AN ANALYSIS OF WILDFIRE IMPACTS ON CLIMATE CHANGE

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Abstract

Abstract: The western United States (U.S.). has recently seen an increase in wildfires that destroyed communities and lives. This researcher seeks to examine the impact of wildfires on climate change by examining recent studies on air quality and air emissions produced by wildfires, and their impact on climate change. Wildfires cause temporary large increases in outdoor airborne particles, such as particulate matter 2.5 (PM 2.5) and particulate matter 10(PM 10). Large wildfires can increase air pollution over thousands of square kilometers (Berkley University, 2021). The researcher will be conducting this research by analyzing PM found in the atmosphere, as well as analyzing air quality reports in the Southwestern portion of the U.S. The focus of this study is to examine the air emissions after wildfires have occurred in Yosemite National Park; and the research analysis will help provide the scientific community with additional data to understand the severity of wildfires and their impacts on climate change.

Project Overview and Hypothesis

This study examines the air quality from prior wildfires in Yosemite National Park. This research effort will help provide additional data for the scientific community and local, state, and federal agencies to better mitigate harmful levels of PM in the atmosphere caused by forest fires. The researcher hypothesizes that elevated PM levels in the Yosemite National Park region correlate with wildfires that are caused by natural sources such as lightning strikes and droughts.

Introduction

The researcher will seek to prove the linkage between wildfires and PM. According to National Geographic "A wildfire is an uncontrolled fire that burns the wildland vegetation, often in rural areas. Wildfires can burn in forests, grasslands, savannas, and other ecosystems, and

have been doing so for hundreds of millions of years. They are not limited to a particular continent or environment (National Geographic Society, 2021)."

There are many ways that can produce a wildfire including: human induced fires; droughts; dry weather; and lightning. Wildfires can pose an enormous risk to humans, from the air quality in the specific region, to geological hazards, and well as PM from the fire itself. These wildfires leave lasting implications on our health, as well as the world we live in. The wildfires are considered dangerous and destructive because of the many dangers they impose on life. For example, wildfires inject aerosols and soot into the atmosphere, causing major issues with cooling and heating. Thus, wildfires and climate change ultimately work hand in hand together. According to the Union of Concerned Scientists (2011), "there is a strong connection between climate change and wildfires. Wildfire activity in the U.S. is changing dangerously, particularly in the west, as conditions become hotter and drier due to climate change" (Union of Concerned Scientists, 2011).

Wildfires pose a major risk to the environment, and therefore the researcher has chosen to investigate this topic. This topic is scientifically significant because forest can produce respiratory illness due to PM in the atmosphere. Thus, the goal of this research project is to examine the impacts of PM caused by forest fires to identify potential mitigation efforts in the Yosemite National Park region. It is time to research the claims, as well as find resources for the future protection of our environment.

Wildfires have become an extreme concern for states such as California. These concerns include altering of terrains, elimination of vegetation that can absorb rainfall, severe flooding, and increase of mudflows (Mono County and the Town of Mammoth Lakes Hazard and

Mitigation Plan, 2021). The world has recently seen an increase in wildfires that tear through communities and destroy them. Many do not realize the impacts of wildfires, and their significant effects on climate change. The purpose of this research will focus on comparing air quality throughout the study period of (2001-2019) from wildfires and seeing the effects it is causing on climate change. The researcher will be analyzing the PM from the 4 counties that make up Yosemite National Park.

Literature Review

The impact of wildfire on climate change has been identified as a frequent problem in the Southwestern U.S., including California, New Mexico, and Arizona. Yosemite National Park is the targeted area of this research. This literature review will focus on the attributing factors that wildfires pose on climate change. To understand these effects better, diving deeper into air quality is important for this research. Air pollution remains as the world's greatest environmental health risk (Roberts, Wooster 2021). In addition to researching air quality, there will also be data analysis conducted on particulate matter found within the atmosphere. This study will look at the last 20 years of air quality in Yosemite National Park. This research will examine Air Quality Index (AQI) reports from the Environmental Protection Agency (EPA), and AIRNow.gov. The researcher anticipates the air quality reports will show an increase in PM, due to the excessive number of wildfires that are happening over the study period.

