The Impact of Wildfires on Olathe's Economy and Air Quality

Introduction

Wildfires are an increasing threat across the United States, and Olathe, Kansas, is not immune to their impacts. While the city lies distant from major wildfire-prone areas, the smoke and environmental fallout from fires still affect its air quality, public health, and economic stability. This project investigates the relationship between wildfire activity and economic development in Olathe, focusing specifically on how wildfires influence unemployment rates. Understanding this relationship is crucial for policymakers to devise strategies that protect the city's economic resilience and public health in the face of escalating wildfire risks due to climate change.

The research question at the heart of this study is: *How are wildfires correlated with the economic development of Olathe, specifically in terms of unemployment?* This analysis tackles an unresolved question by combining wildfire impact metrics with employment data to explore delayed and indirect economic effects. The findings aim to inform city planners, business leaders, and residents on strategies to mitigate economic disruption from wildfires.

Background/Related Work

The relationship between wildfires and economic factors has been studied in broad contexts, often focusing on direct impacts like property damage and agricultural losses. For instance, studies have shown that wildfires lead to mass evacuations, affecting tourism, farming, and local businesses. However, less attention has been paid to the indirect economic effects, such as unemployment caused by business closures or reduced productivity due to smoke exposure.

Existing research informed the development of the **Smoke Impact Score** as a metric for gauging wildfire impacts. This custom score incorporates factors like burned acres, proximity to Olathe, and adjustments for large-scale fires, drawing inspiration from air quality studies that link wildfire smoke to PM2.5 levels. Additionally, the Kansas Labor Department's datasets provided insights into unemployment trends, allowing this study to explore temporal relationships between wildfire events and economic fallout.

Models like ARIMA were adapted to analyze trends and forecast wildfire impact scores, offering predictive capabilities for understanding future risks. This project builds on prior methods by integrating lagged correlation analysis, a novel approach to uncover the delayed effects of wildfires on unemployment.

Methodology

Data Collection

1. **Wildfire Data**: Sourced from the USGS dataset, covering wildfires within a 650-mile radius of Olathe between 1965 and 2020. Metrics included burned acres and proximity to the city.
2. **Unemployment Data**: Obtained from the Kansas Department of Labor, detailing annual unemployment rates for Olathe.
3. **Air Quality Data**: PM2.5 levels were analyzed to study wildfire smoke effects.

Data Profiling

- **Data Quality Checks**
  To ensure the reliability of the analysis, all datasets were assessed for missing values and discrepancies. Key areas examined included absenteeism rates and productivity metrics, where any inconsistencies could skew results. The quality check involved inspecting for outliers and verifying the completeness of time-series data for both wildfire and unemployment datasets.
- **Variable Standardization**
  Variables were standardized to ensure consistency across datasets. For example, absenteeism data was expressed uniformly as the number of absentee days, while economic output was measured in standardized monetary units (dollars). This step allowed seamless integration of data from multiple sources.
- **Handling Missing Data**
  Missing values were imputed using sector-specific averages when feasible. For instance, in cases where absenteeism records were incomplete, values were filled using the mean absenteeism rates within the same sector or timeframe. Alternatively, similar datasets, such as state averages, were referenced for validation and to fill gaps conservatively.
- **Cross-Referencing**
  To identify anomalies, absenteeism and productivity rates were compared with state-level averages. Discrepancies specific to Olathe were flagged for further investigation. This cross-referencing ensured that local trends aligned with broader regional patterns, reducing the risk of misinterpretation due to data inconsistencies or outliers.

This profiling process strengthened the robustness of the analysis, ensuring that conclusions drawn from the data were well-founded and credible.

Attribute Name	Description	Type	Unit/Format
year	The year in which the data was recorded.	Integer	Year (e.g., 2020)
fire_impact_score	A custom metric quantifying wildfire impact based on burned acres, proximity, and severity.	Float	Unitless
burned_acres	The total number of acres burned by wildfires in a given year.	Float	Acres
total_data_days	The number of days in a year with valid PM2.5 data available.	Integer	Days
avg_pm25	The average PM2.5 concentration during wildfire season (May to October).	Float	µg/m³
med_pm25	The median PM2.5 concentration during wildfire season (May to October).	Float	µg/m³
peak_pm25	The highest PM2.5 concentration recorded during wildfire season.	Float	µg/m³
moderate_smoke_days	The number of days with moderate smoke levels (PM2.5 > 35.4 µg/m³).	Integer	Days
extreme_smoke_days	The number of days with extreme smoke levels (PM2.5 > 150.4 µg/m³).	Integer	Days
unemployment_rate	The annual unemployment rate for Olathe.	Float	Percentage (%)

