Final Report: The Impact of Wildfires on Boulder County's Air Quality and Health Outcomes

Radhika Sethi

rsethi3@uw.edu

---

1. Introduction

The interaction between environmental hazards and public health has been a topic of significant research in recent years. Among these hazards, wildfire smoke stands out as a major contributor to air quality deterioration and a potential driver of respiratory and other health-related consequences. Boulder, Colorado, renowned for its natural landscapes and outdoor lifestyle, has increasingly experienced the adverse effects of wildfire smoke, especially as the frequency and intensity of wildfires grow. This report investigates the complex relationship between wildfire smoke and public health outcomes in Boulder, focusing on mortality trends and their potential links to smoke exposure.

Motivation and Significance

The past few decades have seen a rise in wildfire occurrences, largely attributed to climate change and extended drought periods. Colorado, including Boulder, has faced significant wildfire events, such as the Cameron Peak Fire in 2020 and the Marshall Fire in 2021. These fires not only destroy ecosystems and infrastructure but also generate vast amounts of fine particulate matter (PM2.5), which infiltrates surrounding communities and impacts air quality. Prolonged exposure to such pollutants has been associated with severe health risks, including chronic respiratory diseases, cardiovascular conditions, and increased mortality.

Boulder presents an ideal setting for such a study due to its proximity to fire-prone regions, its documented history of wildfire smoke events, and the availability of detailed population and health data. Understanding the impact of wildfire smoke on mortality within Boulder can inform policymakers, healthcare providers, and residents, enabling them to develop effective mitigation strategies. This study aligns with broader efforts to prioritize human-centered approaches to disaster management and public health.

Research Objectives

This project aims to answer the following critical questions:

1. How does wildfire smoke exposure correlate with mortality trends in Boulder?
2. Which respiratory-related causes of death are most impacted during high-smoke years?
3. How can the findings guide actionable strategies to reduce health risks associated with wildfire smoke?

To address these questions, the analysis leverages historical data on wildfire smoke exposure, population demographics, and mortality records from reputable sources, including the United States Geological Survey (USGS), Colorado state air quality data, and the Centers for Disease Control and Prevention (CDC) Wonder API.

Data Sources and Scope

The dataset on wildfire smoke impact was derived from the USGS and AQS API, ensuring coverage of both the intensity and duration of smoke events. For health outcomes, mortality data spanning 1999 to 2020 was accessed through the CDC Wonder API. These datasets were meticulously cleaned and aligned to facilitate a robust analysis of trends over time.

The focus on respiratory-related mortality stems from the well-documented link between wildfire smoke and respiratory health. Specifically, three categories of causes of death were prioritized:

1. Chronic lower respiratory diseases (ICD-10: J40-J47),
2. Influenza and pneumonia (ICD-10: J09-J18), and
3. Other respiratory system diseases (ICD-10: J00-J06, J30-J39, J67, J70-J98).

These categories were selected due to their direct relevance to the inhalation of particulate matter and other wildfire smoke pollutants.

Structure of the Report

This report is organized as follows:

- **Background and Related Work**: A review of previous studies on wildfire smoke and public health, highlighting gaps addressed by this analysis.
- **Methodology**: Detailed steps taken to clean, merge, and analyze the data, including ethical considerations.
- **Findings**: Key trends and correlations observed between smoke exposure and mortality rates, supported by visualizations.
- **Discussion and Implications**: Interpretation of findings, with recommendations for Boulder's policymakers and residents.
- **Limitations**: Acknowledgment of data and methodological constraints that could influence results.

- **Conclusion**: Summary of insights and their significance for human-centered data science.

By comprehensively analyzing the interplay between wildfire smoke and mortality trends, this report aspires to contribute valuable insights to the fields of public health and environmental science while serving the immediate needs of Boulder's residents.

---

2. Background/Related Work

Understanding the impacts of wildfire smoke on public health is a critical area of research, especially as climate change continues to exacerbate the frequency, size, and intensity of wildfires. Boulder, Colorado, with its proximity to fire-prone regions and growing urban population, provides a unique setting to study these interactions. This section explores the prior work in wildfire-related studies, outlines the datasets utilized in this analysis, and highlights the gaps that this study aims to address.

Prior Research on Wildfire Impacts

Wildfire smoke, which contains harmful pollutants such as fine particulate matter (PM2.5), carbon monoxide, and volatile organic compounds (VOCs), has been extensively studied for its health impacts. According to a study by Reid et al. (2016), exposure to wildfire smoke is associated with a range of respiratory conditions, including asthma, chronic obstructive pulmonary disease (COPD), and pneumonia. Long-term exposure may also contribute to cardiovascular diseases and increased all-cause mortality, particularly among vulnerable populations such as children, the elderly, and individuals with pre-existing health conditions.

Several studies have highlighted the correlation between smoke intensity and health outcomes. Liu et al. (2017) quantified the relationship between PM2.5 levels during wildfire events and hospitalizations for respiratory diseases. Similarly, Gan et al. (2020) investigated mortality trends during wildfire seasons in California, finding a statistically significant increase in deaths due to respiratory and cardiovascular causes. These findings provide a foundation for examining similar trends in Boulder.

Despite this growing body of research, most studies focus on large states like California or regions with extensive data availability. Studies specific to Boulder are limited, leaving gaps in understanding how wildfire smoke affects smaller, geographically unique urban centers.

Gap Addressed by This Study

Despite significant advances in understanding wildfire impacts, gaps remain in the application of these findings to smaller urban centers like Boulder. Most studies are

conducted in states with larger populations and wildfire activity, such as California or Washington, making it difficult to generalize their conclusions to Boulder. Additionally, the specific health impacts of wildfire smoke on respiratory-related mortality in Boulder have not been thoroughly explored.

This study seeks to bridge these gaps by:

1. **Localized Focus**: Narrowing the analysis to Boulder ensures that findings are directly applicable to its residents.
2. **Integration of Smoke Impact and Mortality Data**: By combining wildfire smoke exposure data with respiratory mortality rates, this study creates a unique dataset tailored to Boulder.
3. **Actionable Insights**: The findings aim to inform local policymakers and healthcare providers, enabling targeted interventions to mitigate health risks.

---

3. Data and Methodology

This section describes the data sources, the steps taken to clean and preprocess the data, and the methods used to calculate and merge the Smoke Impact and mortality data for Boulder. The methodology reflects a systematic approach to address the research questions while adhering to human-centered data science principles.

Data Sources

Three primary datasets were used to conduct this analysis: wildfire data from the United States Geological Survey (USGS), mortality data from the Centers for Disease Control and Prevention (CDC) Wonder API, and air quality data retrieved through the Environmental Protection Agency (EPA) Air Quality System (AQS) API. Together, these datasets provided the necessary information to examine the relationship between wildfire smoke exposure and respiratory-related mortality in Boulder, Colorado.

1. **USGS Wildfire Dataset**: The USGS wildfire dataset contains detailed records of wildland fires across the United States, including geographic coordinates, the year of occurrence, and the total burned acreage. This dataset was used to calculate an annual Smoke Impact metric for Boulder, focusing on the size and proximity of fires likely to contribute to smoke exposure in the city.

2. **CDC Wonder Mortality Dataset**: Mortality data from the CDC Wonder API offered granular details on deaths categorized by cause and location. Covering the years 1999 to 2020, this dataset provided the foundation for calculating annual mortality rates for respiratory-related causes of death. These causes were defined using ICD-10 codes and included chronic lower respiratory diseases, influenza and

pneumonia, and other respiratory system diseases.

3. **EPA AQS API Data**: The AQS API provides historical air quality data, including daily and annual metrics for pollutants such as PM2.5, which is a primary component of wildfire smoke. For this study, data from the AQS API was accessed for Boulder to validate the Smoke Impact calculations and provide a comparative measure of air quality. While not directly merged into the primary analysis, the AQS data added context to the observed trends in smoke exposure and mortality.