To do this, air quality will be monitored over a 20-year span in the Yosemite National Park area. AQI reports will be a necessity in this research. Comparing the last 20- years of reports will show the significance of wildfires and their impacts on climate change. These reports will be pulled from airnow.gov. AQI reports show a variety of information which is classified into three different categories. These categories consist of ozone pollutants, PM 2.5, as well as

PM 10. When interpreting these reports, the higher the AQI value, the higher the value of PM that are found in the air. AQI values are represented as anything less than fifty is good air quality; anything presented as over 300 represents hazardous air quality (AirNow, 2021). These numbers are important for this study for analysis purposes. The reasons these values are important are due to the increased risk that air pollution causes on people in the area. The risks pose health concerns on the community and are monitored daily for the public to see. Some of the risks associated with air pollution is heart disease, lung cancer, chronic respiratory disease, as well as many others (EPA, 2021). These risks are a threat to areas with increased air pollution produced by wildfires.

The emissions from these wildfires travel over large distances posing threats on air quality in the surrounding communities. Fine PM 2.5 is one of the major pollutants emitted by wildfires (EPA, 2021). PM can be defined as tiny particles in the air that poses a major threat to human health (Requia, et.al, 2019). Emissions of pollutants into the air can result in changes to the climate (EPA, 2021). An example of this includes warming and cooling of the of the climate from PM. The major issue with PM is that it has a heating effect to the climate, which contributes to the warming of the earth (which includes the atmosphere, land, as well as the ocean). "Emissions of pollutants into the air can result in changes to the climate. Ozone in the atmosphere warms the climate, while different components of PM can have either warming or cooling effects on the climate. For example, black carbon, a particulate pollutant from combustion, contributes to the warming of the Earth, while particulate sulfates cool the earth's atmosphere (EPA, 2021)." This is a major breakthrough to showing the impacts of wildfires to climate change.

With the increase number and burning capacity of wildfires, it is immediate that significant fire management needs to happen. These fires are significantly affecting the air quality of the Southwestern U.S (Yosemite National Park area). There are many fire management policies already in place, such as County Mitigation Plans, forest management, and adaptation strategies (EPA, 2021). These wildfires are happening at an increasing rate compared to years past.

Methodology

The purpose of this section is to introduce quantitative research on the impacts of wildfires on climate change. The hypothesis for this research conducted is as follows: Due to the increase in wildfires in Yosemite National Park, the researcher hypothesizes that the air quality reports will show an increased percentage of PM over the course of the last 20- years. The recent wildfires in the area will suggest the region is extremely sensitive to climate change in the years past. The scope of this study is to examine the air quality and emissions in the Yosemite National Park region, where wildfires have been active for many years.

The Environmental Protection Agency (EPA) manages the Air Quality Index (AQI), which is an index for reporting air quality data. These reports are used to communicate to the public how polluted the air is, or how polluted it will be in the forecasted weather. This is important because when the AQI results of PM rise, this leads to public health risks. The EPA is government ran, which is tasked with environmental protection matters such as air quality. “EPA developed the AQI, to make information available about the health effects of the five most common air pollutants, and how to avoid those” (AIRNow, 2021). The five major air pollutants regulated by the EPA are ground-level ozone, particulate pollution, carbon dioxide, sulfur dioxide, and nitrogen dioxide. When analyzing AQI reports, the reports are categorized in

different ways. The AQI reports are categorized by color with green being considered good and Maroon being hazardous.

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

Figure 1 Air Quality Index (AQI) Categories

(Image above retrieved from AIRNow.gov accessed on February 2021.)

The researcher reviewed various AQI reports for the project study period of the last 20- years. The AQI is used to determine hazardous air conditions related to PM in the atmosphere. The sources chosen for this research come from the EPA AIRNow government ran website. This program collects real-time ground-level ozone data that show many pollutants in the area. The EPA's data comes from over 1400 air quality monitors across the U.S. and Canada (EPA, 2021). The AQI was designed to monitor air quality conditions produced by the EPA. There are many stations located in California that monitor the air quality. According to California Air Resources Board, there are 250 monitoring stations. When deciding which stations to use for the scope of this project, the available resources came from government sites such as the EPA, AIRNow, and the U.S. National Park Service for Yosemite National Park. The EPA's recommendation for accessing accurate information is to use AIRNow's website.

The researcher selected specific sites for this project because air quality information was available in archived databases. They were also chosen as they seemed the most authentic.