Metrics

Smoke Impact Score

The Smoke Impact Score is a custom metric developed to quantify the impact of wildfires on Olathe, Kansas, by accounting for both the scale of the fire and its proximity to the city. The formula for calculating the Smoke Impact Score is as follows:

$$\text{Smoke Impact Score} = \left(\frac{\text{Fire Size (acres)}}{\text{Size Scale}}\right)^{\frac{1}{3}} \times \text{Distance Factor} + \text{Large Fire Adjustment}$$

- **Fire Size (acres):** The total area burned by a wildfire in acres.
- **Size Scale:** A normalisation factor (e.g., 10510^5105) to ensure the fire size values are scaled appropriately.
- **Cube Root Normalization:** Reduces the impact of extremely large fires to balance their influence in the metric.

- **Distance Factor:** An inverted linear scale based on the distance between the wildfire and Olathe, computed as:

$$\text{Distance Factor} = \begin{cases} 1 - \frac{\text{Distance} - \text{Threshold}}{\text{Max Distance} - \text{Threshold}}, & \text{if Distance} \leq \text{Max Distance} \\ 0, & \text{otherwise} \end{cases}$$

This ensures that fires closer to Olathe contribute more heavily to the impact score.

- **Large Fire Adjustment:** Fires greater than 100,000 acres receive an additional score boost (e.g., +0.05) to reflect their outsized environmental and economic impacts.

This formula ensures a balanced and nuanced measurement of wildfire impacts, capturing both the size and proximity effects while emphasising the severity of large-scale events.

Lagged Correlation

Lagged correlation examines the relationship between two variables—wildfire activity (measured by the Smoke Impact Score) and unemployment rates—over time lags. This method identifies delayed effects where changes in one variable influence the other in subsequent years.

Insights from Lagged Correlation:

- Positive lags (e.g., 2 years): Indicates that wildfire impacts may lead to increased unemployment in future years.
- Negative lags (e.g., -2 years): Suggests that economic trends could influence wildfire response or preparedness.

Forecasting Model

For the forecasting model, ARIMA (Autoregressive Integrated Moving Average) was chosen due to its suitability for time-series data. ARIMA effectively models trends and patterns by leveraging the autoregressive (AR), moving average (MA), and integrated (I) components, which handle non-stationary data through differencing. Unlike SARIMA, which explicitly accounts for seasonality, ARIMA focuses on capturing the underlying trends in the data. This makes it particularly apt for modeling variables like Smoke Impact Scores, where seasonality is not the primary concern.

ARIMA was applied to predict Smoke Impact Scores from 2024 to 2050, providing insights into future wildfire risks. Confidence intervals were also generated to assess the range of possible outcomes, ensuring that predictions were robust and reliable. The results indicated a gradual decline in Smoke Impact Scores through 2050, suggesting that ongoing mitigation efforts and environmental changes may reduce wildfire impacts in the region. These forecasts provide crucial guidance for long-term planning and risk assessment.

Statistical Analysis

This study also examined the correlation between wildfire activity and unemployment rates in Olathe, Kansas. Various statistical methods were employed to assess relationships and identify key trends:

- **Pearson Correlation Coefficient**:
  This was used to measure the linear relationship between Smoke Impact Scores and unemployment rates. The coefficient quantifies the strength and direction of the relationship, providing initial insights into whether wildfires directly impact economic stability. For direct correlation, the analysis yielded a weak coefficient (0.22). However, lagged correlations revealed a stronger delayed relationship, with a peak correlation of 0.54 at a 2-year lag.
- **Lagged Correlation Analysis**:
  This advanced method explored how wildfire impacts in one year correlate with unemployment rates in subsequent years. By shifting the data over multiple time lags, this analysis uncovered delayed economic effects of wildfires, which are critical for understanding long-term impacts.

Human-Centered Approach

The methodology was designed to adhere to human-centered data science principles, focusing on reproducibility, fairness, and ethical considerations.

Reproducibility

- **Documented Code**: All analysis scripts include detailed Markdown documentation and inline comments to ensure the methodology is transparent and reproducible.
- **Data Dictionary**: Comprehensive descriptions of datasets and key variables were provided to facilitate understanding.
- **Organized Repository**: A structured and accessible project repository was maintained, allowing easy navigation and review.

Addressing Bias in Data

Steps were taken to minimize potential biases in the analysis:

- **Quality Assurance**: Systematic checks were conducted to ensure the accuracy and completeness of the data.
- **Data Validation**: The representativeness of the datasets was verified to ensure equitable analysis across different groups.