Data Cleaning and Preprocessing

The USGS wildfire data was filtered to include fires within a 650-mile radius of Boulder, ensuring a focus on those most likely to affect the city. Geodesic distance calculations identified relevant fires, while fire size (in acres burned) was extracted to calculate Smoke Impact. The dataset was then aggregated annually.

CDC Wonder data was filtered for deaths occurring in Boulder and narrowed to three respiratory-related causes. Mortality data was aggregated annually, with deaths summed and population values averaged to prepare for mortality rate calculations.

The EPA AQS API provided annual averages of PM2.5 levels for Boulder, serving as a supplementary dataset. Accessing the API required an authentication key, and data retrieval was tailored to Boulder's geographic coordinates. Missing or incomplete data from earlier years was noted as a limitation but did not affect the core analysis.

Smoke Impact Calculation

The Smoke Impact metric was developed to estimate the relative exposure of Boulder to wildfire smoke. This calculation considered both the size and proximity of each fire, as larger and closer fires are more likely to affect local air quality. The formula used was:

$$\textit{Smoke Impact} = (\textit{GIS Acres Burned} \times 15.625) / \textit{Distance from Boulder (miles)}$$

This formula ensured that the Smoke Impact values reflected the combined influence of fire size and proximity. The metric was aggregated annually to align with the mortality data. 15.65 is the scaling factor being used to standardize the smoke impact values and make them interpretable for analysis.

Mortality Rate Calculation

Annual mortality rates for Boulder were calculated as:

$$\textit{Mortality Rate} = \textit{Total Deaths} / \textit{Population}.$$

This standardized measure facilitated year-over-year comparisons and alignment with the Smoke Impact data. The focus on respiratory-related causes ensured that the analysis captured health outcomes most likely influenced by wildfire smoke exposure.

Merging Datasets

The Smoke Impact and mortality datasets were merged by aligning their `Year` columns. This allowed for a direct comparison of Smoke Impact with mortality trends. The EPA AQS data was used separately to validate Smoke Impact trends, as it provided independent air quality metrics.

Human-Centered Considerations

Ethical and human-centered principles guided the analysis:

1. **Privacy**: Mortality data from the CDC was aggregated to ensure individual privacy.
2. **Relevance to Residents**: The focus on Boulder ensures that findings directly benefit local stakeholders.
3. **Validation with External Data**: The inclusion of EPA AQS data adds credibility to the Smoke Impact metric, reinforcing its accuracy.
4. **Transparency and Reproducibility**: All methods, data sources, and calculations have been documented to enable replication and verification.

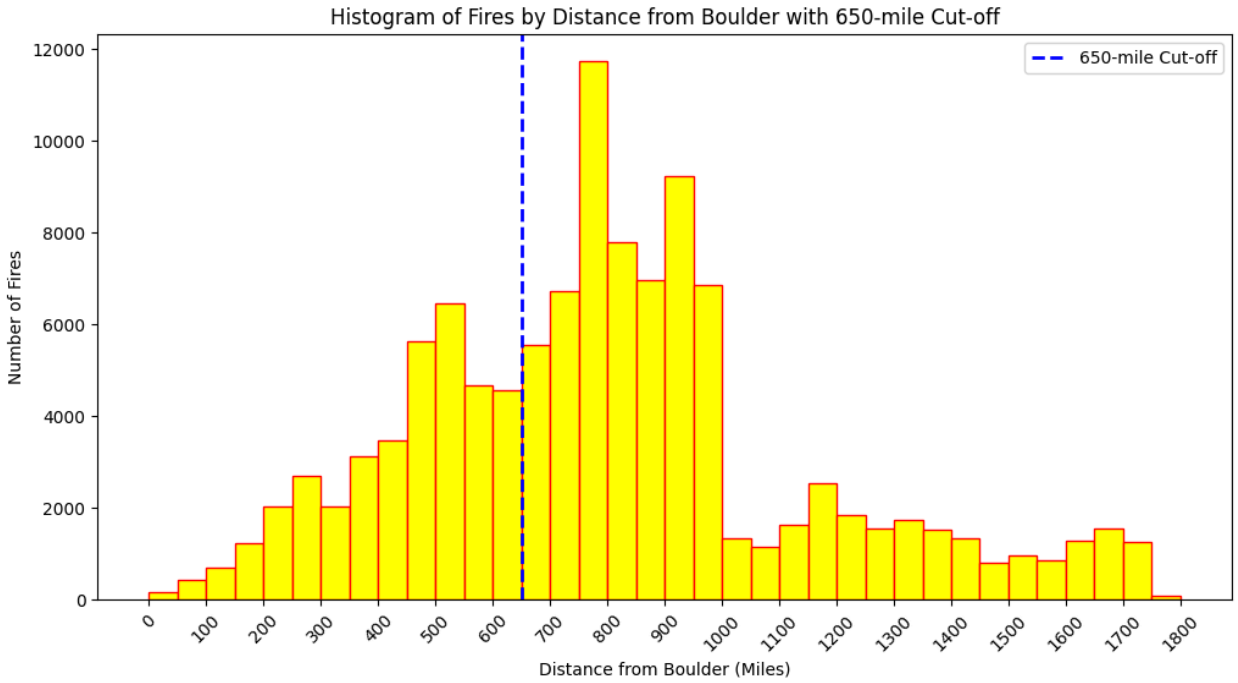
The integration of existing research, trusted datasets, and ethical considerations positions this study to make a meaningful contribution to understanding the impact of wildfire smoke on public health in Boulder. By addressing the specific needs of this community, it demonstrates the value of human-centered approaches in data science.

---

4. Findings

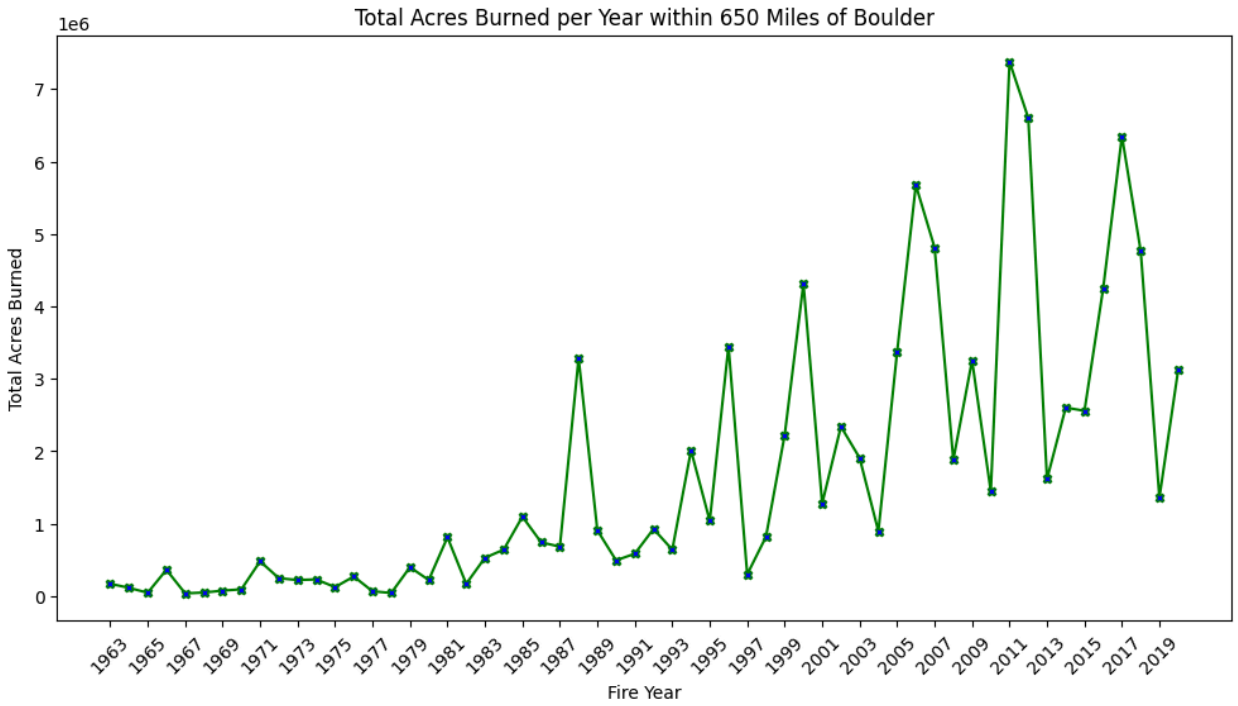
The analysis provided several insights into the wildfire smoke impacts on Boulder, along with its correlation to public health trends. Below, I summarize the findings based on the visualizations provided, integrating key observations for each.