The EPA allowed the researcher to examine back 20-years, and also gave detailed reports each year. To examine this data, the researcher had to focus on the four counties that Yosemite National Park covered. The counties that are covered in this research are Tuolumne, Madera, Mono, and Mariposa. AQI reports were extracted and analyzed over the course of study period of 2001-2019. Upon analyzing the data presented, the items processed were as follows:

- Days with AQI- this is the number of days throughout the year that the measurements from a monitoring site were reported to Air Quality Service (AQS) database.

- Days Good- Good days refer to the number of days in which the AQI report values were between 0 through 50 and are considered generally safe air quality for most individuals.
- Days Moderate- Day's moderate refers to the number of days in which the AQI report values were between 51 through 100 are considered moderately safe air quality for most individuals.
- Days Unhealthy for Sensitive Groups- Refers to the number of days in which the AQI report values were between 101 through 150 are considered as unhealthy air quality conditions for sensitive groups such as those individuals with respiratory illnesses, children, and elderly people.
- Days Unhealthy- Days unhealthy refers to the number of days in which the AQI report values were between 151- through 200 are considered as unhealthy for all populations of people.
- Days Very Unhealthy- Days very unhealthy refer to the number of days in which the AQI report values had a value of 201 or higher. This is considered unhealthy or hazardous as for all populations of people.

- Days PM 2.5- A daily value is calculated for this pollutant. PM 2.5 is tiny inhalable particles in the air that are a major concern to the public's health. PM 2.5 can consist of many sizes and shapes and can be made up of 100's of different compounds. PM 2.5 can range in sizes but is 2.5 micrometers in diameter and smaller. A good comparison for this to show how small this is to compare a hair strand. Hair strands are around 70 micrometers in diameter, making them thirty times larger than the largest fine particle. These particles are emitted from things such as smokestacks or fires.
- Days PM 10- A daily value is calculated for this pollutant. PM 10 is also a small inhalable particle that is generally 10 micrometers and smaller. These particles are also emitted from things such as smokestacks and fires.

This data will be analyzed while wildfires were present, and when wildfires were not present. Comparing each aspect will result insufficient evidence to show the connection between climate change and wildfires. The data will also show whether there is an increase or decrease in PM, as wildfires have been happening at an increasing rate. Comparing this data will lead to results to further confirm the researcher's hypothesis, as well as present accurate data over study period of 2001-2019. The researcher will retrieve and record this data accordingly based on the above categories.

While analyzing this data there should be a peak in the numbers when a wildfire is present. The researcher analyzed fire data from the following fires: 2013 Rim Fire, 2004 Big Meadow Fire, 2005 Quartz Mountain Fire, and 2011 Buckeye Fire (County Mitigation Plans, 2021). When analyzing these fires, the sources used were records from the counties Hazardous Mitigation Plans. This county document was chosen because the authenticity of fire records listed here. Using actual mitigation plans from the county helps with authenticity, as well as

accurate data coming directly from the County itself. The data that will be observed in these reports are as follow: years of fires, and an analysis of air quality during the times of these fires.

This research conducted will pose limitations on the amount of covered material under said research topic. This project scope limited to the dates associated with active wildfires from the study period of 2001 to 2019.By using the above steps the researcher will provide data findings in the next section.

Findings

In this research project conducted, raw data was analyzed from AQI reports over a 20-year study period. The researcher's data analyzed came directly from the EPA and was presented in Figures 1 - 5. This data was extracted, and a total of five graphs were produced. The researcher focused on the four major counties surrounding Yosemite National Park which include: (Mono County, Madera County, Mariposa County, and Tuolumne County). These counties were analyzed based on PM from the years 2001-2019. PM 2.5 and PM 10 were analyzed, and the data was plotted into the figures included in this section. In Figures 1 - 5, a baseline was added to show the EPA guideline for PM. The baseline is set to 12.0 micrograms per cubic meter, and is denoted by a black dotted line. These guidelines are set to reduce air-pollution related deaths and are applied to state and local governments. National Ambient Air Quality Standards (NAAQS) specify the maximum amount of PM to be present. These regulations are in place because it protects human health as well as the environment (EPA, 2021). These regulations are important due to the increased risks of respiratory distress. The airborne particles from PM can become lodged in the lungs, and bloodstream and cause respiratory distress and cardiac issues.