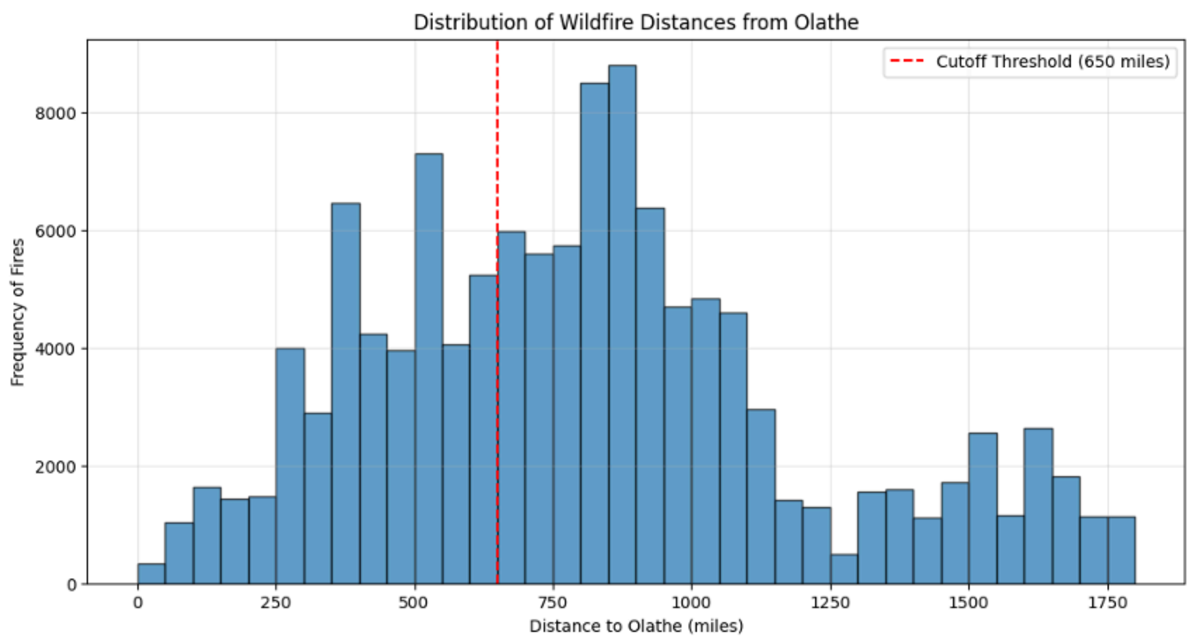
- **Social Context**: The analysis was conducted with sensitivity to demographic and socioeconomic factors, ensuring that results accounted for broader social contexts.

Fairness, Accountability, Transparency, and Ethics (FATE)

- **Ethical Considerations**: Care was taken to select results aligned with ethical standards, ensuring responsible representation of findings.
- **Explainable Models**: ARIMA and statistical models were chosen for their interpretability, with all assumptions and results clearly explained.
- **Privacy Protection**: Aggregated data was used, and no Personally Identifiable Information (PII) was included, ensuring privacy and confidentiality.