1. Histogram of Fires by Distance from Boulder



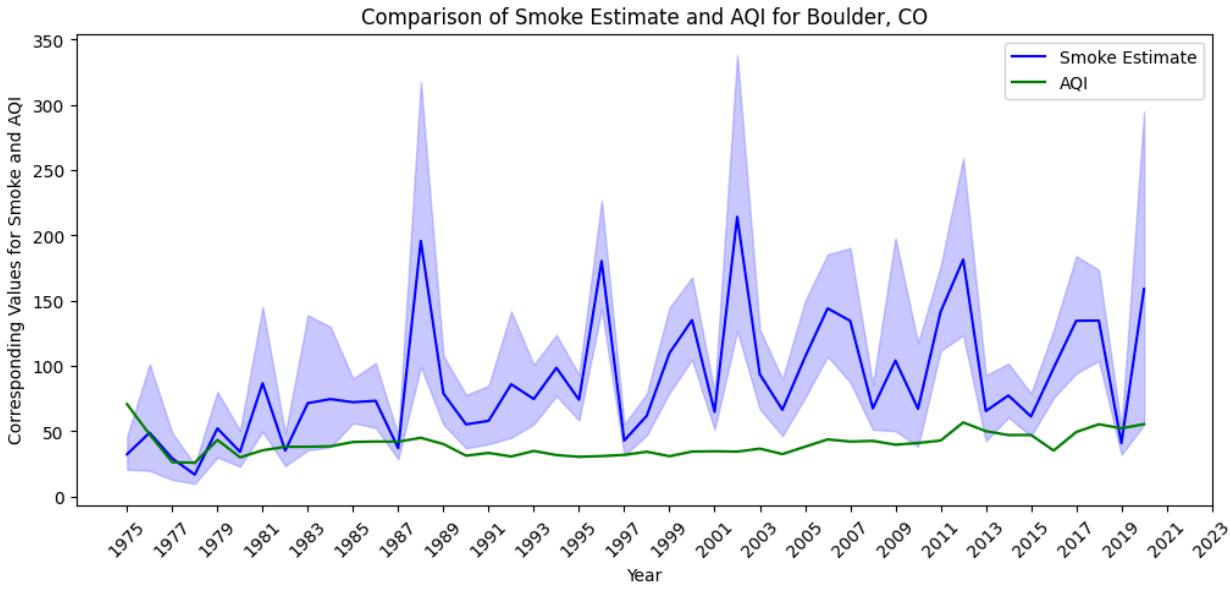
This histogram illustrates the distribution of wildfires by their distance from Boulder, with a clear indication of the 650-mile cut-off used in the study. The highest concentration of fires lies between 500 and 1,000 miles, suggesting that most wildfire smoke impacts on Boulder originate from fires within this range. This visualization validates the choice of the 650-mile threshold for modeling smoke impacts, as it captures a significant portion of the fire activity affecting Boulder.

2. Total Acres Burned per Year



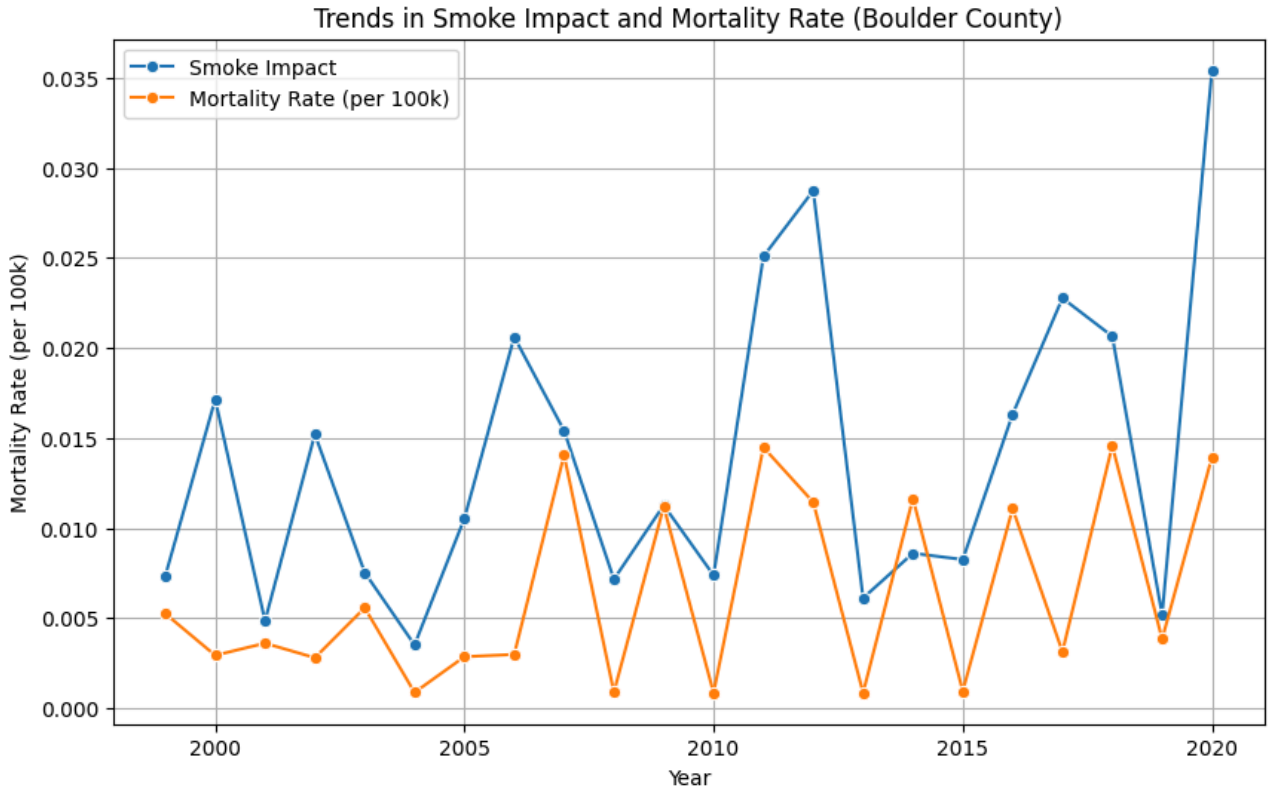
The time-series graph highlights the trends in acres burned annually within the 650-mile radius. The data reveals a steady increase in burned acreage over time, with significant peaks in the 2000s and 2010s, likely driven by intensified wildfire activity due to climate change and other factors. These trends align with observed increases in smoke impact and associated health risks, reinforcing the link between wildfire severity and its consequences for Boulder residents.

