



Lighting off an underburn in the study areas. Each area was about 30 acres.
Credit: USDA Forest Service.

In a Ponderosa Pine Forest, Prescribed Fires Reduce the Likelihood of Scorched Earth

Summary

The Malheur National Forest is located in the Blue Mountains on Oregon's eastern side, the portion of the state that lies east of the Cascade Crest. In the mid 1990s, researchers and land managers conceived a suite of experiments to explore the effects of prescribed fire on forest health. The studies were designed to coincide with prescribed burns conducted by the USDA Forest Service. The experiments took place in the Emigrant Creek Ranger District, a remote area dominated by ponderosa pine. One of the research projects aimed to assess soil health after different intervals of fire frequency and in two burn seasons, spring and fall. Overall, the study revealed that return interval and season of burn had few significantly harmful effects on soil health. Fire can, however, affect the soil's ability to retain moisture, the primary limiting factor in the ability of the tree to thrive.

Key Findings

- Water is the number one limiting factor affecting soils and tree health in the eastern Oregon ponderosa pine forest.
- Initial prescribed fire in the fall burned hotter than the second fall burns and the spring burns, but overall effects on the soil were not significantly different.
- Slightly higher tree mortality was observed on the initial fall burn sites, leading to a reduction in canopy cover and warming the forest floor. Warmer soils may affect the hydrology of the soil in subtle ways.
- Overall, few significant differences in soil were observed between spring and fall burns.

Reducing the threat of wildfire

Ponderosa pine is a western conifer adapted to a wide range of habitats. It thrives in many types of soils, from rich to poor, at elevations from sea level to 10,000 feet, and in temperatures ranging from mild to extremely hot or cold. The most limiting factor to its ability to thrive is soil moisture.

Ponderosa pine is the dominant species in much of the Malheur National Forest, which comprises 1.7 million acres (688,000 hectares) in the southern Blue Mountains of eastern Oregon. The forest, which is located east of the Cascade Peaks, receives low annual precipitation, about 18 inches a year, most of it occurring as heavy winter snowfall. Summers are warm and dry with an occasional thunderstorm.

Historically, fires ignited by lightning or by humans occurred mainly during warm, dry summer months and were typically of low to moderate severity. They spread primarily through the understory and helped maintain the forest in an open, park-like condition. Early settlers and pioneers heading west recorded that they were able to ride horseback and even maneuver wagons unimpeded through the lower elevations of the Blue Mountain forests. At higher elevations, fires of varying extent and severity kept the forest in a patchwork pattern.

Pinus ponderosa and *P. lambertiana*, Prospect, Oregon. Images from the International Phytogeographic Excursion, July–October 1913. Credit: American Environmental Photographs Collection, [AEP Image Number, e.g., AEP-MIN73], Department of Special Collections, University of Chicago Library.



In an effort to reduce the risks of extreme wildfire and return the forest to the historical condition of the mid- to late-1800s, the Forest Service has introduced a regimen of prescribed fire. The main objective is to reduce the heavy fuel load of dead woody debris, saplings, and shrubs. These fuels can act as a ladder, spreading fire to the canopy and resulting in severe, damaging wildfire.

With the heavy fuel loads of today, intentionally setting a fire in the dry summer would be folly. Until the mid 1990s, the prevailing wisdom was that fall, when rains were returning to the forest, was the best window of opportunity for safely applying prescribed fire. Another window of opportunity, however, opens up in late spring, just after snowmelt. Yet many questions about the optimal time and frequency of fire remained unanswered. What would the effect be on insects that can kill trees directly and introduce disease? What changes would occur to ground cover—grass, forbs, and lichens? What would happen to the complex fungal microorganisms that help the soils and root systems heal after fire? And to dig a little deeper, what would be the effect on the soils, which provide the nutrients and retain the moisture necessary for trees to thrive?

To answer some of these questions, the Forest Service and a number of public and private partners teamed up with researchers to work in concert, applying fire in spring and fall and at varying frequencies to reduce fuel load, and using the burn sites as an ongoing experimental laboratory.



Season of Burn study area with typical fuel loads. Credit: USDA Forest Service.

