmworkers, there are suspected effects to the stress and anxiety levels of anyone experiencing a fire disaster or emergency event. This thesis presents several possible explanations for why there are a small number of respiratory encounters for farmworkers. One reason may be that farmworkers may not be troubled with their respiratory health; and therefore, may not need to seek healthcare for this concern. Another reason for the low encounter is the socioeconomic, political, and healthcare accessibility factors that tie in with the demographic of farmworker populations, as described in previous scientific studies. Even though these outcomes are a possibility, I conclude that farmworkers are exposed to $PM_{2.5}$ and other components of fire smoke at a larger extent than those who are not working outdoors during a fire event. In order to investigate these questions, further qualitative and quantitative research needs to be conducted to close the gaps in knowledge about farmworker health and vulnerabilities.

6.2 Limitations

This thesis exhibited some routes to research the pulmonary health of farmworkers and the general public during fire events. Because these are simple assessments, further analyses incorporating more complicated variables are needed to get a more comprehensive analysis and representation of farmworker experiences. Some limitations of this study include the low records of farmworker encounters, possibly due to the nature of the population groupings or stated reasons above, use of the EPA's unverified $PM_{2.5}$ dataset, and small number of farmworker encounters represented in the VCMC health records. Because of the small farmworker population reflected in the health data, it is difficult to realistically compare whether or not farmworkers experience more pulmonary health effects, due to the inhalation of fire smoke, than non-farmworkers. When comparing farmworkers to non-farmworkers during each major fire event, I found that there was a greater percent change among farmworkers than non-farmworkers; however, when examining sheer encounter numbers, there are more non-farmworkers seeking healthcare because non-farmworkers consist of everyone in Ventura County above the age of 18 and not a farmworker. This makes studying farmworker health more challenging. In the future, comparisons between farmworkers and other essential, occupational workers can be done to better understand realistic poor air quality effects on the pulmonary health of these populations.

Another limitation to this study is that fire-sourced $PM_{2.5}$ and all sources were not differentiated. This is due to the difficulty in developing emission models to accurately reflect these differences. Instead, I used the EPA's $PM_{2.5}$ datasets available on their website to capture the air quality between 2015-202. While $PM_{2.5}$ measurements were not

precisely fire-associated in this study, literature suggests a strong relationship between the inhalation of fire-specific PM2.5 and respiratory morbidity (Aguilera et al., 2021; Corrieri et al., 2019; Reid et al., 2015).

Lastly, the COVID-19 pandemic has been a difficult year for everyone; however, it has been an exceptionally challenging year for the healthcare industry. Public health departments have paid all of their attention to limiting the spread of disease, so getting in touch healthcare professionals to have conversations about respiratory health among farmworkers were tough. I was lucky to be contacted by Dr. Carroll and Dr. Landon from VCMC to ease the barriers to accessing healthcare records. Despite the leg in, there were remaining obstacles that prevented me from receiving the data, ensuring HIPAA standards, and doing certain analyses. In order to satisfy VCMC IRB, for example, I had to access the data on a VCMC computer to ensure that HIPAA regulations were not violated. On the other hand, I could only visit the clinic a limited number of times because of COVID-19 restrictions. Despite these obstacles, conducting this study was worthwhile to learn the process of scientific research in the clinical field.

6.3 Future Research

All of the natural disasters, highlighted inequities, and social movements that occurred in 2020 were the inspiration for this project. As I was scrolling through social media, I remember seeing photos of farmworkers harvesting food during the 2020 Bay Area Lightning Fires and COVID-19 pandemic (CAL FIRE, n.d.). These photos illustrated their strenuous work, saving crops from falling ash while a blazing fire was climbing the mountains behind them. As these farmworkers were working closely to each

other during a pandemic and enduring other existing outdoor occupation vulnerabilities, wildfire smoke inhalation is one more problem they have to face. Even though we have certain legislative regulations to protect farmworker labor rights, these rules are often not well enforced (Méndez, Flores-Haro, & Zucker, 2020; MICOP, 2021; Maxwell et al., 2015). These disparities and inequities are deeply ingrained in our structural systems and policy makers and public health officials need to include farmworkers as a priority population for emergency preparedness plans.