3. Comparison of Smoke Estimate and AQI



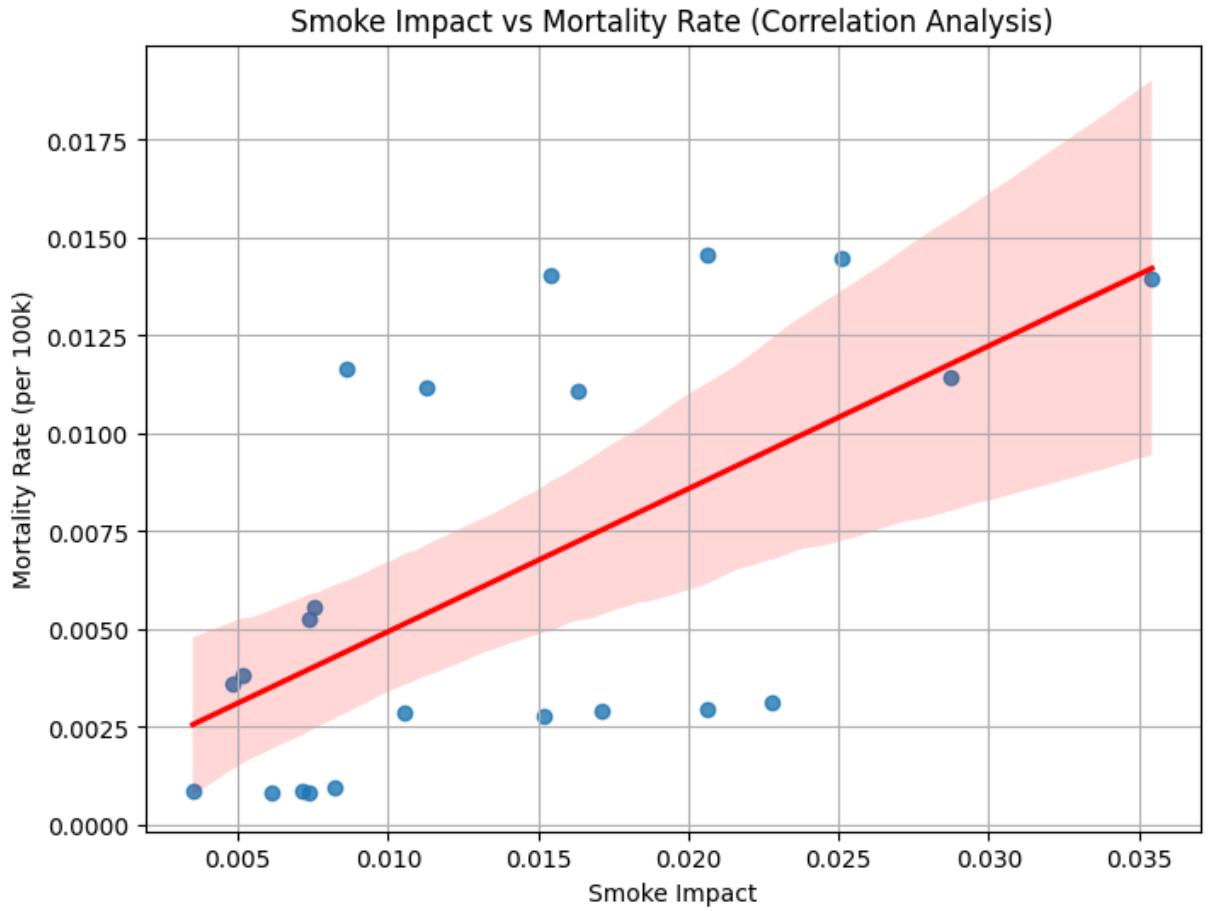
This visualization compares the modeled smoke estimates with observed AQI (Air Quality Index) data for Boulder. While the two metrics exhibit broadly similar trends, discrepancies in certain years highlight the limitations of relying solely on AQI to measure wildfire smoke impacts. For instance, AQI often fails to account for transient or localized smoke events that are captured in the modeled estimates. This reinforces the importance of integrating multiple metrics for a robust assessment of air quality.

4. Trends in Smoke Impact and Mortality Rates



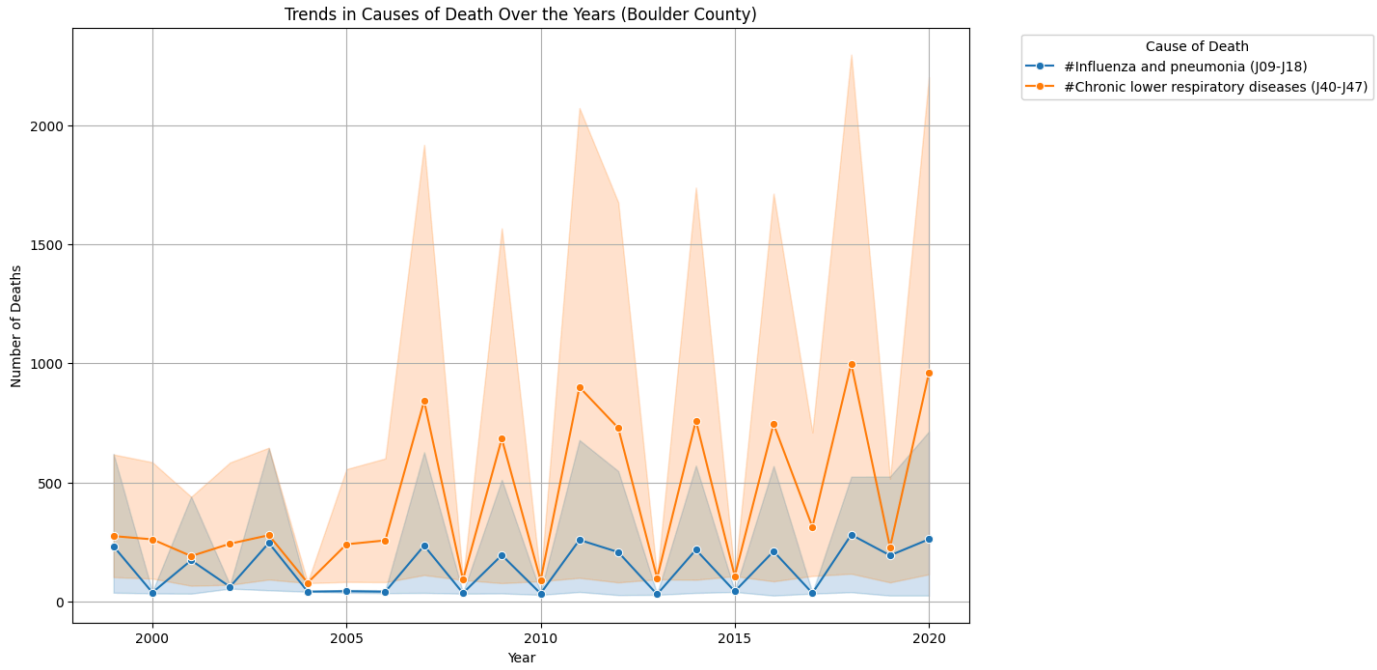
This visualization depicts the historical trends in wildfire smoke impact and corresponding mortality rates over time. While the smoke impact shows significant fluctuations across the years, peaking in recent decades, the mortality rate displays a comparatively smoother variation. However, there is a notable increase in mortality rates during years of high smoke impact, suggesting a potential correlation between smoke exposure and health outcomes. This correlation warrants deeper statistical investigation.