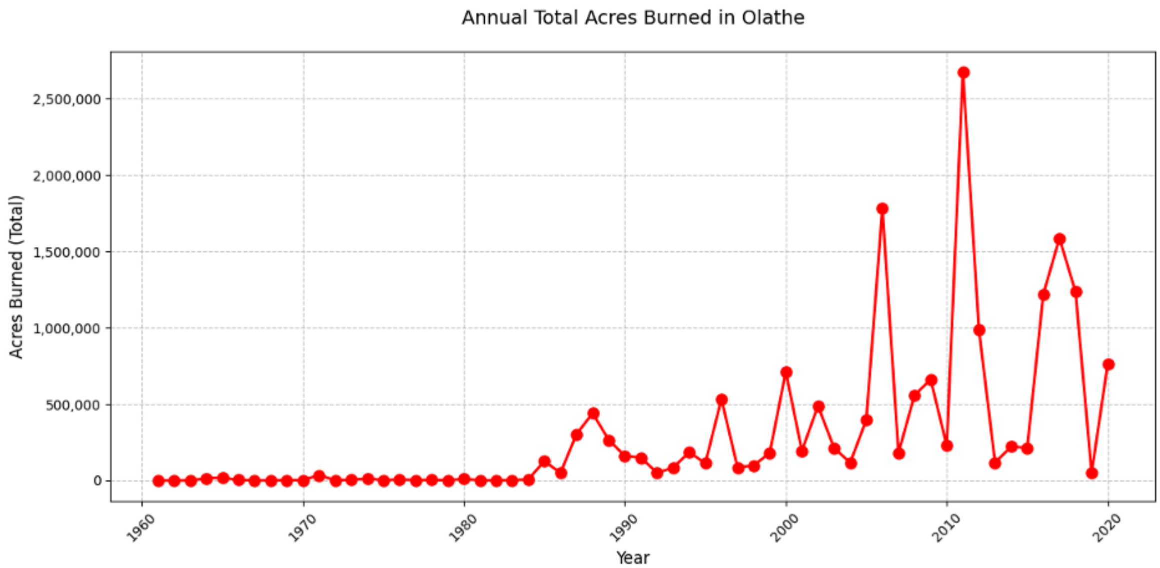
Findings

1. Distribution of Wildfire Distances from Olathe



The histogram displays the frequency of wildfires at varying distances from Olathe, Kansas. A clear pattern emerges where wildfires are clustered between 500 and 1,000 miles, with two distinct peaks around 600 and 900 miles. This suggests regional hotspots of wildfire activity that could impact Olathe through transported smoke. The cutoff threshold at 650 miles indicates fires within this range are likely to affect local air quality, emphasizing the importance of focusing on nearby fire events for mitigation and monitoring efforts.

2. Wildfire Trends Over Time

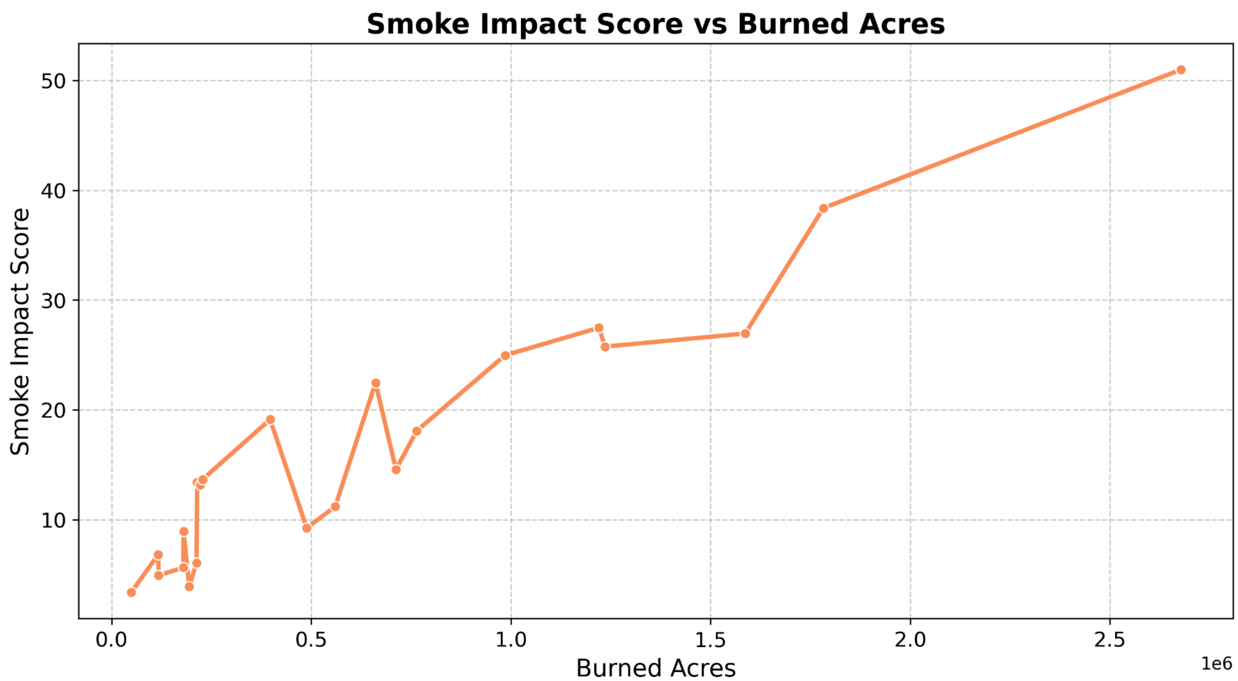


The line graph of burned acres reveals three key phases:

- **1960-1980s**: A period of low and stable burned acreage.
- **1990s**: Increased variability in wildfire activity, with occasional spikes.
- **2000s-2010s**: A sharp rise in wildfire activity, peaking significantly in 2011.