To enhance scientific knowledge about farmworker health and assist in strengthening policy, farmworker experiences could be better documented through surveys and qualitative studies and/or the quantification of a correlation analysis between farmworker pulmonary health and fire-associated $PM_{2.5}$. One analysis that could be done is a dose-response quantification of $PM_{2.5}$ increases and farmworker health responses. Climate models and fire smoke emission factors could be further incorporated in future analyses to more accurately correlate these variables and attribute $PM_{2.5}$ to fire incidents.

Future research could also investigate longer time periods to capture more fire events and evaluate natural disaster emergency responses in-depth. Lessons learned from scientific literature, news reports, and this thesis, regarding this subject, can be further explored to develop more inclusive disaster response and climate change plans. Hearing the voices of the farmworkers experiencing these harsh realities are also essential in building more informed official actions and mitigation legislation to reduce fire and other natural disaster effects on farmworkers and other outdoor occupational workers.

6.4 Conclusion

Slow violence conceptualizes the "slow moving injurious and deadly harms, stemming from human-caused environmental degradation or climate change" (Mendez, Flores-Haro, & Zucker, 2020; Nixon, 2011). This term emphasizes the need to address the readily ignored, environmental injustices that reap on poor communities of color over a course of a decade or longer. Disempowered and poor communities often do not have the time or resources to engage in solutions to the invisible and gradual effects climate change, pollution, and environmental change subjected to them. This means that government entities and agencies that have the resources to must evaluate the disproportionate impacts fires and other natural disasters have on marginalized communities and incorporate these groups, and those along the border of these communities, into their climate change and disaster response plans. As anthropogenic climate change intensifies, we need to build community resilience and uplift the communities that our society relies on most for our food, economy, and well-being.

REFERENCES

Austin, E., Kasner, E., Seto, E., & Spector, J. (2020). Combined burden of heat and particulate matter air quality in WA agriculture. *Journal of Agromedicine*, 1–10. https://doi.org/10.1080/1059924X.2020.1795032.

Aguilera, R., Corringham, T., Gershunov, A., & Benmarhnia, T. (2021). Wildfire smoke impacts respiratory health more than fine particles from other sources: Observational evidence from Southern California. *Nature Communications*, *12*(1), 1493. https://doi.org/10.1038/s41467-021-21708-0.

Bill Text—SB-160 Emergency services: Cultural competence. (2019). Retrieved January 30, 2021 from https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200SB160.

Borchers Arriagada, N., Horsley, J. A., Palmer, A. J., Morgan, G. G., Tham, R., & Johnston, F. H. (2019). Association between fire smoke fine particulate matter and asthma-related outcomes: Systematic review and meta-analysis. *Environmental Research*, *179*, 108777. Retrieved December 9, 2020 from https://doi.org/10.1016/j.envres.2019.108777.

California Department of Forestry and Fire Protection (CAL FIRE). (n.d.). Incidents overview. Retrieved May 02, 2021, from https://www.fire.ca.gov/incidents/.

California Department of Forestry and Fire Protection (CAL FIRE). (n.d.). Welcome to Incident. Retrieved November 20, 2020, from https://fire.ca.gov/incident/?incident=d28bc34e-73a8-454d-9e55-dea7bdd40bee.

California Department of Food & Agriculture (CDFA). (2018). *California Agricultural Exports 2018-2019*. 15.

Central Coast Alliance United for a Sustainable Economy (CAUSE). (n.d.a). Community resilience in the Thomas Fire. Retrieved November 20, 2020 from https://causenow.org/our-work/community-resilience-thomas-fire.

Central Coast Alliance United for A Sustainable Economy (CAUSE). (n.d.b). Justice for farmworkers. Retrieved December 9, 2020 from https://causenow.org/our-work/justice-farmworkers.

Central Coast Alliance United for a Sustainable Economy (CAUSE). (2015). Rising Up Farm Workers. Retrieved October 2020 from https://causenow.org/content/report-raising-farmworkers.

Centers for Disease Control and Prevention (CDC). (2021, May 06). *The Flu Season*. Centers for Disease Control and Prevention. https://www.cdc.gov/flu/about/season/flu-season.htm#:~:text=In%20the%20United%20States%2C%20flu%20season%20occurs%20in%20the%20fall,last%20as%20late%20as%20May.

City of Ventura. (n.d.). Thomas Fire. Retrieved January 31, 2021 from https://www.cityofventura.ca.gov/1254/Thomas-Fire-Information.

