**The Power Grid/Wildfire Nexus:**

**Using GIS and Satellite Remote Sensing to Identify Vulnerabilities**

Alyssa D. Farnes

Idaho State University; GIS Training and Research Center

HONS 3391-01: Introduction to Honors Thesis

April 29, 2022

## Introduction

Two prominent aspects of modern life collide at the nexus between the power grid and wildfire. One is vital to human systems, but the other is vital to ecological systems. So how can we enable utility companies and public land managers to strike a balance between reliable power supply infrastructure and healthy ecosystems?

The research question I am pursuing is: How can Geographic Information Systems (GIS) be used to identify vulnerabilities in the power grid due to wildfire? To answer this question, I will develop a power grid/wildfire database that will map and identify areas where the power grid is vulnerable due to wildfire. This will enable land and utility managers to gain actionable information that will support well-informed decisions. I will be working with Keith Weber of the ISU GIS Training and Research Center (webekeit@isu.edu) on this project.

## Background

In recent years, a number of large wildfires have been ignited by the electrical power grid. Conversely, a number of either unplanned or preemptive power outages have resulted from wildfires or the risk of wildfire. Historically, wildfires were never seen as a widespread threat to the power grid. However, more recent assessments, like the National Academy of Sciences' 2017 publication, "Enhancing the Resilience of The Nation's Electricity System," suggest climate change -- and the subsequent escalation in wildfire frequency -- has made fire a significant threat meriting increased research and preparedness.

The potential for wildfires to impact the power grid is likely to increase for two reasons. First, the mean size of wildfires across the western United States has grown from 1,665 acres in 1950 to over 6,000 acres in 2020 (Weber and Yadav 2020). In addition, the number of fires has increased from a low of approximately 350 documented fires in 1950 to well over 1,300 fires in

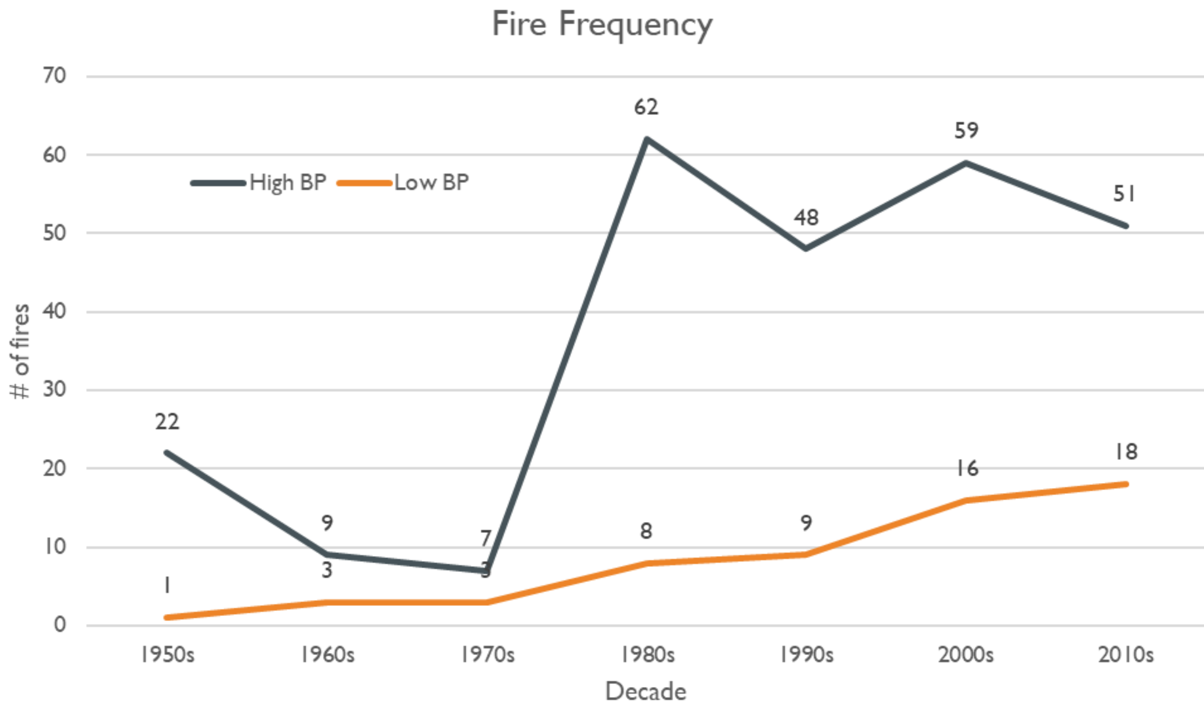


*Figure 1. Fire Frequency over the last 70 years within two Idaho study areas. High BP denotes the study area with high burn probability and Low BP denotes the study area with low burn probability, both further described in the methods section.*