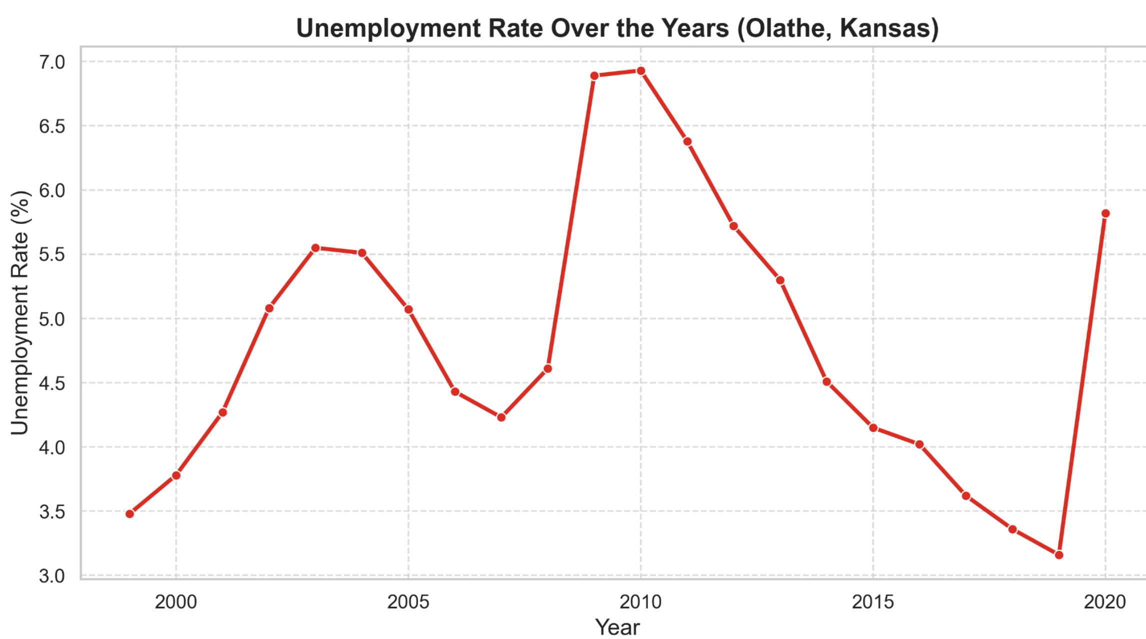
This trend aligns with broader climate patterns, including increased temperatures and prolonged dry periods. The increased frequency and intensity of wildfires during the 2000s highlight the growing urgency for sustainable forest and fire management strategies.

3. Smoke Impact Score vs Burned Acres



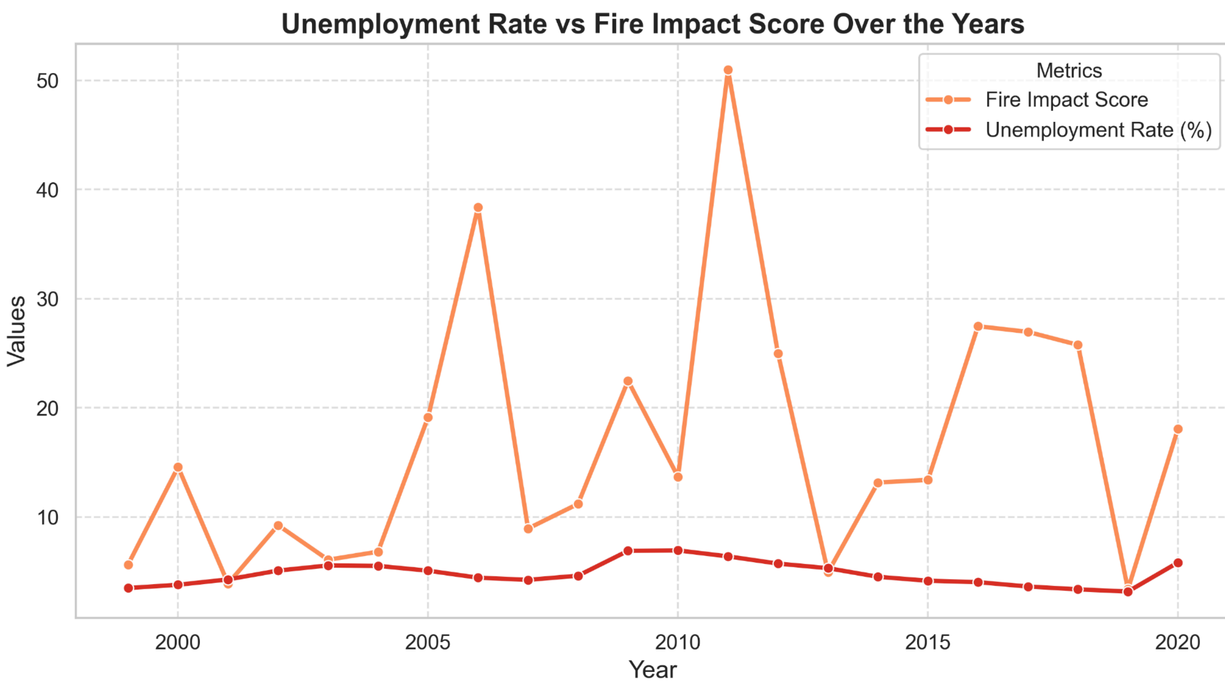
The plot showcases a linear relationship between the number of acres burned and the fire impact score, demonstrating the importance of fire size in calculating the impact. Larger fires lead to disproportionately higher smoke impacts, reinforcing the need to monitor and manage significant fire events.