Cohen, J. (2018, May 08). The sundowner experiment. *The UCSB Current.* Retrieved January 24, 2021 from https://www.news.ucsb.edu/2018/018973/sundowner-experiment.

Cormier, Y. (2007). Respiratory health and farming: An essay. *Canadian Respiratory Journal: Journal of the Canadian Thoracic Society*, 14(7), 419–422.

Corrieri, M. L., Roy, N. C., Rose-Davison, K. N., & Roy, C. J. (2019). Wildfire associated health risks impacting farmers and ranchers. *Journal of Agromedicine*, *24*(2), 129–132. https://doi.org/10.1080/1059924X.2019.1581494.

Curl, C. L., Spivak, M., Phinney, R., & Montrose, L. (2020). Synthetic pesticides and health in vulnerable populations: Agricultural workers. Retrieved December 8, 2020 from https://link.springer.com/article/10.1007%2Fs40572-020-00266-5.

Davies, I. P., Haugo, R. D., Robertson, J. C., & Levin, P. S. (2018). The unequal vulnerability of communities of color to wildfire. *PloS one*, *13*(11), e0205825. https://doi.org/10.1371/journal.pone.0205825.

Delfino, R. J., Brummel, S., Wu, J., Stern, H., Ostro, B., Lipsett, M., Winer, A., Street, D. H., Zhang, L., Tjoa, T., & Gillen, D. L. (2009). The relationship of respiratory and cardiovascular hospital admissions to the southern California wildfires of 2003. *Occupational and Environmental Medicine*, *66*(3), 189–197. https://doi.org/10.1136/oem.2008.041376.

Department of Health Care Services (DHCS). (2021). Medi-Cal monthly Enrollment recent trends. Retrieved May 09, 2021, from https://www.dhcs.ca.gov/dataandstats/statistics/Pages/Medi-Cal-Certified-Eligibles.aspx.

Department of Health Care Services (DHCS). (2019). Health Insurance Portability & Accountability Act. Retrieved May 09, 2021, from https://www.dhcs.ca.gov/formsandpubs/laws/hipaa/Pages/1.00WhatisHIPAA.aspx.

Diskin, M. (2020, October 30). In the redacted Woolsey fire report, authorities blame Edison equipment for blaze. Retrieved May 09, 2021, from https://www.vcstar.com/story/news/local/communities/simi-valley/2020/10/29/redacted-2018-woolsey-fire-report-authorities-blame-edison-equipment/6057616002.

Faber, B. (2018, January 4). Estimates of agricultural damage from Thomas Fire. *Topics in Subtropics - Agriculture and Natural Resources Blogs.* Retrieved on January 29, 2021 from https://ucanr.edu/blogs/Topics/index.cfm.

Farm Bureau of Ventura County (FBVC). (2018). *2017 Crop & Livestock Report*. http://www.farmbureauvc.com/county-crop-data.

Farmworker Justice. (2021). Health care access. Retrieved May 09, 2021, from https://www.farmworkerjustice.org/advocacy_program/accessing-healthcare/.

Fix, J., Annesi-Maesano, I., Baldi, I., Boulanger, M., Cheng, S., Cortes, S., Dalphin, J.-C., Dalvie, M. A., Degano, B., Douwes, J., Eduard, W., Elholm, G., Ferreccio, C., Harding, A.-H., Jeebhay, M., Kelly, K. M., Kromhout, H., MacFarlane, E., Maesano, C. N., … Hoppin, J. A. (2020). Gender differences in respiratory health outcomes among farming cohorts around the globe: Findings from the AGRICOH consortium. *Journal of Agromedicine*, 1–12. https://doi.org/10.1080/1059924X.2020.1713274.

Garofalo, M. (n.d.). Explaining santa ana winds. *WeatherNation*. Retrieved January 24, 2021, from https://www.weathernationtv.com/news/explaining-santa-ana-winds/.

Guidimadjegbe, S. J., Lastra-Morales, L., Siwabessy, A. G., Yang, L. L., & Rodrigue, C. M. (2019). A mixed-methods approach case study: The dynamics of differential social vulnerability in communities affected by the Thomas Fire and subsequent debris flows in southern California, United States. 26.