Figure 1 shows the trends of PM in Mono County. While wildfires were actively present during these years, Mono County experienced a significant increase over the years of PM 10 in the atmosphere. These numbers started dropping in 2017, while this drop occurred PM 2.5 was on a significant increase. Throughout the study period, the data trends indicated that PM increased. In 2002, Mono county experienced a severe wildfire season in which over seven million acres were burned. This correlates with the increase in Figure 1. Around 2003, Mono County continued an upward trend due to the wildfires present in the area. Some of the wildfires that happened between 2003-2017 would include Slinkard Fire 2017, Owens River 2016, Indian Fire 2012, Buckeye Fire 2011 (Mono County and the Town of Mammoth Lakes Multi-Jurisdictional Hazard Mitigation Plan*,* 2021*)*. All of the fires mentioned were all present during the peaks of Figure 1. PM was present during active wildfires throughout the research period.

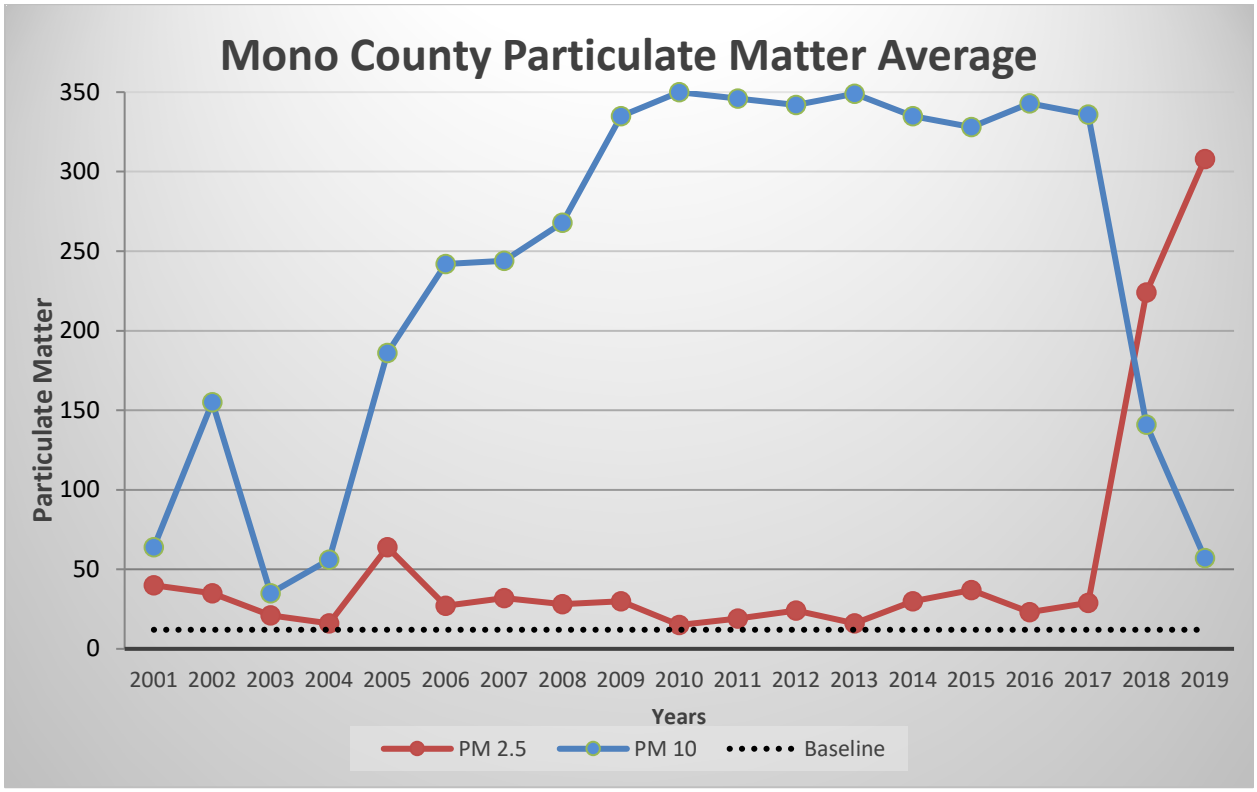

Figure 1

Figure 2 reflects Madera County PM matter averages. In Figure 2, Madera County had the opposite results happen. During the timeframe of active wildfires, Madera County experienced a high peak of PM 2.5 in 2011 and the trend started decreasing over the next couple of years. The data indicated that the PM was increasing over the study period. The increase in PM during the study period in Madera County correlates to the following wildfires including: Quartz Mountain Fire 2005; Aspen Fire 2013; French Fire 2014; and Junction and Courtney Fire in 2014 (Madera County Local Hazard Mitigation Plan Update, 2021*)*. Wildfires were actively present during high cases of PM.

