Independent Study: The Effects of Burn Severity on Soil Chemistry and *Pinus ponderosa*Regeneration in Waldo Canyon, Colorado

By Sydney Morris

High severity fires can be detrimental to forest types that have not historically experienced these conditions, leading to a low likelihood of forest regeneration and the development of novel post-fire ecological trajectories. Pinus ponderosa forest is a dominant forest type in the western United States and poorly adapted to regenerate following high severity fires. While factors such as elevation and climate are known to affect P. ponderosa regeneration post-fire, less is known regarding how fire-altered soils may impact forest regrowth, specifically in relation to the soil's chemical properties. A concurrent study of how soil nitrogen, carbon, and aluminum oxides across high and low burn severity sites may be correlated with P. ponderosa regeneration. ArcGIS was used to randomly select 12 sites from both north and south aspects. Each site was divided into six plots and categorized unburned, high, or low severity burn areas (Figure 13). Soil samples were collected, and organic debris was removed. Then, samples were dried at 70°C for 24 hours to remove any remaining moisture and pulverized for two minutes. A Tracer Handheld XRF Spectrometer to measure levels of aluminum oxide and a NC2100 elemental analyzer was used to quantify levels of nitrogen and carbon. Data were log transformed and analyzed in RStudio using One-way ANOVAs. Findings indicate that the limiting factor for P. ponderosa sapling regeneration may be unrelated to soil chemistry. These results help better understand future directions for conservation of P. ponderosa, specifically focusing on the potential limiting factors for regeneration including soil moisture and temperature.

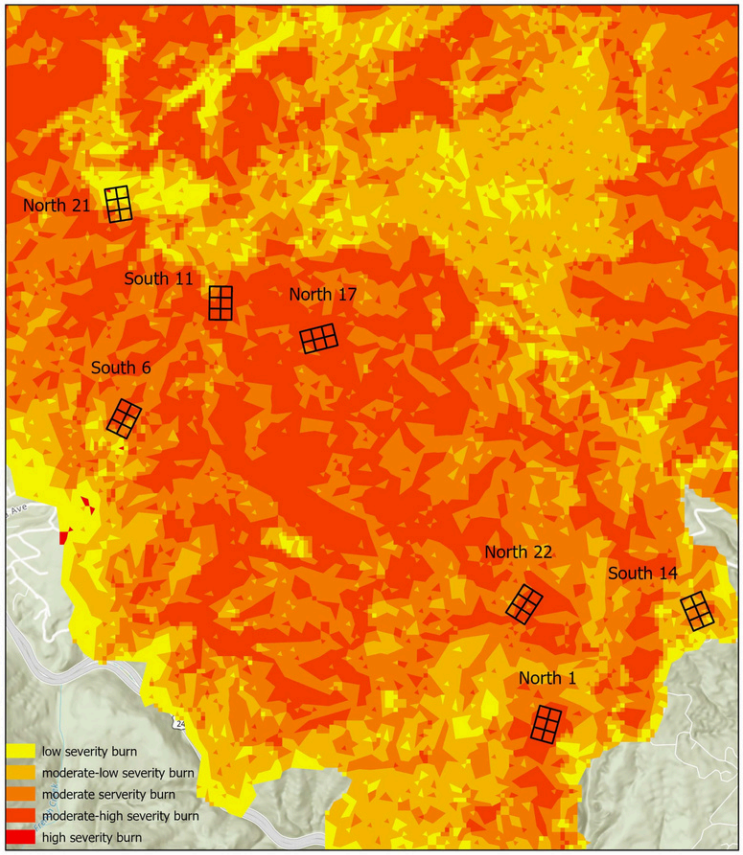

Figure 1. Predicted Burn Severity Map of Waldo Canyon, Colorado Springs adapted from Herros, A. 2018.

Results:

ponderosa pine sapling abundance differed significantly between the control (unburned) and high severity burn plots ($F_{2, 65} = 5.742$, $p = 0.006$). In addition, there was no significant difference in soil nitrogen, carbon, and aluminum oxide levels among the 3 burn treatments.

The preliminary statistical analysis of this research reveals a lack of statistical significance when comparing soil chemistry across the Waldo Canyon burn scar. Considering this fire occurred 11 years ago, it is plausible that the impacts of fire on soil were temporary, even in high severity burns where exceedingly high temperatures can have permanent impacts on soil. Despite these findings, my data show a significant difference in sapling abundance. This could indicate that, in contrast to previous studies done in Canada and the Pacific Northwest, the limiting factor for ponderosa pine sapling regeneration is unrelated to soil chemistry. Studies done in the southwestern United States suggest potential limiting factors for sapling. ponderosa pine regeneration post-fire include soil moisture and temperature. ▲

Thalictrum spp. in day 1 burn area, Waldo Canyon, Woodland Park, Colorado. June 2023. Photo By Cyndy Hines

Dr. Roxaneh Khorsand

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Broadly, my research focuses on the interaction between plant reproductive ecology and the abiotic environment. Specifically, I investigate plant phenology, plant-pollinator networks, floral rewards, and breeding systems in the context of a changing climate. My current research focuses on tundra pollination ecology and plant reproduction. While plant phenological and growth responses to warming are widely documented in the Arctic, less is known about warming effects on plant-pollinator interactions and floral rewards, as well as the implications of these changes on plant and pollinator diversity.