Hersko, T. (n.d.). Ventura County agriculture suffers over $170 million in damages from Thomas Fire. *Ventura County Star*. Retrieved January 23, 2021, from https://www.vcstar.com/story/money/business/2018/01/23/over-170-million-damage-sustained-ventura-countys-agricultural-industry-thomas-fire-according-data-p/1055678001/.

HouseFarmworkers. (2021, January 19). Why our work matters. Retrieved May 10, 2021, from https://housefarmworkers.org/.

HRSA Privacy Act of 1974; Report of an Altered System of Records (SOR), 75 Fed. Reg. 19652 (2010, April 15). Retrieved from https://www.govinfo.gov/content/pkg/FR-2010-04-15/pdf/2010-8620.pdf.

Jazi, M. (2019, February 07). Ventura County Avocado, lemon growers blame power shut-offs for many of their losses. Retrieved May 09, 2021, from https://www.vcstar.com/story/news/2019/11/12/ventura-county-avocado-lemon-growers-blame-losses-power-shut-offs/4171383002/.

Johnston, F. H., Purdie, S., Jalaludin, B., Martin, K. L., Henderson, S. B., & Morgan, G. G. (2014). Air pollution events from forest fires and emergency department attendances in Sydney, Australia 1996–2007: A case-crossover analysis. *Environmental Health*, *13*(1), 105. https://doi.org/10.1186/1476-069X-13-105.

Kim, Y., Knowles, S., Manley, J., & Radoias, V. (2017). Long-run health consequences of air pollution: Evidence from Indonesia's forest fires of 1997. *Economics and Human Biology*, *26*, 186–198. https://doi.org/10.1016/j.ehb.2017.03.006.

Kollanus, V., Tiittanen, P., Niemi, J. V., & Lanki, T. (2016). Effects of long-range transported air pollution from vegetation fires on daily mortality and hospital admissions in the Helsinki metropolitan area, Finland. *Environmental Research*, *151*, 351–358. https://doi.org/10.1016/j.envres.2016.08.003.

Koman, P. D., Billmire, M., Baker, K. R., de Majo, R., Anderson, F. J., Hoshiko, S., Thelen, B. J., & French, N. H. F. (2019). Mapping modeled exposure of wildland fire smoke for human health studies in California. *Atmosphere*, *10*(6), 308. https://doi.org/10.3390/atmos10060308.

Lee, S.-J., Mehler, L., Beckman, J., Diebolt-Brown, B., Prado, J., Lackovic, M., Waltz, J., Mulay, P., Schwartz, A., Mitchell, Y., Moraga-McHaley, S., Gergely, R., & Calvert, G. M. (2011). Acute pesticide illnesses associated with off-target pesticide drift from agricultural applications: 11 States, 1998–2006. *Environmental Health Perspectives*, *119*(8), 1162–1169. https://doi.org/10.1289/ehp.1002843.

Li, D. & Romero, D. (2019, November 02). Fast-moving Maria fire in rural Southern California threatens avocado, citrus crops. Retrieved May 09, 2021, from https://www.nbcnews.com/news/us-news/fast-moving-maria-fire-rural-southern-california-threatens-avocado-citrus-n1075116.

Liu, J. C., Mickley, L. J., Sulprizio, M. P., Dominici, F., Yue, X., Ebisu, K., Anderson, G. B., Khan, R. F. A., Bravo, M. A., & Bell, M. L. (2016). Particulate air pollution from wildfires in the Western US under climate change. *Climatic Change*, *138*(3), 655–666. https://doi.org/10.1007/s10584-016-1762-6.

Margolis, J. (2020, August 13). *'Lake Fire' Near Lake Hughes Explodes To 10,000 Acres In 'Extreme' Fire Conditions*. LAist. https://laist.com/news/lake-fire-santa-clarita-valley-brush-august-12.

Mamane, A., Baldi, I., Tessier, J.-F., Raherison, C., & Bouvier, G. (2015). Occupational exposure to pesticides and respiratory health. *European Respiratory Review: An Official Journal of the European Respiratory Society*, *24*(136), 306–319. https://doi.org/10.1183/16000617.00006014.

Marshall, G. N., Schell, T. L., Elliott, M. N., Rayburn, N. R., & Jaycox, L. H. (2007). Psychiatric Disorders Among Adults Seeking Emergency Disaster Assistance After a Wildland-Urban Interface Fire. *PSYCHIATRIC SERVICES*, *58*(4), 6.