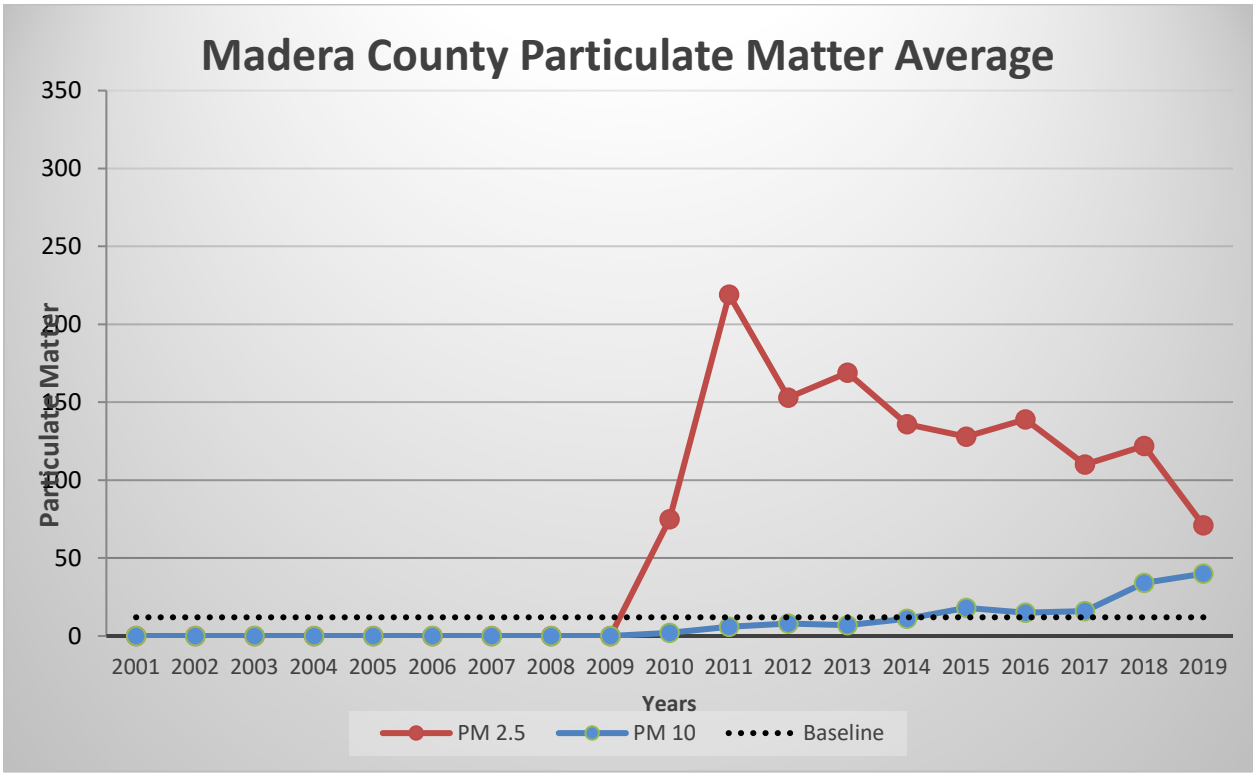

Figure 2

Figure 3 illustrates the PM concentrations in Mariposa County. During active wildfires, Mariposa County experienced high results in in PM 2.5, while PM 10 was present throughout these years; it remained at a steady level throughout the timeframe researched. PM 2.5 increased, as well as decreased in the years researched while PM 10 did not. Mariposa County has seen its most destructive fires from 2001-2018. Mariposa County experienced its first PM peak in 2001. During this time, the county experienced the Creek Fire which burned over 11,000 acres. In 2004 when Mariposa County takes an upward shift, this county experiences two wildfires. The Old Highway Fire burned approximately 1347 acres. The Meadow Fire of 2004 burned approximately 5060 acres (Mariposa County Local Hazard Mitigation Plan, 2021*)*. In 2005 Mariposa trend line declines in Figure 3. 2015 is the next spike in the Figures plotted data. The researcher also found many fires present such as Ferguson Fire 2018, Railroad Fire 2017, as well as Briceburg Fire 2019. Wildfires were present when peaks in PM were observed in Figure 3.