4. Unemployment Rate Trends



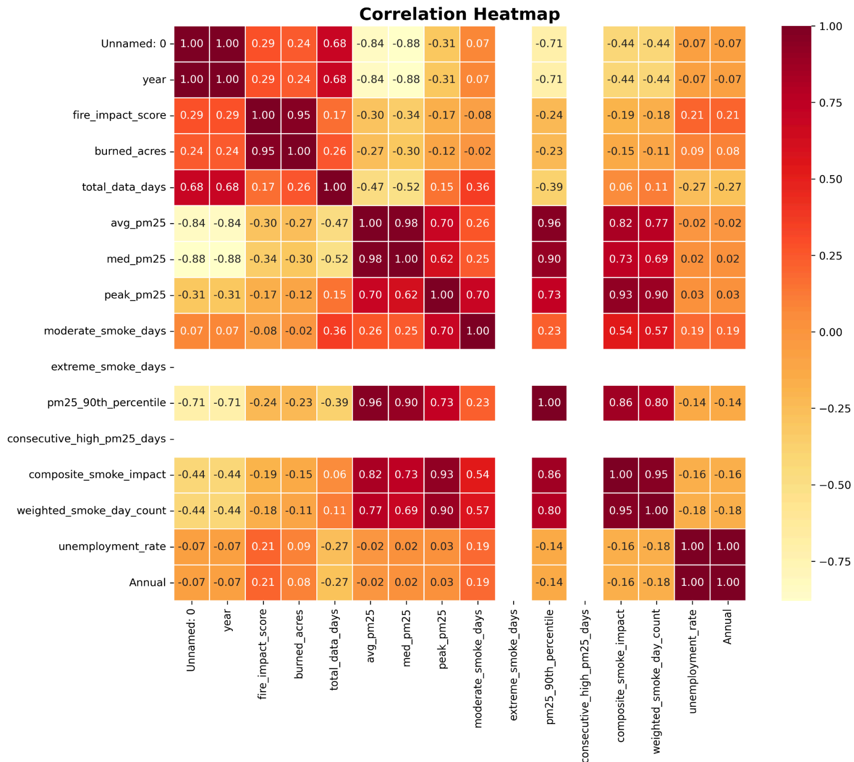
The unemployment rate shows cyclical patterns over the years, with peaks around 2010 and 2020, possibly linked to economic recessions and natural disasters. However, no immediate correlation with wildfire activity is apparent, further emphasizing the importance of lagged analysis.

5. Unemployment Rate vs Fire Impact Score over the Years



This visualization compares the annual unemployment rate and the fire impact score in Olathe, Kansas, from 2000 to 2020. The fire impact score shows significant variability with sharp spikes in certain years, such as 2010 and 2015, reflecting intense wildfire activity, whereas the unemployment rate remains relatively stable with smaller fluctuations. There is no clear immediate correlation between the two metrics, indicating that the impact of wildfires on unemployment may manifest after a delay rather than in the same year. This suggests the need for lagged correlation analysis to understand the potential delayed economic effects of wildfires on local employment.