Protecting the soil

Severe wildfire tends to scorch the earth, consuming both coarse woody debris and the organic O horizon of leaf litter and fine woody debris, and affecting soil chemistry

and composition down through deeper soil horizons. A key objective of prescribed fire is to reduce this potential fire hazard, hopefully with minimal negative effects on the forest floor and beneath. “We want to reduce the woody fuels without eliminating the O horizon,” says Darlene Zabowski, a professor of forest soils in the College of Forest Resources at the University of Washington.



An example of a clay-rich soil profile at the season of burn study site. Notice the deep organic-rich A horizon and thinner O horizon. Credit: Darlene Zabowski.

In 2003, a team of researchers led by Zabowski set out to discover whether there were significant, measurable differences between season of burn, spring or fall, on soil health. The study, which was supported by the Joint Fire Science Program, also examined the effects of a frequent or less frequent fire return interval.

Historically, fire return intervals ranged from 6 to 45 years with an average interval of 15 years. The intervals chosen for this series of prescribed fires were 5 and 15 years. The five-year return regimen was intended to imitate the most frequent return interval, and the 15-year interval to model the average historical frequency. For the longer interval, the second round of prescribed fires has not yet been conducted.

The plots are located in a high-elevation stand ranging from 5,200 to nearly 6,000 feet (1,585 to 1,815 meters) on the Emigrant Creek Ranger District. Here, the forest is dominated by ponderosa pine (*Pinus ponderosa*) with some western juniper and mountain mahogany. The area is remote, and there is no evidence of logging activity in recent years.

Three to five years before the studies began, the experimental stands were thinned. The study blocks ranged from 15 to 32 acres (6 to 13 hectares), and were sited in places that would make fire easy to control, using road access and natural barriers such as creeks.

Three treatments, spring burn, fall burn, or no burn, were randomly assigned by the flip of a coin. The first fall

fire was conducted in 1997, and the first spring fire in 1998. Fires were started with a drip torch in strips of a few acres each to eventually cover the entire plot. Canopy and ground cover were measured before and after fire, and the severity of the fire was calculated, from low to moderate to high, by measuring char height on tree boles and the thickness of the forest floor, the O horizon.



Typical underburn after prescribed fire. Credit: USDA Forest Service.

Soil samples were taken down to 30 centimeters and analyzed to determine a number of variables affecting soil health such as pH, carbon and nitrogen content, total organic matter, available phosphorus, and cation exchange capacity, which is a measure of capacity of the soil to retain nutrients. The researchers also measured tree ring growth, and soil moisture and temperature. “We found that spring burns don’t damage the soil but do get rid of enough woody debris to reduce the fuel load,” Zabowski says.

Initial fall fires did burn somewhat hotter than the spring burns or the second fall burns, suggesting that initial spring burns can lower fuel load and decrease the severity of fall burns. The second fall burn at the 5-year interval reduced the thickness of the O horizon by 65 percent compared to the control, leading to patchy exposure of the mineral soil and an increased possibility of erosion. On sites in the 15-year return interval regimen, which were burned just once, the forest floor had time to recover due to the additional accumulation of needle litter and debris.

Phosphorus is an essential nutrient for trees and plants in the understory. The ash that falls to the forest floor after fire tended to increase the concentration of phosphorus available for uptake by plants. Moreover, the fires had no negative effects on the ability of the soil to store and exchange essential nutrients. Future burns could result in further reductions in organic matter of the mineral soil, the A horizon, and eventually reduce the resilience of the soil.

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The research team also found that carbon and nitrogen concentration of the mineral soil was not significantly altered no matter the season or frequency of burn, though

the fall burns reduced carbon concentration by about 17 percent in the A horizon.

The predominant soil type in this study is a Mollisol, which is one of the most nutrient rich soils on Earth, what Zabowski calls ‘primo soil.’ “These soils are rich in soil organic matter and resilient to fire treatments,” says Jeff Hatten, a graduate student at the University of Washington who was involved in the soil studies at the time. Nevertheless, increased consumption of soil organic matter in the hotter fall fires may in the long run lead to changes in soil processes. Hatten, who is currently a post-doctoral research associate at Oregon State University, also cautions that the conclusions from these studies may not apply to forests with less nutrient-rich soils.

Measurements of effects on soil moisture and temperature yielded less clear-cut results. “The higher soil temperatures and lower water content with the fall burns are a little bit of a concern,” says Zabowski. “Nutrients are not the major limiting factor, the biggest factor is water.” If the fall burns open up the canopy and expose the soil to more sunlight, this could affect water availability. Higher soil temperatures may also lead to earlier germination of plants, though if less moisture is available, that might impede the ability of plants to survive.

