2011

Assessing Post-fire Treatment Effects and Burn Severity on the Sandy Loam Soils of Oregon

Shari Anstedt
US Forest Service, sanstedt@comcast.net

Joint Fire Science Program
Fire Science Brief
RESEARCH SUPPORTING SOUND DECISIONS

A blanket of severely burned red soil remains after the 2003 Booth and Bear Butte (B&B) fire, providing a timely opportunity for researchers to collect study samples. Credit: Douglas Shank.

Assessing Post-fire Treatment Effects and Burn Severity on the Sandy Loam Soils of Oregon

Summary

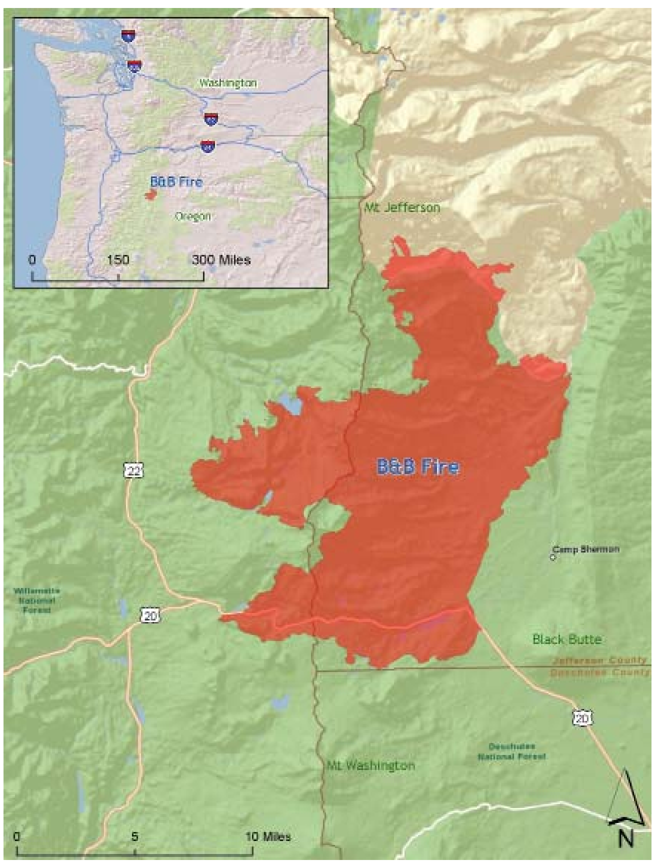
Fire helps reduce dead and accumulated vegetation and enriches the soil by releasing nutrients bound in litter. But when fuel loads are too high and wildfires burn too hot, problems may arise. A perfect example of this is the 2003 Booth and Bear Butte (B&B) fire in central Oregon, which consumed more than 90,000 acres of mixed conifer forest. On the surface, the effects on trees and vegetation seemed obvious, but what about the wildfire effects on what we don't see? How do post-fire management activities support or impede forest recovery? Furthermore, how were the soils, and essential underground ecosystem, affected? To help provide necessary answers and better understand the effects of salvage logging, sub-soiling, and fire severity on soil microbial communities and properties, vegetation, and forest recovery, researchers conducted two interrelated studies in the B&B Fire Complex area. This project was developed in response to the concerns of forest and resource managers with the intention of using the study results to fine-tune post-fire treatment methods and speed the forest recovery process.

Key Findings

- Plant available nitrogen was on average 27 percent less—ranging from 7 to 47 percent—in soils compacted by logging equipment without subsoiling and plant available phosphorus was on average 26 percent less—ranging from 2 to 49 percent—in soils that had been subsoiled after compaction, compared to soils exposed to burning with no mechanical disturbance.
- Fungal and bacterial communities displayed short term or no differences among treatments.
- Subsoiling positively affected seedling survival and growth of out-planted ponderosa pine and Douglas-fir seedlings.
- Soil burn severity was the most important factor influencing microbial community structure the first two years after fire.
- Total microbial abundance was 60 percent less in severely burned red soils than in less severely burned black soils.
- Vegetation surveys conducted two years post-fire indicated 50 percent less plant cover on severely burned red soil plots compared to mildly burned black soil plots.

Heat-sensitive soil

Soil is the backbone of forest biodiversity. It is a complex living system consisting of weathered rock, organic matter, and small living organisms. It provides aboveground plants with the critical elements needed to thrive, such as nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. And it benefits from frequent, low-intensity fire.



The study location consisted of open and dry mixed conifer forests in the eastern Cascade Mountains. Historically, this region experienced frequent, low-severity fire.