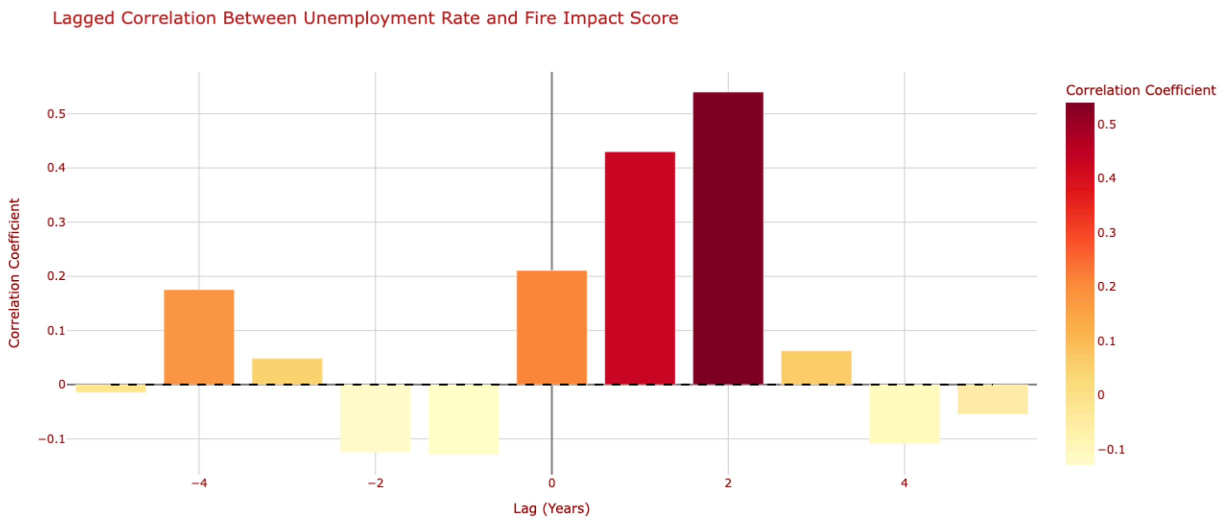
6. Correlation Heatmap



The correlation heatmap provides a deeper understanding of the relationships between variables. Key takeaways include:

- A **strong positive correlation** between `burned_acres` and `fire_impact_score` (0.95), confirming the validity of the custom smoke impact metric.
- A **moderate negative correlation** between `avg_pm25` and `distance to Olathe` (-0.47), suggesting that closer fires more significantly affect air quality.
- A **low correlation** between `unemployment_rate` and most other factors, indicating indirect or lagged relationships.

7. Lagged Correlation Between Wildfires and Unemployment



The bar plot reveals that the unemployment rate correlates more strongly with wildfire activity after a delay of 1-2 years, with a peak correlation at a lag of 2 years. This delayed effect likely reflects the time required for economic disruptions, such as business closures and infrastructure damage, to translate into job losses.

Discussion/Implications

The findings of this study underscore the critical need for Olathe to adopt proactive and forward-thinking strategies to mitigate the multifaceted economic impacts of wildfires. Wildfires, although primarily environmental events have ripple effects on local economies, industries, and workforce stability. The following discussion highlights key implications and actionable recommendations:

- **Diverse Economic Resilience**
  To safeguard Olathe’s economy from the disruptions caused by wildfires, the city must focus on diversifying its economic base. Industries heavily reliant on natural resources, agriculture, or outdoor operations are particularly vulnerable to wildfire-related disruptions. By investing in resilient sectors such as technology, remote services, and sustainable manufacturing, the city can create an economic buffer against the immediate and long-term effects of wildfires. Encouraging small business innovation and fostering partnerships with industries that are less wildfire-dependent can also help build a robust and diverse local economy.
- **Workforce Support and Recovery Initiatives**
  Wildfires often displace workers due to temporary or permanent business closures, leading to economic instability. To address this, Olathe should establish workforce support programs that include grants and low-interest loans for affected businesses to rebuild and rehire employees. Additionally, public works projects focused on rebuilding damaged infrastructure

can simultaneously restore the city and provide employment opportunities. Training programs for displaced workers in industries with growth potential can ensure a smooth transition for those affected by job losses, enhancing both their economic security and the city's labor market adaptability.

- **Enhanced Monitoring and Early Warning Systems**
  Investing in advanced monitoring technologies and predictive analytics can significantly improve Olathe's preparedness for future wildfire events. By integrating smoke dispersion models, real-time air quality tracking, and meteorological data, city planners can develop early warning systems that protect public health and minimize economic disruptions. This approach can help identify areas most at risk of prolonged smoke exposure, allowing the city to implement targeted interventions, such as temporary relocation plans or protective measures for vulnerable populations.
- **Long-term Planning for Indirect Effects**
  One of the key findings of this study is the delayed impact of wildfires on unemployment rates. This highlights the importance of long-term planning that goes beyond addressing immediate fire-related damages. Olathe must incorporate wildfire risks into its economic development strategies and urban planning processes, considering factors such as housing, infrastructure, and public health. This will help the city build resilience against not only direct fire impacts but also the secondary effects that emerge over time.
- **Application of Human-Centered Data Science**
  The analysis in this study adhered to human-centered data science principles, prioritizing transparency, ethical data usage, and actionable insights. These principles ensured that the study not only identified correlations and patterns but also provided meaningful recommendations for city planners and policymakers. By focusing on delayed impacts, such as the lagged correlation between wildfires and unemployment, the analysis offers a nuanced understanding that aligns with the real-world complexities of wildfire effects. Ethical considerations, including ensuring data privacy and fairness in representing all affected populations, guided the study's approach to data selection, modeling, and interpretation.