2020, a nearly 400% increase (Weber, 2021). As a result, the likelihood of a wildfire affecting any part of the power grid has subsequently increased due to the sheer size and frequency of fires and the increased occurrence of critical infrastructure supporting America's growing population (the US population in 1950 was 150 million and has more than doubled to 331 million today). Second, an increasing number of Americans are opting to live in areas defined as the wildland-urban interface (WUI). While these areas clearly offer attractive quality of life benefits, they also pose enhanced risk to wildfire.

Over just the past decade, fires have caused major impacts to electrical substations and transmission lines. In several instances, the threat of wildfire has caused power companies to pre-emptively de-energize transmission lines resulting in temporary blackouts for their customers.

Today, wildfires are recognized as a real and significant threat to the power grid. In fact, a 2021 symposium sponsored by the Department of Energy focused on this threat and described the current and future efforts necessary to manage and mitigate these risks. Interestingly, many of the solutions described throughout this event rely on spatial analysis and GIS.

The Power Grid/Wildfire Nexus project advances the procedures and practices of spatial analysis to assess risk to the electric grid. Idaho presents a unique laboratory exhibiting a number of fire-prone ecosystems and a long history of wildfire, set within the most rapid population growth in the country. Changes to population, infrastructure, vegetation, and climate are all impacting the likelihood of wildfire throughout the West and this project enables observations and analysis to occur in real time. The interactions of all these systems are largely unexplored and the upstream and downstream impacts are likely to have far-reaching applications in social, political, and ecological systems across the globe.  In addition, this project will initiate a critical collaboration between subject matter experts at ISU, BSU, and the INL.

## Methods

I am using industry-standard software, ArcGIS Pro and other ESRI products, to complete geoprocessing and spatial analysis. I am spatially concentrating this study on Idaho by first identifying study areas based on current wildfire Burn Probability (BP) from the Wildfires Communities at Risk project. The selected study areas are Mountain Home (between Boise and along the I-84 corridor) and Goshen (south of Idaho Falls). Both areas contain a high density of power grid infrastructure. Mountain Home has multiple high voltage lines inside a relatively high BP zone, while the Goshen area has multiple high use substations but a very low BP.

Within each study area, I will identify the vulnerability of the power grid infrastructure due to wildfire. This will be accomplished using existing layers, shown in Table 1.

*Table 1. Layers that will be used in the multi-variable analysis.*

| | Data currency | Source | Spatial Resolution |
|---|---|---|---|
| National Vegetation Classification (land cover) | 2016 | LANDFIRE | 30 m |
| National Elevation Dataset | 2018 | USGS | 10 m |
| Historic Fires Database | 2021 | Weber | N/A |
| Wildland-Urban Interface | 2010 | Radeloff | N/A |
| Lighting Frequency Data | 2018-2021 | NOAA | 8 x 11 km grid |
| NDVI (vegetation greenness) | 2018-2021 | MODIS - NASA | 250 m |
| Regional Wind Speed Data | 2018-2021 | Idaho Power | N/A |
| Wildfire Communities at Risk<br>Burn Probability | 2020<br>2015 | Scott | 30 m |

Completing this primary part of this study will entail a multi-criteria evaluation of each of these variables, including the collection of summary statistics from each study area. By working with collaborators at BSU's Energy Policy Institute (EPI), I will be exposed to a broader perspective on energy systems and learn the socio-technical and economic underpinnings of energy policy (Araujo and Koerner) to include planning for resilience, urban growth, and the special risks associated with the wildland urban interface (WUI). I will use the knowledge I gain from these energy leaders and apply it to this project to ensure that the information the final geodatabase provides is accessible and relevant to current energy issues and modern mitigation strategies.

## Anticipated Results

### Outcome 1

An evaluation of the broader power grid/wildfire nexus will be completed to include a thorough literature review of the various interactions between wildfire and the power grid in the form of a summary paper. Details of these interactions will be sourced from both established literature and may include my own findings.