5. Correlation Between Smoke Impact and Mortality Rate



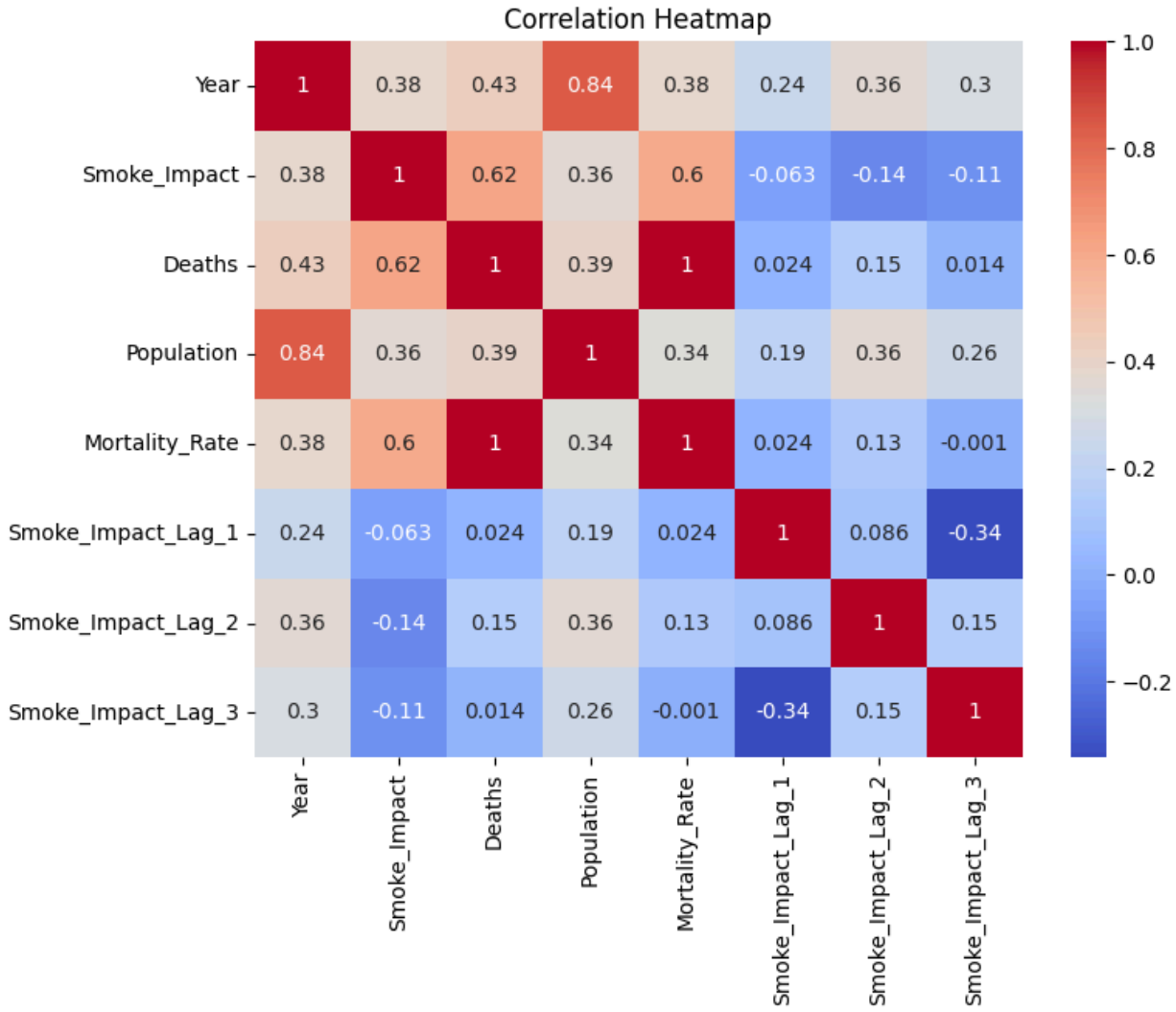
The scatter plot, complemented by a regression line, quantifies the correlation between smoke impact and mortality rates. With a Pearson correlation coefficient of 0.604 and a p-value below 0.01, the analysis indicates a moderately strong, statistically significant positive correlation. This suggests that increased wildfire smoke exposure is associated with higher mortality rates, emphasizing the importance of mitigation strategies during fire seasons.

6. Cause-Specific Trends in Respiratory Mortality



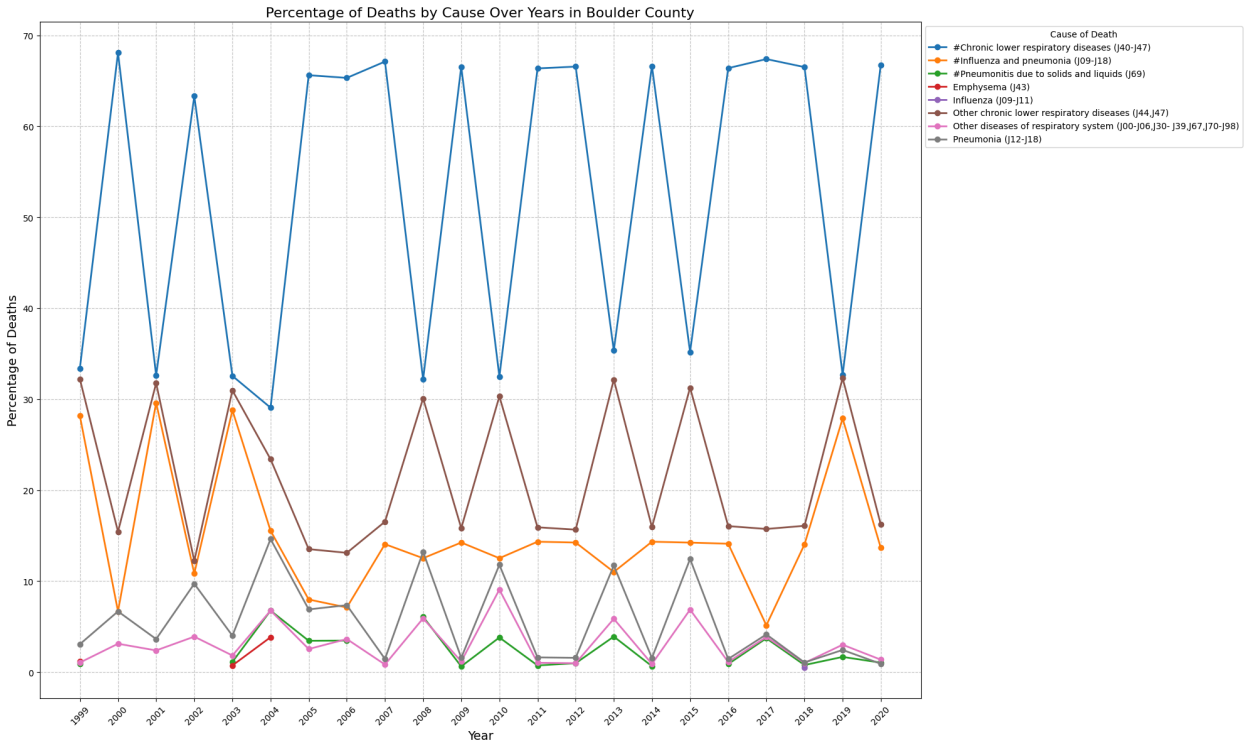
This figure explores trends in specific respiratory-related causes of death, such as chronic lower respiratory diseases and influenza. The data reveals that deaths due to chronic lower respiratory diseases exhibit substantial variability and align closely with years of heightened smoke impact. Influenza-related deaths show a similar, though less pronounced, pattern. This supports the hypothesis that wildfire smoke exacerbates existing respiratory conditions.