The temperature and duration of fire is important because the biological properties of soil are sensitive to heating—with 212 degrees Fahrenheit being the fatal threshold for most living organisms. When soils are severely burned, they undergo a distinctive color change, where the top layer of mineral soil changes to various shades of red. This red soil is commonly believed to be sterile, but this has not been proven.

In the western United States, fire suppression has contributed to a change in fire dynamics, from the low-intensity fires of the past to more severe, stand-replacing wildfires. One such fire, the 2003 Booth and Bear Butte (B&B) Fire, burned more than 90,000 acres in the Cascade Mountains of central Oregon. With high fuel loads and dense stands, the fires were extremely hot, intense, and difficult to control. Fire intensity and soil burn severity were also high in areas with large amounts of down wood. After the fire, a significant amount of standing dead timber remained, putting the soil at further risk of being severely burned in the event of a future fire.

To help speed forest recovery, managers perform post-fire management activities such as salvage logging and sub-soiling. While salvage logging removes large fire-killed trees and helps reduce future burn severity, the heavy machinery can compact the soil, reducing pore size and oxygen availability and impeding the flow of water and nutrients to tree roots. The dense, compacted soil is also more difficult for burrowing animals to penetrate. Therefore, sub-soiling, or deep tillage, may follow salvage logging to help break up the dense soil and improve infiltration, aeration, and tree growth.

Despite the efforts to alleviate the impacts of high-severity fire, there are many unanswered questions on how the soils—and overall forest ecosystem—respond to such disturbances. To help answer these questions and to better understand an understudied topic, researchers conducted two interrelated studies in the B&B Fire Complex area. Aligned with the region's highest resource management priorities, the study objectives focused on:

- Examining post-fire salvage logging effects on soil microbial communities and soil properties.
- Investigating effects of compaction and subsoiling on ponderosa pine and Douglas-fir tree seedling growth planted after harvesting.

- Assessing the recovery and differences in soil microbial community composition between severely burned soils and less severely burned soils.
- Analyzing differences in soil chemical, physical, and biological properties between the two burn severities.

Located on the eastern side of the Cascade Mountains, the studies took place in the Deschutes National Forest. Since the Cascade Mountains block marine air masses from the Pacific Ocean, the eastern slope is comparatively drier than the west slope, with sandy loam soils and a wide variety of mixed conifer tree species including White fir (*Abies concolor*), Grand fir (*Abies grandis*), Ponderosa pine (*Pinus ponderosa*), and Douglas-fir (*Pseudotsuga menziesii*).

One year after the B&B fire, timber harvesting was performed, providing a timely opportunity for this research. To assess post-fire treatment effects, seven salvage-logged stands were sampled with three treatments each, including burning with no further disturbance, compaction from heavy ground-based machinery, and compaction followed by subsoiling. In total, 63 plots were sampled over the course of two years.

For the burn severity portion of the study, researchers gathered 12 paired samples of severely burned red and black soils immediately after the containment of the B&B fire and in plots that had not been salvage logged. In 2004, the study was expanded to include a total of five stands within the perimeter of the fire where significant percentages of severely burned soils accompanied significant tree mortality due to stand-replacing wildfire.

Soil samples reveal stark color differences between different burn severities. Credit: Cassie Hebel.

In both studies, a combination of methods was used to examine the effects of post-fire salvage logging and burn severity on soil microbial communities. Researchers used polymerase chain reaction (PCR)-based molecular techniques to determine species richness and community composition, phospholipid fatty acid (PLFA) analyses to detect the presence and abundance of broad microbial groups, and community-level physiological profiles (CLPP) to assess functional diversity.

Research revelations

Salvage logging

Compaction and subsoiling treatments had either no effect or a short-term effect on the soil microbial communities in this study. However, the disturbance of heavy equipment did affect plant available forms of nitrogen and phosphorus, which are macronutrients that are critical to plant growth and soil productivity. In soils compacted by logging equipment only, plant available nitrogen was on average 27 percent less—ranging from 7 to 47 percent—and in soils that had been subsoiled after compaction, plant available phosphorus was on average 26 percent less—ranging from 2 to 49 percent—compared to soils that had been exposed to burning with no mechanical disturbance. Conversely, the bacterial and fungal communities in the soil did not differ among the treatments. Principal investigator Jane Smith stated, “It would be interesting to follow changes in these soils over time to determine how long-lasting the disturbance effects on plant nutrient availability will be, especially since the microbial communities necessary for cycling these nutrients appear resilient to the mechanical disturbances.”