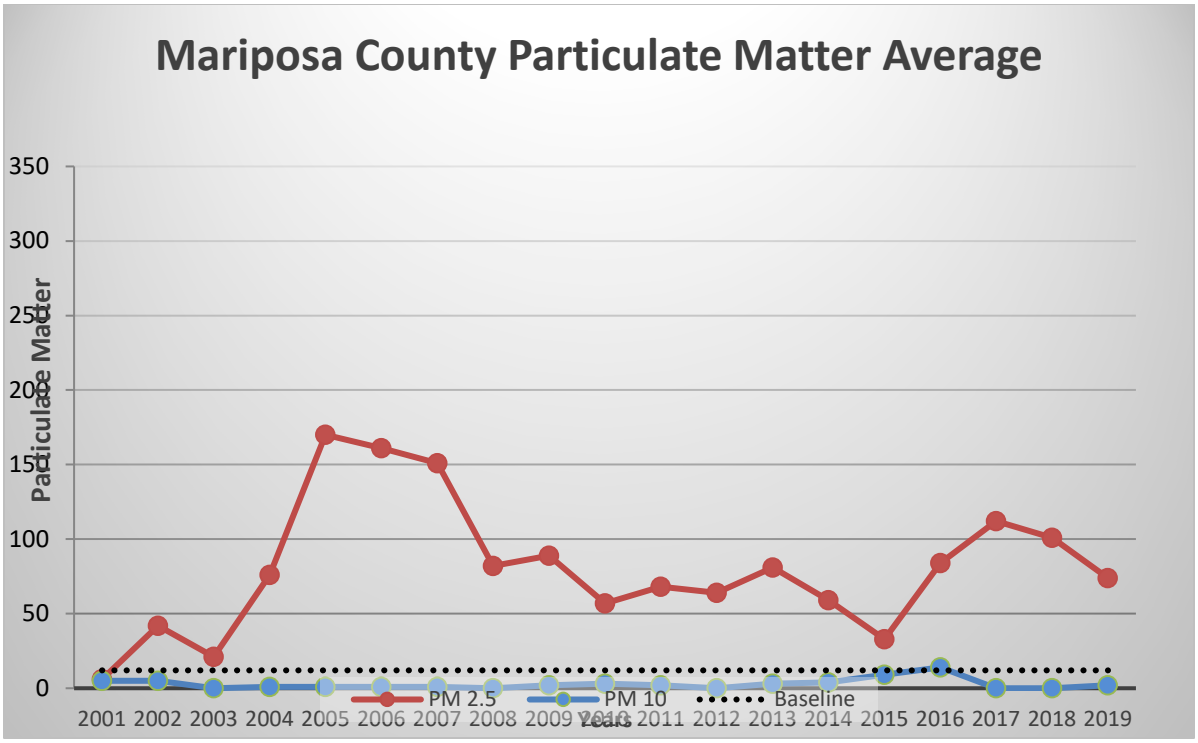

Figure 3

Figure 4 represents Tuolumne County throughout the study period. Tuolumne County had a significant peak in 2006 in PM 2.5. During 2006 Tuolumne County faced many active wildfires, resulting in a significant peak in PM 2.5 within the atmosphere. Tuolumne County experienced a major wildfire in 2006 named Pedro Fire, which burned over 1997 acres. One of the most tragic wildfires this county faced was Rim Fire, which burned over 257, 314 acres of land (Tuolumne County Multi-Jurisdictional Hazard Mitigation Plan, 2021).