7. Correlation Heatmap



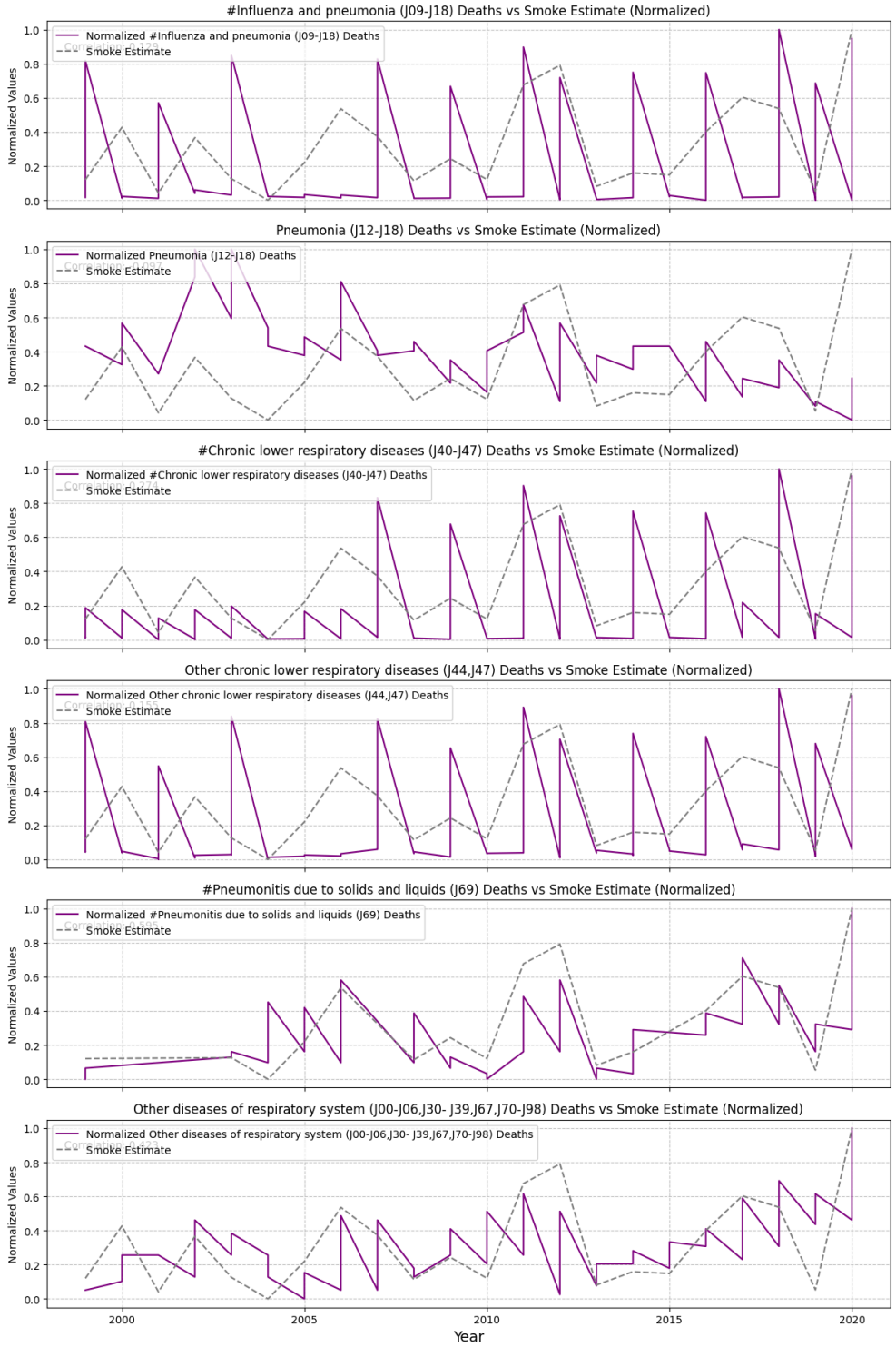
The heatmap provides a deeper statistical perspective by showing correlations across various metrics, including smoke impact, mortality rates, and lagged smoke impact. The findings highlight strong correlations between smoke impact and deaths (0.62), and a weaker correlation between lagged smoke impact and mortality rates. These results suggest that while the immediate impact of smoke is evident, its delayed effects on health may require further study.

8. Percentage of Deaths by Cause Over the Years



This visualization illustrates the proportion of deaths attributed to different respiratory conditions annually. Chronic lower respiratory diseases consistently dominate the dataset, constituting the majority of respiratory-related deaths. Years with elevated smoke impact correspond to an increased percentage of deaths due to respiratory conditions, further reinforcing the link between air quality and public health outcomes.

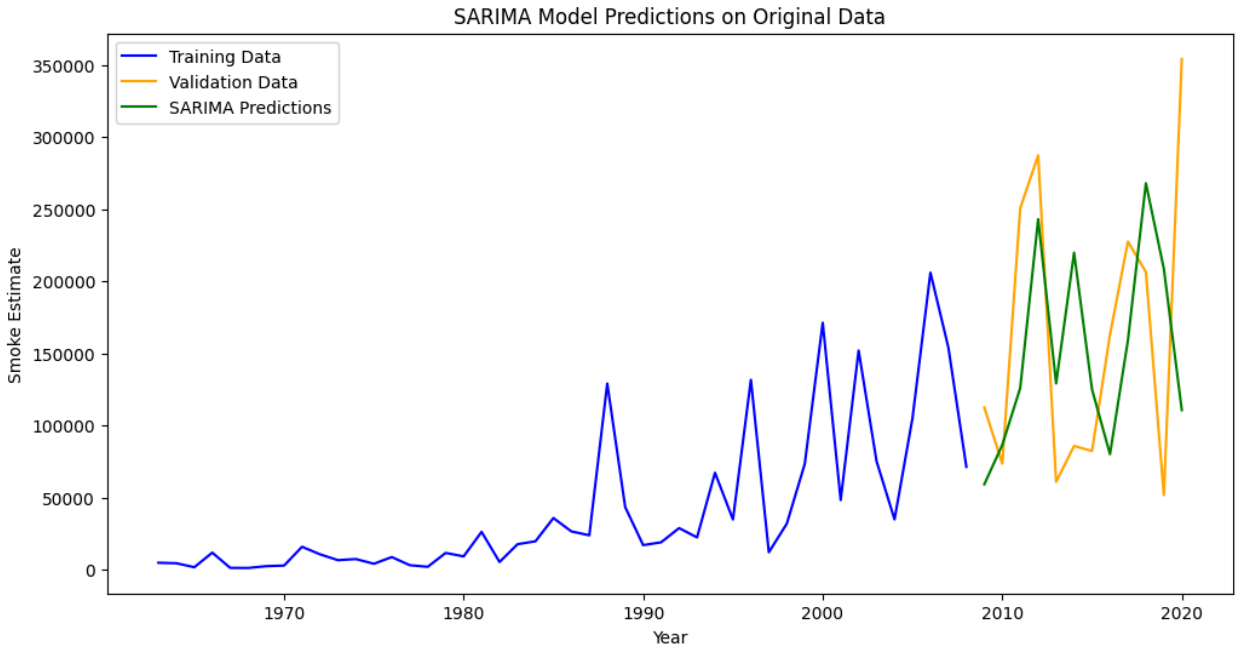
9. Normalized Trends in Smoke Impact and Cause-Specific Deaths

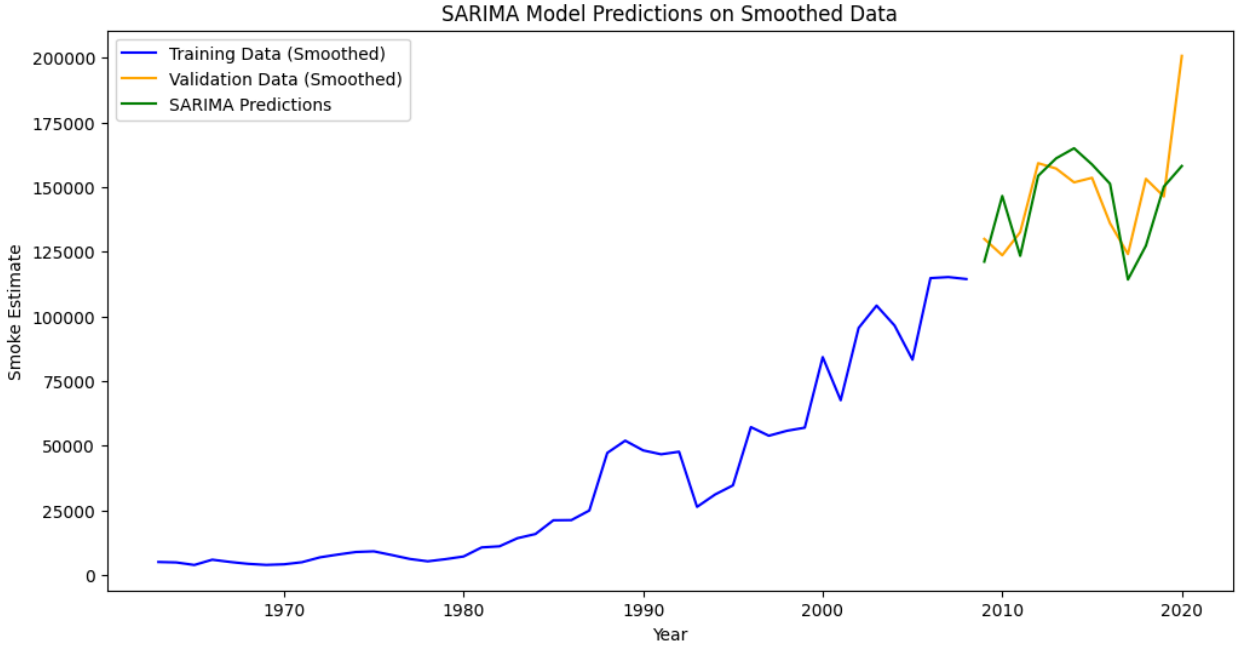


The normalized trends provide a comparative view of smoke impact and deaths caused by various respiratory conditions. Most causes exhibit similar trajectories, with peaks aligning

with years of intense wildfire activity. This normalization allows for a clearer comparison, emphasizing the widespread health implications of increased smoke exposure.