Martin, K. L., Hanigan, I. C., Morgan, G. G., Henderson, S. B., & Johnston, F. H. (2013). Air pollution from bushfires and their association with hospital admissions in Sydney, Newcastle and Wollongong, Australia 1994-2007. *Australian and New Zealand Journal of Public Health*, *37*(3), 238–243. https://doi.org/10.1111/1753-6405.12065.

Maxwell, A. E., Young, S., Crespi, C. M., Vega, R. R., Cayetano, R. T., & Bastani, R. (2015). Social determinants of health in the Mixtec and Zapotec community in Ventura County, California. *International Journal for Equity in Health*, *14*(1), 16. https://doi.org/10.1186/s12939-015-0148-0.

Méndez, M., Flores-Haro, G., & Zucker, L. (2020). The (in)visible victims of disaster: Understanding the vulnerability of undocumented Latino/a and indigenous immigrants. *Geoforum*, *116*, 50–62. https://doi.org/10.1016/j.geoforum.2020.07.007.

Mixteco Indigena Community Organizing Project (MICOP). (2021, April 15). Home. Retrieved May 22, 2021, from https://mixteco.org/.

National Center for Farmworker Health, Inc. (NCFH). (n.d.). Heath center tool box. Retrieved May 10, 2021, from http://www.ncfh.org/health-center-toolbox.html.

Nakayama Wong, L. S., Aung, H. H., Lamé, M. W., Wegesser, T. C., & Wilson, D. W. (2011). Fine particulate matter from urban ambient and wildfire sources from California's San Joaquin Valley initiate differential inflammatory, oxidative stress, and xenobiotic responses in human bronchial epithelial cells. *Toxicology in Vitro: An International Journal Published in Association with BIBRA*, *25*(8), 1895–1905. https://doi.org/10.1016/j.tiv.2011.06.001.

Nauslar, N. J., Abatzoglou, J. T., & Marsh, P. T. (2018). The 2017 North Bay and Southern California Fires: A Case Study. 17.

Nixon, R. (2011). *Slow Violence and the Environmentalism of the Poor*. Cambridge, Massachusetts; London, England: Harvard University Press. Retrieved June 2, 2021, from http://www.jstor.org/stable/j.ctt2jbsgw.

Nordgren, T. M., & Bailey, K. L. (2016). Pulmonary Health Effects of Agriculture. *Current Opinion in Pulmonary Medicine*, *22*(2), 144–149. https://doi.org/10.1097/MCP.0000000000000247.

Office of Governor Gavin Newsom. (2019, August 20). Governor Newsom announces launch of $50 million "Listos California" campaign to help build community resilience to wildfires. Retrieved January 26, 2021 from https://www.gov.ca.gov/2019/08/20/governor-newsom-announces-launch-of-50-million-listos-california-campaign-to-help-build-community-resilience-to-wildfires.

Pearson, D., Ebisu, K., Wu, X., & Basu, R. (2019). A review of Coccidioidomycosis in California: Exploring the intersection of land use, population movement, and

climate change. *Epidemiologic Reviews*, *41*(1), 145–157. https://doi.org/10.1093/epirev/mxz004.

Rappold, A. G., Stone, S. L., Cascio, W. E., Neas, L. M., Kilaru, V. J., Carraway, M. S., Szykman, J. J., Ising, A., Cleve, W. E., Meredith, J. T., Vaughan-Batten, H., Deyneka, L., & Devlin, R. B. (2011). Peat bog wildfire smoke exposure in rural North Carolina is associated with cardiopulmonary emergency department visits assessed through syndromic surveillance. *Environmental Health Perspectives*, *119*(10), 1415–1420. https://doi.org/10.1289/ehp.1003206.

Reid, C. E., Brauer, M., Johnston, F. H., Jerrett, M., Balmes, J. R., & Elliott, C. T. (2016). Critical review of health impacts of wildfire smoke exposure. *Environmental Health Perspectives*, *124*(9), 1334–1343. https://doi.org/10.1289/ehp.1409277.

Reid, C. E., & Maestas, M. M. (2019). Wildfire smoke exposure under climate change: Impact on respiratory health of affected communities. *Current Opinion in Pulmonary Medicine*, *25*(2), 179–187. https://doi.org/10.1097/MCP.0000000000000552.