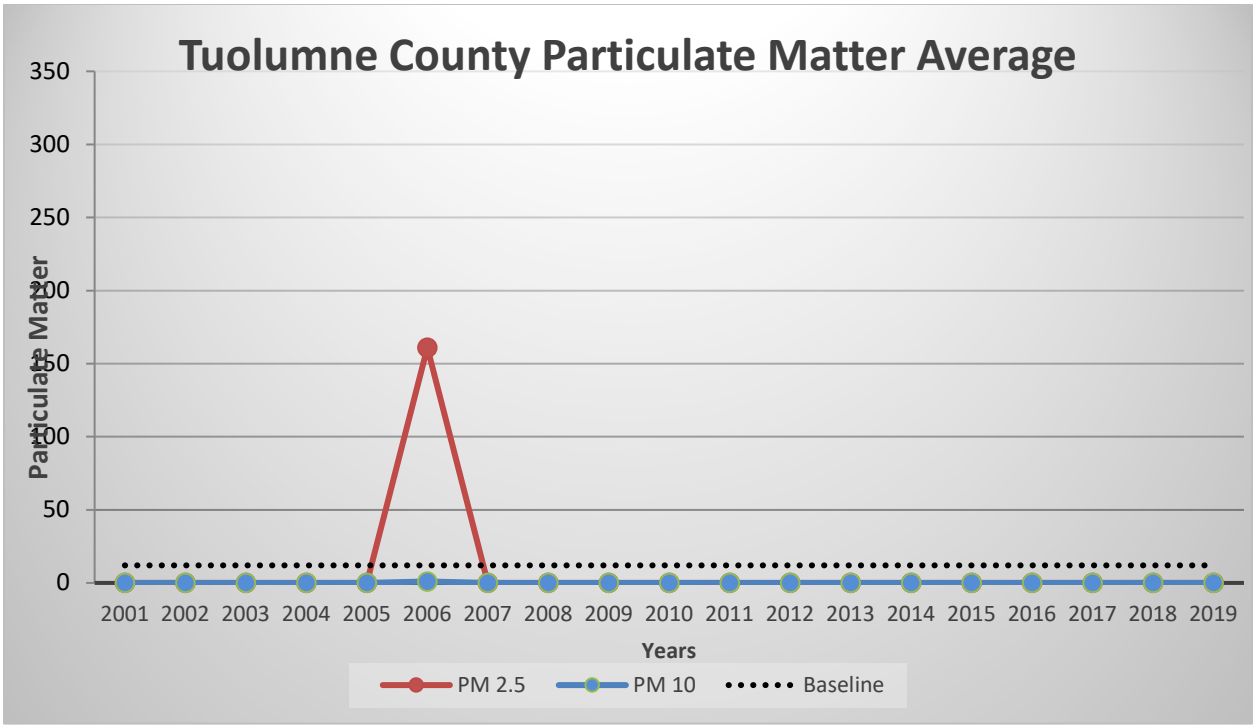

Figure 4

Figure 5 presents data averages over the researched time frame for all four counties. These counties were analyzed based on Days AQI reported, Days Moderate, Days unhealthy for sensitive groups, Days Unhealthy, Days Very Unhealthy, and Hazardous. These charts indicate the exceeded limit for a Good day according to AQI ranges. With the significant number of wildfires in the counties researched, Figure 5 shows the correlating information. With PM rising, these categories rose over the research time period.

