Spatiotemporal Trends in Pacific Northwest Wildfire Occurrence and Firefighting Resource Demand

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1 Background and Research Objectives

Wildfires are a growing concern across the Pacific Northwest (PNW), where rising temperatures, prolonged droughts, and increasing human development along the wildland–urban interface have amplified both the frequency and severity of fire events. Studies in recent years have documented a strong correlation between climate variability and wildfire occurrence, while others (such as those published in Nature Communications and Ecosphere) highlight the compounding social and infrastructural impacts that follow major fire seasons. In the PNW, the interaction between regional climate patterns, vegetation dynamics, and human settlement has produced increasingly complex fire regimes that challenge both ecological stability and resource management.

Wildfire research has traditionally focused on burn severity, vegetation recovery, or climate drivers. However, fewer studies have developed integrated models that connect wildfire occurrence to infrastructure and environmental consequences, such as changes in energy production, water quality, or firefighting resource demand. Understanding these cascading effects is critical for anticipating the full impact of large fire events and for improving strategic resource allocation during response efforts.

The objective of this research is to identify and model spatiotemporal trends in wildfire occurrence and firefighting resource demand across the Pacific Northwest, and to build a predictive framework that estimates downstream environmental and infrastructural effects of new wildfire events. Specifically, the study seeks to:

- Analyze temporal and spatial patterns in wildfire occurrence from 2002–2024 using historical satellite and incident data.

- Model relationships between wildfire location, size, and intensity with key environmental and infrastructural factors such as energy output, population displacement, and water system proximity.
- Develop a Python-based predictive model capable of estimating indices for potential impact severity (e.g., energy disruption index, displacement risk index, resource demand index) when given a new wildfire location.
- Visualize trends and predictive outputs using QGIS to support regional planning and firefighting decision-making.

This research aims to bridge data science and environmental management by integrating time-series analysis, spatial modeling, and supervised learning to quantify and forecast wildfire impacts within the PNW.

2 Sources of Data and Description of Analyses/Methods

This research integrates multiple datasets to examine and model the relationships among wildfire occurrence, firefighting resource demand, and secondary environmental and infrastructural impacts in the Pacific Northwest (PNW). The framework combines temporal modeling, spatial analysis, and predictive modeling using open-access geospatial and tabular data. The selection of data sources and analytical methods is informed by previous studies that have quantified wildfire impacts on solar energy generation, power grids, hydrological systems, atmospheric processes, and community vulnerability.

2.1 Data Sources

2.1.1 Wildfire Activity and Severity

Historical wildfire data will be obtained from:

- **Monitoring Trends in Burn Severity (MTBS)** for perimeters, burn severity indices, and postfire vegetation conditions across the PNW.
- **National Interagency Fire Center (NIFC)** and Incident Command System (ICS-209) records for resource mobilization, fire duration, personnel deployment, and suppression costs.

2.1.2 Environmental and Climatic Variables

Environmental conditions influencing and influenced by wildfires will be captured from:

- **PRISM Climate Group** datasets for temperature and precipitation.
- **TerraClimate** reanalysis datasets for wind speed.
- **Stanford EchoLab** wildfire smoke PM2.5 data.

2.1.3 Infrastructure and Energy Systems

Wildfire impacts on energy infrastructure will be modeled using:

- **U.S. Energy Information Administration (EIA)** data on electricity generation and total energy output.

2.1.4 Socioeconomic and Community Vulnerability

Societal exposure and displacement potential will be analyzed through:

- **U.S. Census Bureau and FEMA** datasets for population density and social vulnerability index.

Together, these datasets provide a comprehensive foundation for examining the intersection of wildfire occurrence, firefighting resource demand, and multi-sectoral impacts across the Pacific Northwest.

2.2 Analytical Methods

2.2.1 Temporal Analysis

Python-based time series analysis will be used to explore changes in wildfire frequency, burned area, and resource demand over time.

Libraries. pandas, geopandas, numpy, rasterstats, matplotlib

Methods. Trend decomposition, forecasting, and correlation analysis between climate anomalies, ICS-209 information, energy data, and fire activity.

2.2.2 Spatial Analysis

Spatial modeling will be conducted in QGIS and Python to visualize and quantify spatial clustering of wildfire activity relative to infrastructure and natural systems:

- Hotspot detection.
- Raster overlay analysis to assess proximity of fires to power lines, solar farms, rivers, and populated areas.
- Terrain and vegetation correlation.

2.2.3 Predictive Modeling

A supervised machine learning model will be trained to estimate likely downstream impacts of new wildfire events.

Framework. scikit-learn

Inputs. Fire location, drought index, proximity to infrastructure, atmospheric conditions, SVI.

Outputs. Normalized indices representing predicted severity in five categories — (1) fire acreage, (2) firefighting resource demand, (3) energy disruption, (4) atmospheric/smoke impact, and (5) displacement risk.

3 Results

4 Discussion and Conclusions

5 Statement of AI Usage

6 References

7 Appendix