### Outcome 2

I will develop a power grid/wildfire nexus geodatabase that will contain GIS data layers necessary for the management and mitigation of relevant risks as well as the refinement and documentation of spatial analysis models. This information will be presented in a way that is helpful to the needs of land and utility managers. For example, land managers need to know where to prioritize fuel management or fire suppression, and utility companies need to know where to prioritize hardening of

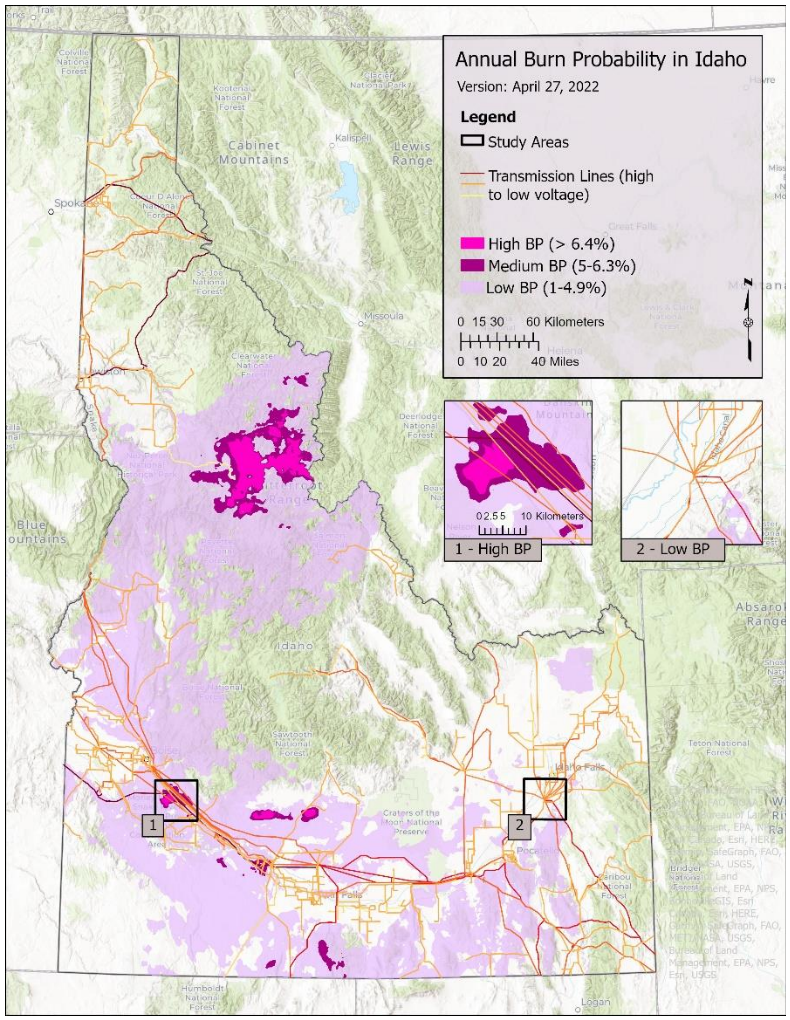


*Figure 1. Annual Burn Probability (BP). The West area (1) is Mountain Home, the East area (2) is Goshen. The final geodatabase will look similar to this map by highlighting areas where infrastructure is especially susceptible to wildfire. The lower bound of Low BP is based on the mean BP; the lower bound of Medium BP is based on 3 standard deviations from the mean; the lower bound of High BP is based on 4 standard deviations.*

infrastructure like removing fuels, adjusting substation height, and adding fireproofing to poles. This geodatabase will consolidate information across the fire, energy, and GIS fields to produce a tool that will help not only Idahoans but will hopefully be a model that can be applied to the Western United States in the future.

**Outcome 3**

I will write a white paper manuscript ready for submission to a targeted peer-reviewed journal. I will defend this project to a board of professors both within and outside of my field to complete an Honors Senior Thesis.

## Conclusion

By creating a geodatabase that can be used for the management and mitigation of wildfire risk and power grid susceptibility, I will learn how to present actionable information that will support well-informed decisions. I will practice communicating new technologies and information in an easy-to-access manner, which is an important skill I will use in future research and collaboration endeavors. This project aligns with the Center for Advanced Energy Studies (CAES) focus on cyber- and homeland security, energy policy, and computing/data/visualization. The completion of study will support and promote the national security mission.