“The good news from all these findings is that these management treatments may not have a big effect on soil health.”

“The good news from all these findings is that these management treatments may not have a big effect on soil health,” says Zabowski. Since the window of opportunity for prescribed fire can be so small, due to weather conditions and concerns about air quality, the decision when to burn may confidently be guided by the

overriding need to reduce fuel loads and the risk of stand-replacing, severe wildfire.

Fungal disease sparks a suite of studies

Darlene Zabowski’s soil study is one of several that “piggyback” on a much larger research effort. A number of collaborative projects have combined the concerns of managers over forest health, the immediate needs of Forest Service personnel to reduce fuel loads, and the willingness of researchers to collaborate with managers conducting prescribed fire.

In the early 1990s, a Forest Service silviculturist approached Walter G. Thies with a problem. Thies, now an emeritus scientist, was then a field-going forest pathologist with the Pacific Northwest Research Station. The concern was black stain root disease, which was killing thousands of trees in Oregon’s eastern side.

Traditionally, prescribed burns to reduce fine fuel loads were conducted in the autumn, after the fall rains begin. In the 1990s, spring fires became an important part of the burning program, giving two windows of opportunity for burning more acres in a safe, controlled manner. The forester wanted to know whether prescribed burns in spring were leading to an increased incidence of the disease. Black



(Left) Black stain root disease attacks the roots and plugs the vessels, thus depriving the tree of water. (Right) After a burn, the red carpenter beetle (*Dendroctonus valens*) will attack the base of trees, causing a distinctive pitch to form. Credit: USDA Forest Service.

stain root disease is a fungal disease of conifers that is thought to be carried by insects such as root feeding bark beetles, which emerge in the spring and early summer.

Foresters noted that the disease appeared more often in stands burned in the spring and wondered if spring burns were somehow encouraging infestations. Eventually, the facts did not bear out this hypothesis, but the encounter and specific research need spawned a long-term, collaborative project on the Emigrant Creek Ranger district. The effort has involved multiple organizations and research scientists concerned about a number of forest health issues related to prescribed burns.

Initially, the disease studies explored differences in tree mortality between spring and fall prescribed fire. Researchers collected data on 18 units, 12 burn units and six control units covering a total of more than 900 acres (364 hectares). “The miracle is that considering weather conditions and staff availability, all 12 burns were conducted on schedule and within prescription,” says Thies. “It took careful planning and an extra effort by the staff of the ranger district and the staff of the Burns Interagency Fire Zone.”

Foresters then asked about the effects of return interval on tree mortality and other parts of the ecosystem. The 12 burn units were each divided into two, half to be burned at 5-year intervals—so far two repeat burns have been conducted—and half at year 15. So far, 36 burns (12 each at study year 0, 5, and 10) have been conducted on schedule and within prescription. Eventually, the scope of the study expanded, and researchers in various disciplines became involved in the project. “This study started off looking at one thing, black stain root disease, and then morphed and morphed again, building on earlier efforts and data to look at soils, lichens, grasses and forbs, and mycorrhizae,” says Thies. The size of the experimental plots, 15 to 32 acres (6 to 13 hectares), is large relative to many studies. “Often field studies involve small plots or focus on only one part of the ecosystem,” he says. The number of acres burned closely

reflects the actual behavior of low to moderate severity fires that were the historical norm.

From his ongoing research, Thies has recently developed a simple model foresters can use to determine the

"We think we have a simple field guide to predict the probability of mortality of fire-damaged ponderosa pine."

effects of prescribed fire on mortality of fire-damaged ponderosa pine, a crucial piece of information regardless of management objectives. Choosing from five predictive variables, the model uses only two that are easily measured by a walk-through of the forest, proportion of crown scorch and proportion of bole scorch. "We think

we have a simple field guide to predict the probability of mortality of fire-damaged ponderosa pine," Thies says.

The good earth

Mollisols, the predominant topsoil of the experimental area, belong to an order of soil taxonomy characterized by high concentrations of organic matter, high fertility, and good physical properties. Mollisols typically developed under grasslands and are associated with areas of high agricultural productivity. As the grass roots die back, they release carbon and other nutrients back into the soil. Scientists speculate that the ponderosa pine forest of Malheur today may have been a prairie 500 years ago. As the climate changed from 6,000 years ago, when it was hotter and drier, to the cooler and wetter climate of the 1800s, the forest may have slowly moved downslope to take over the rich grasslands.