Riden, H. E., Giacinto, R., Wadsworth, G., Rainwater, J., Andrews, T., & Pinkerton, K. E. (2020). Wildfire smoke exposure: awareness and safety responses in the agricultural workplace. *Journal of Agromedicine*, *25*(3), 330–338. https://doi.org/10.1080/1059924X.2020.1725699.

Rosenbaum, S. J., & Shin, P. (2005). Migrant and seasonal farmworkers: health insurance coverage and access to care.

Santa Barbara County Agricultural Commission (SB CAC). (2018). *2017 Agricultural Production Report.* http://www.farmbureauvc.com/county-crop-data.

Saxton, D. I. (2015). Strawberry fields as extreme environments: The ecobiopolitics of farmworker health. *Medical Anthropology*, *34*(2), 166–183. https://doi.org/10.1080/01459740.2014.959167.

Schenker, M. B., Pinkerton, K. E., Mitchell, D., Vallyathan, V., Elvine-Kreis, B., & Green, F. H. Y. (2009). Pneumoconiosis from agricultural dust exposure among young California farmworkers. *Environmental Health Perspectives*, *117*(6), 988–994. https://doi.org/10.1289/ehp.0800144.

Schenker, M. (2000). Exposures and health effects from inorganic agricultural dusts. *Environmental Health Perspectives*, *108*, 4.

United States (US) Census Bureau. (n.d.). QuickFacts Ventura County, California. Retrieved 2021, from https://www.census.gov/quickfacts/venturacountycalifornia.

United States (US) Census Bureau. (2019, December 11). FAQ. Retrieved 2021, from https://www.census.gov/topics/population/foreign-born/about/faq.html.

United States Department of Agriculture Economic Research Service (USDA AERS). (n.d.). Cash receipts by state. Retrieved December 14, 2020, from https://data.ers.usda.gov/reports.aspx?ID=17843#Pb4924df2876b45d4ab3e6c3434cf07ea_3_17iT0R0x5.

United States Environmental Protection Agency (EPA). (2019, August 13). Wildfire smoke and your patients' health: The air quality index. *US EPA*. https://www.epa.gov/wildfire-smoke-course/wildfire-smoke-and-your-patients-health-air-quality-index.

United States Environmental Protection Agency (EPA). (2018, November 30). Download daily data. Retrieved May 02, 2021, from https://www.epa.gov/outdoor-air-quality-data/download-daily-data.
United States Environmental Protection Agency (EPA). (2016, April 19). Particulate matter (PM) basics. *US EPA*. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics.s
United States Environmental Protection Agency (EPA). (2014, April 10). National Ambient Air Quality Standard (NAAQS) table. *US EPA*. https://www.epa.gov/criteria-air-pollutants/naaqs-table.
United States Environmental Protection Agency (EPA). (1992). Guidelines for exposure Assessment. 139. *Federal Register*, 57(104), 22888-938.
United States Environmental Protection Agency (EPA). (1974). Guidance for air quality monitoring network design and instrument siting, Draft.
United States Geological Survey (USGS). (2021). GNIS Results: Ventura County Hospitals. Retrieved May 06, 2021, from https://geonames.usgs.gov/apex/f?p=138%3A2%3A5320555756719%3Apg_R_135562735852083345 9%3ANO&pg_min_row=16&pg_max_rows=15&pg_rows_fetched=15.
Ventura County Fire Department (VCFD). (n.d.). VCFD determines the cause of the Thomas Fire. Retrieved January 24, 2021 from https://vcfd.org/news/vcfd-determines-cause-of-the-thomas-fire/.
Ventura County Health Care Agency (VCHCA). (n.d.). Health care for all. Retrieved May 09, 2021, from https://vchca.org/health-care-for-all.
Ventura County Public Health. (2019). Community health assessment. Retrieved May 06, 2021, from http://www.healthmattersinvc.org/index.php?module=indicators&controller=index&action=dashboard&id=102258093434962616.
World Health Organization (WHO). (n.d.). Ambient (outdoor) air pollution. Retrieved December 13, 2020, from https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.
Yao, J., Eyamie, J., & Henderson, S. B. (2016). Evaluation of a spatially resolved forest fire smoke model for population-based epidemiologic exposure assessment. *Journal of Exposure Science & Environmental Epidemiology*, *26*(3), 233–240. https://doi.org/10.1038/jes.2014.67.