Today, more than ever before, the health, prosperity and basic daily lives of Americans are irrevocably tied to electricity. Without electricity, Americans lose not only lights in their homes, but the ability to make purchases, pump gas, conduct business across the Internet, and work in any of the multitude of technology-enabled fields. While wildfires are not the only threat to America’s power grid, it is a growing threat that must be better understood if its vulnerabilities are to be properly managed and mitigated.

## Timeline

By the end of Spring 2022, I will have completed the initial methods identification. At the end of Summer 2022, the Literature Review will be complete. During Fall 2022, I will complete my final draft in the form of a white paper manuscript. In Spring of 2023, I will submit the paper to a peer-reviewed journal and participate in a formal Thesis Defense.

## Collaborators

The project team meets on a regular monthly basis using Zoom webinar, and I hope to meet in-person as travel allows. During these meetings, I present my project progress, receive a review and critique from team members as well as guidance and mentoring. Collaborators include:

Kathleen Araujo, Boise State University, kathleenaraujo@boisestate.edu

Cassandra Koerner, Boise State University, cassiekoerner@boisestate.edu

Kelly Wilson, Idaho National Laboratory, kelly.wilson@inl.gov

Ryan Hruska, Idaho National Laboratory, ryan.hruska@inl.gov

Shiloh Elliott, Idaho National Laboratory, shiloh.elliott@inl.gov

Christopher Forsgren, Idaho National Laboratory, christopher.forsgren@inl.gov

References


Finney, M.A., McHugh, C.W., Grenfell, I.C. et al. A simulation of probabilistic wildfire risk components for the continental United States. Stoch Environ Res Risk Assess 25, 973–1000 (2011). https://doi.org/10.1007/s00477-011-0462-z

Department of Homeland Security. Homeland Infrastructure Foundation Level Database (HIFLD). (https://gii.dhs.gov/HIFLD)

Idaho Power. Hourly Wind Speed Data, 2018-2021.

Koerner, C., K. Araujo, A. Muth, and P. Kharel (in prep). Utility-Wildfire Policy and Practices: A Review of 10 Western States in the US.

LANDFIRE: LANDFIRE Existing Vegetation Type layer. (2013, June - last update). U.S. Department of Interior, Geological Survey, and U.S. Department of Agriculture. [Online]. Available: http://landfire.cr.usgs.gov/viewer/ [2021].

NASA. Moderate Resolution Imaging Spectroradiometer (MODIS).

National Academies of Sciences, Engineering, and Medicine 2017. Enhancing the Resilience of the Nation's Electricity System. Washington, DC: The National Academies Press. https://doi.org/10.17226/24836.

NOAA National Severe Storms Laboratory Lightning Detection, 2018-2021. https://www.nssl.noaa.gov/education/svrwx101/lightning/detection/

Radeloff, V.C., Helmers, David P,; Kramer, H.A.; Mockrin, M.H.; Alexandre, P.M.; Bar Massada, A.; Butsic, V.; Hawbaker, T.J.; Martinuzzi, S.; Syphard, A.D.; Stewart, S.I. 2017. The 1990-2010 wildland-urban interface of the conterminous United States - geospatial data. 2nd Edition. Fort Collins, CO: Forest Service Research Data Archive. doi.org/10.2737/RDS-2015-001202

Scott, Joe H.; Gilbertson-Day, Julie W.; Moran, Christopher; Dillon, Gregory K.; Short, Karen C.; Vogler, Kevin C. 2020. Wildfire Risk to Communities: Spatial datasets of landscape-wide wildfire risk components for the United States. Fort Collins, CO: Forest Service Research Data Archive. https://doi.org/10.2737/RDS-2020-0016

Weber, K. T., Idaho State University GIS Training and Research Center. 2020. Historic Fires Database (HFD) version 3.0. https://giscenter.isu.edu/research/Techpg/HFD

Weber, K. T. and R. Yadav, 2020. Spatiotemporal Trends in Wildfires across the Western United States (1950–2019). Remote Sens. 12, no. 18: 2959. https://doi.org/10.3390/rs12182959

U.S. Geological Survey (USGS), EROS Data Center. National Elevation Dataset. https://gdg.sc.egov.usda.gov/Catalog/ProductDescription/NED.html