Since ponderosa pine grows on a wide variety of soils, fire's effects on soil health in other pine forest stands with different soils may not yield similar results.



The central concept of Mollisols is that of soils that have a dark colored surface horizon and are base rich. Credit: Natural Resources Conservation Service, U.S. Department of Agriculture.

Management Implications

- Frequent prescribed fire of low to moderate severity significantly reduces fuel loads and is less destructive to forests and the soil than scorching, severe wildfire.
- Ponderosa pine thrives on widely different soils, from nutrient deficient to very rich. Since the soils on the experimental plots are among the richest on Earth, the outcome using prescribed fire in forests with different soils may be different.
- If conditions allow, initial spring burns may reduce fuel loads and allow subsequent use of fall burns with lower severity and less potential damage to soils.
- A more frequent return interval repeated for many years may be harsher for soils than less frequent burns.

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Scientist Profiles

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Does Season of Burn and Burn Interval Affect Soil Productivity and Processes in a Ponderosa Pine Ecosystem?

Written By: Paige Houston

Purpose of this opinion piece

Manager's Viewpoint is an opinion piece written by a fire or land manager based on information in a JFSP final report and other supporting documents. This is our way of helping managers interpret science findings. If readers have differing viewpoints, we encourage further dialogue through additional opinions. Please contact Tim Swedberg to submit input (timothy_swedberg@nifc.blm.gov). Our intent is to start conversations about what works and what doesn't.

Problem

Even though prescribed burning has been a form of fuels reduction for many decades, limited knowledge of exactly how burning impacts soil properties—both short-term and long-term—is still being researched and debated. Ponderosa pine ecosystems historically underwent frequent burning that led to lower intensities and severity. Fuel loadings today are much greater, contributing to higher-intensity and higher-severity fires that, in turn, result in changes to soil properties.

This study researched how fire frequency and time of season for conducting prescribed burns contribute to effects on soil properties by altering the carbon and nitrogen cycling levels throughout sites in ponderosa pine ecosystems. The study also addressed how initial entry of fire onto sites that haven't had fire for several decades could pose long-term problems such as harsher soils and possibly introducing weeds. This study explains the pros and cons of burning during each season and how time of year can be critical.

Application by Land Managers: Meeting Desired Burn Objectives

Much of the conceptual information collected from this study will provide fire managers the tools for analyzing strategies that identify which burn season—and fire frequency—will best meet the desired objectives.

The methods described include soil sampling strategies that measure carbon and nitrogen fluctuations after burns implemented at 5- and 15-year intervals, with frequency occurring once during the 15-year interval and twice—during spring and fall—for the 5-year interval. In addition, the pH levels were measured at various soil horizons during the respective intervals, with pH levels increasing after fall burning due to increased consumption (Thies 2007).

The study concludes that carbon and nitrogen levels are dependent on fire severity and consumption of soil organic matter. It determined that fall burning contributes to this outcome due to this season's hotter and drier conditions when moisture within the soil is lower. The result: higher burning intensities and severities.

The removal of the O horizon creates a change in site conditions leading to increased snow melt, longer growing seasons, and decreased soil moisture values (Thies 2007). The study illustrates how fall burning under these conditions can create soil hydrophobicity (repelling water) that alters how nutrient cycling is conducted on site (Thies 2007). Many of the nutrients come from the O horizon. If you are conducting an initial entry in the fall season, you might want to reconsider a spring burn that would be less intense and severe; thus, leaving more of the O horizon on site for nutrient cycling (Thies 2007). In addition, spring burning offers lower severity and intensity with an increase in coarse woody debris, grasses, forbs and nutrient cycling ability.

Soil Sampling Studies

This study illustrates a great detail of soil sampling strategies. However, considering the amount of time that it took to gather this information, it might not be possible for fire managers to conduct such strategies. Moreover, rarely do managers have access to soil scientists to accomplish this type of sampling across vast landscapes before implementing a district-level prescribed burn.