10. SARIMA Model Predictions (Original and Smoothed Data)

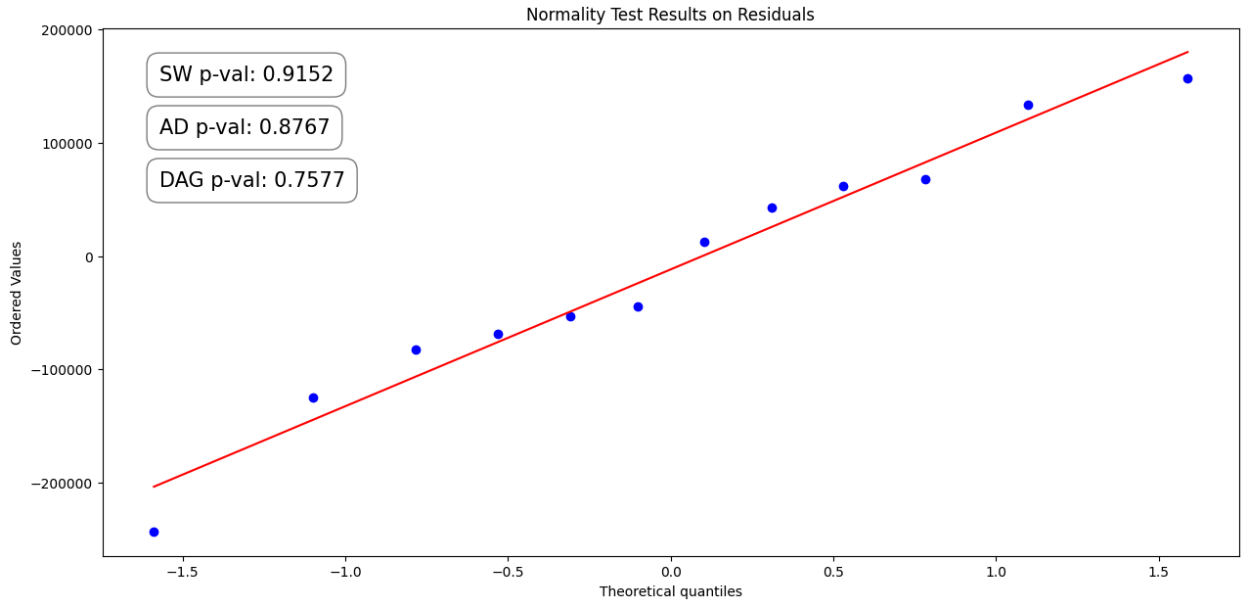




Predictive modeling using SARIMA provides insights into future trends in smoke impact. The models, trained on historical data, suggest a continued increase in smoke impact over the coming decades, consistent with projections of heightened wildfire activity due to climate change. The smoothed data offers a clearer depiction of long-term trends,

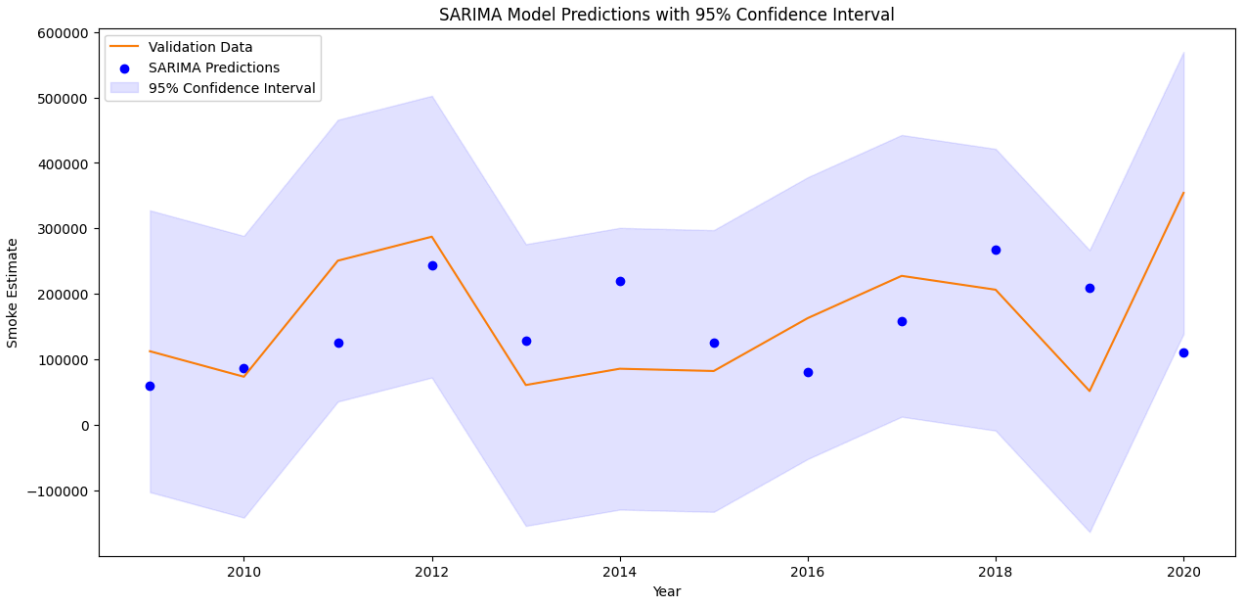
removing short-term volatility to focus on the overarching trajectory. These predictions emphasize the need for proactive planning to mitigate future health and environmental impacts.

11. Normality Test on Residuals



The normality test on SARIMA model residuals confirms the appropriateness of the model for predictive analysis. With p-values from tests such as Shapiro-Wilk, Anderson-Darling, and D'Agostino greater than 0.05, the residuals exhibit normal behavior, validating the robustness of the model in capturing the dynamics of smoke impact trends.

12. SARIMA Model Predictions with Confidence Intervals



This visualization presents SARIMA model predictions with a 95% confidence interval, highlighting the inherent uncertainty in future estimates. While the predicted values suggest a significant rise in smoke impact, the wide confidence intervals underscore the variability and unpredictability of wildfire activity. This reinforces the importance of adaptable and resilient mitigation strategies.

Integration of Findings

These findings collectively highlight the critical public health implications of wildfire smoke in Boulder. By correlating smoke impact with mortality rates and cause-specific deaths, the study underscores the urgency of implementing air quality mitigation policies, especially during wildfire seasons. The strong statistical correlations observed, coupled with the temporal alignment of respiratory deaths and smoke impact peaks, provide compelling evidence for targeted interventions aimed at reducing health risks.

---

5. Discussion and Implications

Impacts on Boulder Residents and Policy Makers

The findings of this study reveal a concerning trend for Boulder residents. With increasing wildfire activity in proximity to Boulder, the associated smoke impacts have grown more severe, as evidenced by both the historical trends in smoke estimates and the predictive SARIMA models. The clear correlation between smoke impact and mortality rates, especially for respiratory-related illnesses, underscores the pressing health risks posed by

wildfire smoke exposure. These risks are particularly acute for vulnerable populations such as the elderly, individuals with pre-existing respiratory conditions, and children.

Policy makers in Boulder are at a critical juncture. The results call for immediate action to mitigate the dual threats of worsening air quality and its associated health outcomes. The evidence demonstrates that wildfire activity is not just a seasonal nuisance—it is a growing public health crisis that demands a coordinated, proactive response.