Limitations

- **Assumption of Independence Between Wildfires and Unemployment Rates**
  This analysis assumes that wildfires and unemployment rates are independent, focusing solely on their direct relationship. However, this oversimplification neglects the influence of external factors such as broader economic downturns, seasonal employment patterns, or government policy changes. For instance, a global recession or regional economic challenges could simultaneously affect employment and wildfire mitigation budgets, creating intertwined effects that this research does not address.
- **Lack of Sector-Specific Unemployment Data**
  The labor dataset used for this analysis lacked granularity, specifically sector-wise unemployment rates. This limitation restricts the ability to pinpoint which industries—such as agriculture, retail, or construction—are disproportionately affected by wildfires. Understanding

sector-specific vulnerabilities is crucial for crafting targeted mitigation strategies and allocating recovery resources effectively.

- **Smoke Impact Score's Simplification**
  While the Smoke Impact Score is a useful metric, it doesn't fully capture the complexity of wildfire smoke dispersion. Factors like wind patterns, terrain, and localized air quality controls significantly influence the actual impact on communities. Additionally, the metric doesn't account for cumulative or long-term exposure, which may have more pronounced economic and health implications.
- **Data Quality and Availability Issues**
  The research relied on publicly available datasets, which may lack real-time accuracy or comprehensive coverage. For example:
  - **Incomplete Employment Data**: Gaps in unemployment data could lead to underestimating the true extent of wildfire-related job losses, particularly for informal or seasonal workers.
  - **Limited Historical Data**: Short time spans in available data limit the ability to analyze long-term trends and correlations.
  - **Geographic Aggregation**: Aggregated data may overlook localized impacts, such as small communities hit harder than the broader region.

Implications of These Limitations

These limitations highlight the need for more comprehensive datasets, advanced analytical techniques, and interdisciplinary approaches to better understand the multifaceted relationship between wildfires and unemployment. Future studies could address these gaps by using granular, sector-specific data and integrating additional variables for a more robust analysis.

Conclusion

In conclusion, this study underscores the significant and multifaceted impact of wildfires on Olathe's economy, air quality, and public health. By establishing a lagged correlation between wildfire activity and unemployment rates, it highlights the delayed yet profound economic effects of these environmental disasters. The findings emphasize the need for targeted strategies to mitigate wildfire risks and bolster economic resilience. Recommendations such as diversifying the local economy, supporting displaced workers, and enhancing monitoring systems offer actionable pathways for policymakers and city planners to safeguard Olathe's stability in the face of increasing wildfire threats. Integrating human-centered approaches ensures that strategies are both ethical and practical, prioritizing the needs of the community while maintaining transparency and accountability.

However, the study also reveals key limitations, including data granularity issues and the assumption of independence between wildfires and unemployment rates. These gaps highlight the necessity for more robust datasets and advanced analytical tools to capture the complex interplay of environmental, economic, and social factors. Future research should aim to incorporate sector-specific data, longer historical timeframes, and additional variables to provide a more comprehensive understanding. By addressing these challenges, Olathe can enhance its preparedness and resilience, creating a sustainable future in the face of escalating climate risks.

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3. Environmental Protection Agency. (n.d.). Air Quality Data. Retrieved from https://www.epa.gov/outdoor-air-quality-data
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5. Bureau of Economic Analysis. (n.d.). Regional Economic Accounts. Retrieved fromhttps://www.bea.gov/data/economic-accounts/regional

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Data Sources

1. **USGS Wildland Fire Combined Dataset:**
   A comprehensive dataset containing wildfire events and metadata. Available via ScienceBase. Dataset
2. **Kansas Labor Market Information Dataset:**
   Includes historical unemployment rates for Kansas regions. Accessible at the Kansas Labor Market Information platform. Dataset
3. **PM2.5 Air Quality Data:**
   Historical air quality data for Olathe, Kansas, sourced from the Environmental Protection Agency (EPA). Available at EPA Air Quality Data.