Through frequent burning, a greater reduction in carbon and nitrogen follows fall burns versus spring burns. This is attributed to the increased consumption of the organic matter at the O and A horizons (Thies 2007). Depending on the size class and consumption, soil productivity is also greatly altered and coarse woody debris has various amounts of carbon and nitrogen (Thies 2007). Other studies indicate that fire regimes are closely tied to the cycling of carbon after fire events and illustrate how fires transform those landscapes over time (Keane 2007). Comparatively speaking, fire managers understand that fire greatly influences how sites come back after fire and that frequency and severity are contributing factors.

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Much Still to be Learned

The statistical data analysis for this study was also collected from exotic species, native plant species, soil moistures, tree growth, insects and diseases, nutrient cycling, fuel consumption, fire intensity and severity, and fluctuations in organic material—all of which affect soil productivity.

While the goal of this study was to determine time of season and how often fire managers should implement prescribed burning, its scientists determined that much is still to be learned about the long-term effects brought on by prescribed burning.

The assumption that fire managers implement burning without understanding the ecological “big picture” (Vose 2000) can motivate fire managers to defend their rationale. Furthermore, as stated by this study, fire managers typically have two choices: either burning in spring or fall. However, managers must make a range of decisions surrounding whether or not all

burn objectives can be attained. Often times, fire managers must confront the unrealistic expectations that scientists can place on them.

Today, more and more studies agree that information is still being gathered and that not all variables are known regarding ecological changes in the ponderosa pine ecosystems (DeLuca 2006). Fire managers understand these processes; they are doing the best they can with the science that is available.

Fire managers understand these processes; they are doing the best they can with the science that is available.

Other statistical analyses illustrate that spring burns contribute to lower intensity and severity, and fall burns contribute to greater reduction in fuel loads but higher intensity and severity. Trying to determine which time of year to burn can be challenging. Oftentimes, other uncontrollable factors—such as weather constraints and available suppression resources—impact this decision-making process. On reflection, it seems that this study did not address such factors.

Other studies indicate that fire intervals in ponderosa pine forests were somewhere between 15-23 year intervals and anywhere up to 40 years (Graham 2005). This study shows how frequent burning at 5-year intervals versus 15-year intervals contributes to reductions in soil productivity and that fall burns usually occur under higher temperatures, lower soil moistures, and increased fuel loadings—hence, higher fire intensity and on-site severity.

On the other hand, this same scenario can produce longer growing seasons by reduced O horizon and competing vegetation (Thies 2007). Each site, however, will have unique characteristics and different moisture values (Swift 1993) that will change the characteristics of the fire behavior and the impact on soil properties. But the initial entry of a fall burn with the intention to reduce heavy or high fuel loads can contribute to more of an impact on the soil as well as a longer recovery period (Thies 2007). This study suggests that before implementing a fall burn as the initial entry, a spring burn could reduce the fuel loadings to a more manageable level (Thies 2007).

The overall consensus from this study and other studies is that fire managers have the ability to put fire back on the landscape, therefore influencing sites for decades to come. More specifically, the research from this study provides insight to how timing and intervals impact soil and other processes. Such discussion encourages the application of alternative prescribed burning methods.

As scientists are quick to point out, for fire managers to become better acquainted with the impacts of fire on ecological processes such as soil properties, scientists also need to become better acquainted with the various complexities that fire managers face when implementing fire. These complexities include life, property, and values-at-risk—in that order.

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Manager Profile

Paige Houston is the Regional Aviation Training Specialist at the Northern Rockies Training Center in Missoula, MT. She has 22 years experience in fire management across several USDA Forest Service regions, and a few years with the USDI Bureau of Land Management. She currently serves as a primary Division Group Supervisor on the Northern Rockies Type 1 Incident Management Team and instructs a variety of fire and leadership courses in northwest Montana, at the Wildland Fire Apprentice Academy, and with the National Smokejumper Association. She spent eight years with the Bitterroot and Lolo hotshot crews and worked two seasons with the Alaska Smokejumpers.



She has several more years of experience in other primary firefighter and fuel management positions, including a season with the rappellers out of Chelan, WA. She's a graduate of the University of Montana where she received a degree in resource conservation.

The information for this Manager's Viewpoint is based on JFSP Project 04-2-1-85, Does Season of Burn and Burn Interval Affect Soil Productivity and Processes in a Ponderosa Pine Ecosystem?; Principal Investigators were Walter G. Thies and D. Zabowski.