The Effects of Burn Severity on Soil Chemistry and *Pinus ponderosa* Regeneration in Waldo Canyon, CO

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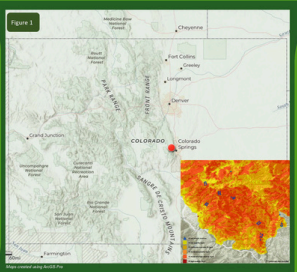
Background: High severity fires can be detrimental to forest types that have not historically experienced these conditions, leading to a low likelihood of forest regeneration and the development of novel post-fire ecological trajectories[1,2]. *Pinus ponderosa* forest is a dominant forest type in the western United States and is poorly adapted to regenerate following high severity fires[3,4]. While factors such as elevation and climate are known to affect *P. ponderosa* regeneration post-fire, less is known regarding how fire-altered soils may impact forest regrowth[5,6]. In this study, I investigate how soil nitrogen, carbon, and aluminum oxide across high and low burn severity sites may be correlated with *P. ponderosa* regeneration. I quantified soil nutrients and sapling abundance in the historic 2012 Waldo Canyon burn scar in Colorado. Given the prediction that high severity fires will increase as the climate continues to warm, understanding the relationship between *P. ponderosa* regeneration and soil chemistry has major implications for land management and conservation in the Rocky Mountain West[1]. The preservation of these forests is crucial due to their importance in providing habitat to numerous native fauna, flora, and providing spaces for human recreation.

Research Questions:

Is there a significant difference in one or more of the following variables among unburned, high, and low severity burn areas of Waldo Canyon, CO?

1. Soil nitrogen levels (N)
2. Soil carbon levels (C)
3. Soil aluminum oxide levels (Al_2O_3)
4. *Pinus ponderosa* sapling abundance

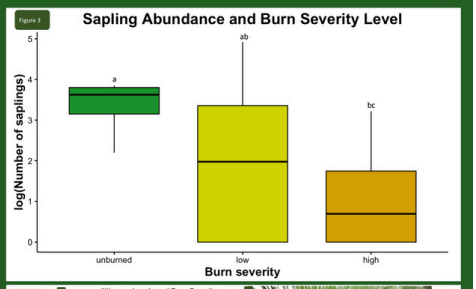


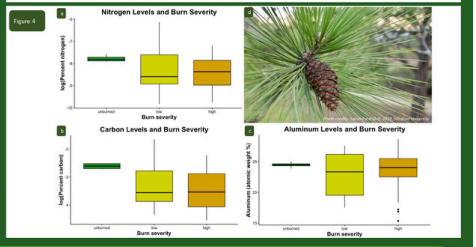
Study Area: The Waldo Canyon fire occurred in Colorado's Front Range in 2012[9]. The burn has been categorized as 19% high severity, 40% moderate severity, and 41% low severity (Figure 1)[7]. Our study area is in the Pike National Forest where much of the burn occurred (Figure 2a). This region is dominated by piñon-juniper woodlands, ponderosa pine, and Douglas fir. Sites were located between 8,500 ft – 9,500 ft in elevation, 38°-39° longitude, and 104°-105° latitude.

Results & Interpretations:

- Pinus ponderosa sapling abundance differed significantly between the control (unburned) and high severity burn plots ($F_{2, 65} = 5.742$, $p = 0.006$) (Figure 3)
- There was no significant difference in soil N,C, and Al_2O_3 levels among the 3 burn treatments (Figure 4a, 4b, 4c)

The preliminary statistical analyses of my research reveal a lack of statistical significance when comparing soil chemistry across the Waldo Canyon burn scar. Considering this fire occurred 11 years ago, it is plausible that the impacts of fire on soil were temporary, even in high severity burn where exceedingly high temperatures can have permanent impacts on soil[6]. Despite these findings, my data show a significant difference in sapling abundance. This could indicate that, unlike previous studies done in Canada and the Pacific Northwest, the limiting factor for *P. ponderosa* sapling regeneration is unrelated to soil chemistry[6]. Studies done in the southwestern United States suggest potential limiting factors for sapling *P. ponderosa* regeneration post-fire include soil moisture and temperature[7].





Methods:

- Used ArcGIS to randomly 12 sites from both north and south aspects; divided each site into six plots for a total of 72 plots.
- Collected six soil samples from each 200 m x 300 m plot; categorized plots as either unburned, high, or low severity burn areas; collected soil samples in a 10 cm x 10 cm square, going to a depth of 10 cm (Figure 2b). A total of 72 samples were collected.
- Removed organic debris, dried at 70°C for 24 hours to remove any remaining moisture, and pulverized for two minutes (Figure 2c).
- Used a Tracer Handheld XRF Spectrometer to measure levels of aluminum oxide; used NC2100 elemental analyzer to quantify levels of nitrogen and carbon.
- Data were log transformed and analyzed in RStudio using One-way ANOVAs.

Future Directions: As research conducted by the Colorado College State of the Rockies Project continues in years to come, the continuation of this dataset for the long-term will allow for the development of a larger sample size that may be able to detect more significant trends among these variables. Furthermore, the introduction of new variables could assist in our understanding of the limiting factor for the regeneration of *Pinus ponderosa* saplings post-fire. More specifically, monitoring soil moisture could add to this dataset as drought is expected to become more severe in these forests as the climate warms[8].

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Figure 2. Results of burn severity on soil chemistry and Pinus ponderosa regeneration in Waldo Canyon, Colorado.

Site 14S in Waldo Canyon. Photo by Maren Greene ‘24.

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