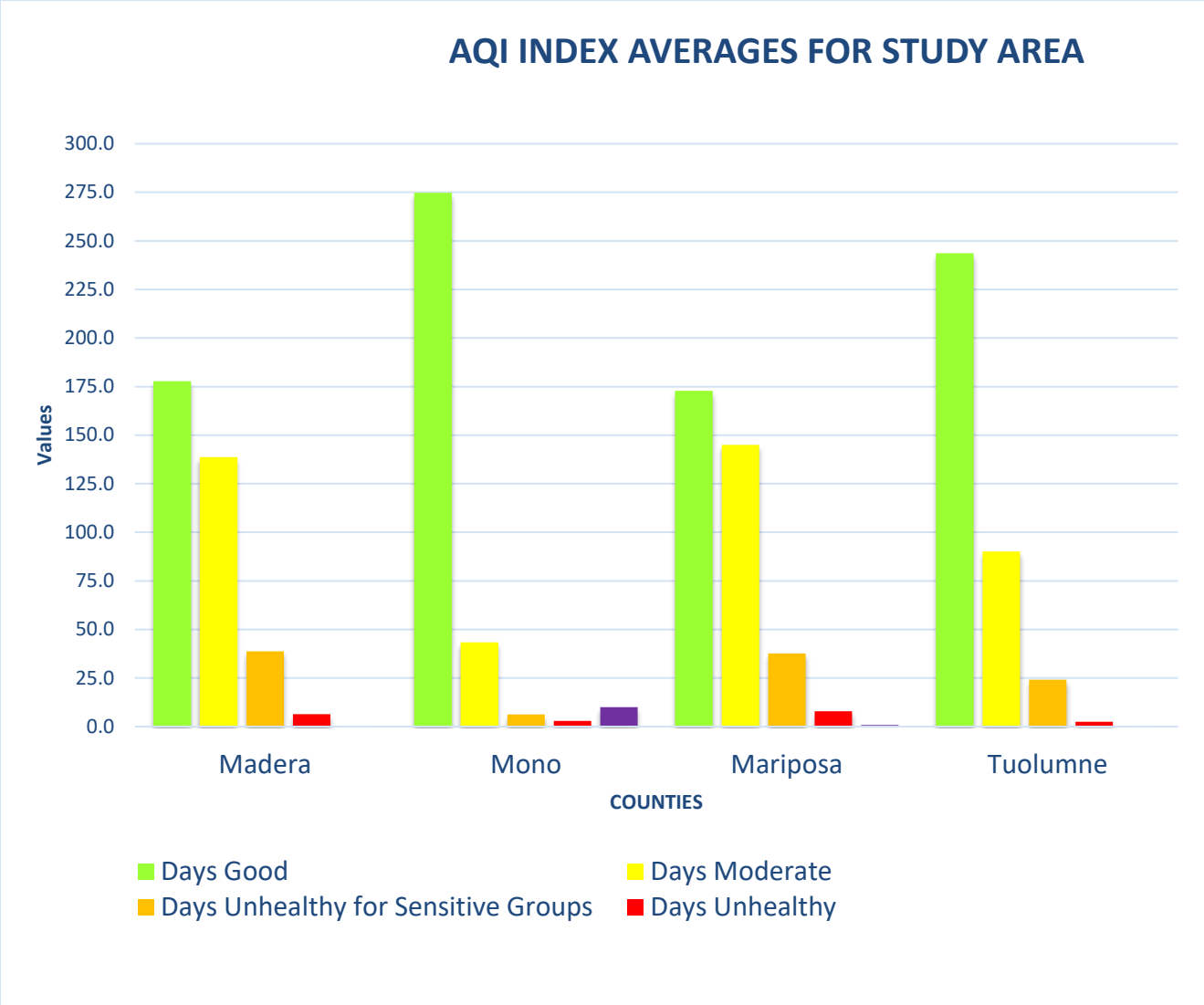

Figure 5

Conclusions

The purpose of this study was to analyze data from the AQI to justify the impacts wildfires have on climate change. The researcher's project hypothesis was proven to be accurate. For example, each county's data was analyzed and over the research period, the researcher found that PM was present in all four counties. PM was above baseline level for significant years in

each county. The researcher was able to prove their initial hypothesis was accurate by correlating wildfires to the PM peaks illustrated in Figures 1-5. The researcher reviewed EPA standards for PM and found that many of the years exceeded the baseline level. This indicates a direct correlation between high percentages of PM and wildfires.

Recommendations for Future Research

After performing data analysis, the researcher identified multiple recommendations for future studies related to air quality. Some of those recommendations include soil samples from recently burned areas, to compare pollutants found in the soil. Performing soil studies could benefit the overall project and give an analysis on pollutants found in soil after wildfires are present. Another recommendation for expanding the project is looking at a bigger study area. A site closer to Los Angeles may show a different data trend. Due to the scope of the project and limited time, the researcher recommends pursuing a longer study period that exceeds 20 years to observe longer air quality trends. One unexpected finding discovered was National Geographic (2021) has cited that most wildfires are started by humans. The researcher knew this was a problem, however, did not realize this was the biggest attribution to wildfires. Analyzing how human induced fires contribute to the problem is a recommendation for the project. The final recommendation for future research includes analyzing additional parameters such as sulfur dioxide, volatile organic compounds, and ozone concentrations to see if wildfires cause increase in the constituents. Seeing the harm from all pollutants would benefit this project.

This additional research stated above would benefit the scientific community. It would show a more comprehensive view of how wildfires affect human health. These recommendations

listed above would help with improved mitigation planning for each of the counties researched. The analysis of human induced fires would help counties with improved mitigation planning as well. The researcher also believes that studying the other major pollutants regulated by the EPA would also benefit human health concerns as well.

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