Recommendations for Action

1. **Wildfire Mitigation Strategies**
    - **Controlled Burns and Vegetation Management**: Initiate and expand controlled burn programs to reduce wildfire fuel loads, particularly within the 650-mile radius most relevant to Boulder's smoke impacts. Partnering with neighboring counties and states will ensure a regional approach to fire prevention.
    - **Improved Fire Detection and Response**: Invest in advanced technologies such as satellite-based monitoring systems for early fire detection. Faster response times can limit the scale of fires and reduce their potential smoke output.
2. **Air Quality Management**
    - **Enhanced Monitoring**: Increase the number of AQI monitoring stations in and around Boulder to provide more localized and accurate air quality data. This will enable timely public health advisories during smoke events.
    - **Real-Time Alerts**: Develop and deploy a real-time alert system that notifies residents of hazardous air quality levels, similar to weather alerts. These alerts can guide residents to take precautionary measures, such as using air purifiers or wearing masks during high-risk periods.
3. **Public Health Interventions**
    - **Healthcare Preparedness**: Strengthen local healthcare infrastructure to handle respiratory-related health crises during wildfire seasons. This includes stocking up on medications, expanding emergency services, and training medical staff for smoke-related health emergencies.
    - **Community Outreach and Education**: Conduct awareness campaigns to educate residents about the health risks of wildfire smoke, proper use of air filtration systems, and the importance of staying indoors during poor air quality days.
4. **Climate Adaptation Policies**

- Recognizing the link between climate change and increased wildfire activity, Boulder's policy makers should integrate wildfire mitigation into broader climate adaptation plans. This could include advocating for regional and national policies to address greenhouse gas emissions, which contribute to the conditions fueling larger and more frequent wildfires.

Human-Centered Data Science Principles

Throughout this analysis, human-centered data science principles were integral to shaping the study's design, execution, and recommendations. By focusing on Boulder, the research was localized to provide actionable insights tailored to the needs of its residents. Ethical considerations were paramount in handling sensitive mortality data, ensuring privacy and accuracy in the analysis. The study also prioritized transparency, documenting all methodologies and assumptions to allow for reproducibility and accountability.

Additionally, the inclusion of predictive modeling was not just a technical exercise but a deliberate effort to forecast future impacts, enabling decision-makers to plan for scenarios that could otherwise blindside the community. This forward-thinking approach aligns with the human-centered principle of proactive problem-solving, emphasizing the welfare of people above all.

Key Takeaways

1. **Rising Risks**: Wildfire smoke impacts on Boulder are increasing, both in severity and frequency. These impacts have a measurable correlation with respiratory-related mortality rates, indicating significant health risks for residents.
2. **Actionable Insights**: Effective wildfire mitigation strategies and public health interventions can significantly reduce the risks posed by wildfire smoke. Early detection systems, real-time air quality alerts, and healthcare preparedness are critical steps for Boulder to safeguard its residents.
3. **Urgent Need for Collaboration**: Wildfires are not confined by borders. Tackling their impacts requires regional cooperation, combining resources and expertise to address the root causes and mitigate the consequences.
4. **The Value of Data-Driven Decisions**: This study demonstrates the power of leveraging historical and predictive data to inform policy. By understanding trends and projecting future risks, Boulder can transition from reactive measures to proactive planning.

Remarks

For Boulder residents, the findings of this study are both a warning and a call to action. The trends observed underscore the importance of immediate, coordinated efforts to address

the growing wildfire threat. By combining data-driven insights with human-centered strategies, Boulder has the opportunity to lead by example, demonstrating how communities can adapt to and mitigate the impacts of climate-driven challenges. The choices made today will shape not only the health and safety of Boulder's current population but also the resilience of future generations.

---

6. Limitations

No study is without limitations, and this analysis is no exception. While I aimed to provide a robust examination of wildfire smoke impacts on Boulder, several factors limit the scope and generalizability of my findings:

1. **Data Granularity**
   The wildfire dataset used in this study aggregates data at an annual level. This lacks the temporal precision to capture short-term fluctuations in wildfire activity and smoke impacts, such as day-to-day or week-to-week variations. Similarly, mortality data was only available on a yearly basis, preventing me from analyzing immediate health impacts during peak wildfire periods.

2. **Assumptions in the Smoke Impact Formula**
   The formula used to estimate smoke impacts relied on assumptions about the linearity of relationships between fire size, proximity, and smoke intensity. Factors such as wind direction, weather patterns, and topographical barriers, which could significantly influence smoke dispersion, were not included due to data limitations.

3. **Absence of Socioeconomic Variables**
   This study did not incorporate socioeconomic factors, such as income levels, housing conditions, or access to healthcare, which could influence the vulnerability of Boulder residents to wildfire smoke. Including such variables could have provided a more nuanced understanding of health outcomes across different demographic groups.

4. **Potential for Unseen Confounders**
   The observed correlations between smoke impacts and mortality rates may be influenced by unmeasured confounding variables, such as concurrent environmental hazards (e.g., ozone pollution or industrial emissions) or other health crises (e.g., flu outbreaks).

5. **Prediction Model Limitations**
   While the SARIMA model provided predictive insights, its forecasts are inherently limited by the assumptions and variability in the historical data. The model cannot

account for unexpected changes in climate, policy, or fire management practices, which could significantly alter future wildfire activity.

6. **AQI Data Limitations**
   The Air Quality Index (AQI) data sourced through the EPA AQS API provides a valuable comparison to the smoke estimates, but it is not a direct measure of wildfire smoke. AQI values are influenced by multiple pollutants, and attributing changes solely to wildfire activity introduces potential biases.

By acknowledging these limitations, I aim to provide a balanced perspective on the study's findings and advocate for future research to address these gaps.

---

7. Conclusion

This study set out to investigate the relationship between wildfire smoke impacts and public health outcomes in Boulder, Colorado, over the past six decades. Using data from the USGS, CDC WONDER API, and EPA AQS, I estimated annual smoke impacts and examined their correlation with mortality rates from respiratory-related illnesses. Predictive modeling further extended this analysis, providing insights into potential future trends.

Key findings include:

- A significant upward trend in wildfire smoke impacts, driven by increasing wildfire activity and acreage burned within 650 miles of Boulder.
- Strong correlations between smoke impact estimates and mortality rates, particularly for diseases such as chronic lower respiratory illnesses and pneumonia.
- Predictive models highlighting the growing risks of smoke exposure in the coming decades.

This study underscores the critical need for targeted wildfire mitigation strategies and public health interventions to protect Boulder residents. By leveraging historical data, this analysis provides a foundation for informed decision-making and proactive planning. Future research should address the limitations outlined, incorporate socioeconomic factors, and explore more granular datasets to refine these findings further.

---

8. Data Sources

1. **USGS Wildfire Data**
    - **Source**: United States Geological Survey (USGS)
    - **Link**: Wildfire Polygons Dataset
    - **Relevance**: This dataset provided the spatial and temporal data on wildfires required to calculate smoke impacts for Boulder. Fires within a 650-mile radius were used for analysis.
2. **CDC WONDER Mortality Data**
    - **Source**: CDC WONDER API
    - **Link**: Underlying Cause of Death
    - **Relevance**: This dataset included annual mortality counts and population data for Boulder, enabling the calculation of mortality rates for respiratory-related diseases.
3. **EPA Air Quality Data**
    - **Source**: Environmental Protection Agency (EPA) AQS API
    - **Link**: AQS API
    - **Relevance**: The AQI values from this dataset were used to compare smoke estimates to observed air quality trends in Boulder, providing an external validation metric.

---

9. References

- **Datasets**:
    - United States Geological Survey (USGS): Wildfire Polygons Dataset
    - CDC WONDER API: Underlying Cause of Death
    - Environmental Protection Agency (EPA): Air Quality System (AQS) API
- **Tools and Libraries**:
    - Python Libraries: Pandas, NumPy, Matplotlib, Seaborn, Statsmodels
    - GeoJSON Reader for wildfire proximity calculations
- **Prior Research**:
    - Finlay, S. E., et al. (2012). *The health impacts of wildfires*.
    - Liu, J. C., et al. (2015). *Wildfire-specific fine particulate matter and risk of hospital admissions in urban and rural counties*.