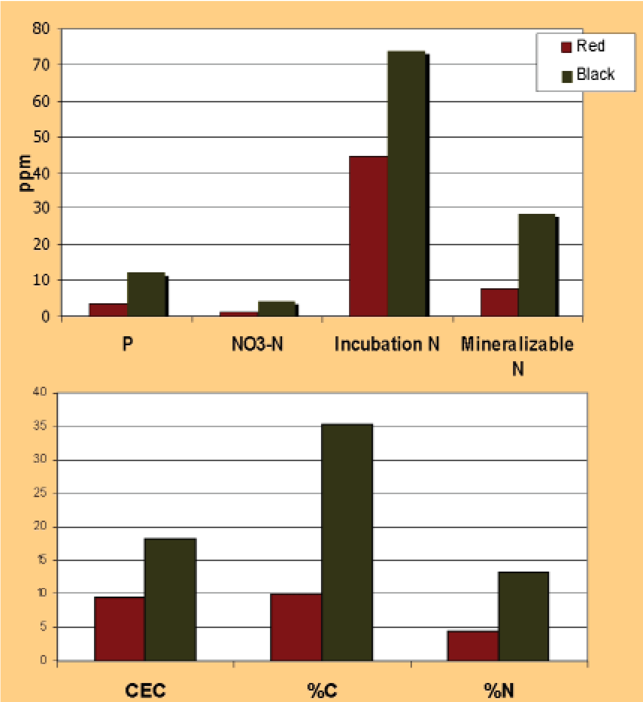
Douglas-fir and ponderosa pine seedlings were positively affected by subsoiling treatments, with the median percent survival and height growth in subsoiled plots being significantly higher than in compacted and undisturbed plots. The median diameter growth of ponderosa pine in subsoiled plots was significantly higher than in compacted and undisturbed plots. The median diameter growth of Douglas-fir in subsoiled plots was also significantly higher than in undisturbed plots, but did not differ between subsoiled and compacted plots.

Fire severity

In the first two years after fire, soil burn severity was the most important factor influencing microbial community structure. Although the preliminary study indicated that severely burned red soils were initially greatly reduced of microbes, they were not sterile. Smith stated, “In our early preliminary sampling immediately after the fire, we were surprised to find only a single fungus species in the majority of the severely burned red soil samples. DNA sequencing showed that it is a species of saprobic ‘fire-loving fungi,’ because they typically fruit only after fire.”

Two years after fire, mean fungal species richness remained significantly less in the severely burned soils compared to the moderately burned soils. Results of the PLFA analysis showed that the soil microbial communities of severely burned red soil differed from moderately burned black soil. Severe soil heating as well as loss of organic matter increased the mortality of all soil microbial groups in red soils.

Four years after fire there was no difference in the cumulative mean number or mean number of fungal or bacterial species between burn severities. Fungal and bacterial community composition of the burn severities did not differ four years after the fire even though some species were detected only in red or black soils. According to Smith, “We have observed what appears to be resiliency of the soil fungal and bacterial communities to fire severity, but it is important to look at a more complete picture of the forest soil ecosystem. Soil nutrients, critical to plant growth, were highly reduced in the severely burned red soils. Such nutrient reductions will most likely not rebound in our lifetime."



Study results indicated that soil nutrients were substantially lower in severely burned red soils than black soils.

Burn severity influences microbial dynamics and soil nutrient availability, which affect plant initiation and development in burned areas. Two years post-fire, vegetation surveys revealed that percent cover was more than 51 percent lower in severely burned red soil plots compared to less severely burned black soil plots. Net mineralizable N and available soil P were substantially reduced in red soil by 73 percent and 71 percent respectively, possibly contributing to the lower percent vegetation cover observed on these soils.

Mindful steps forward

Decreased nitrogen and phosphorus in the soil from severe wildfire and mechanical disturbance may have long-lasting effects in an already nutrient-limited system, yet soil microbes, critical to mediating decomposition and nutrient cycling, appear resilient to the occurrence of wildfire and mechanical disturbance in sandy loam soils. When contemplating post-fire salvage logging, researchers recommend that managers first consider the results of these studies, the recovery potential of a site, and the impending risk of future fire in stands that differ in structure from historic conditions.

To help reduce the possibility of severely burned soils in areas with high densities of fire-killed trees, researchers suggest using fuel treatments that produce a low-density stand structure and include large, fire-resistant pines. Also, when applying fuel treatments, managers should try to keep soil disturbance to a minimum.

To the naked eye, post-fire vegetative cover appears to recover quickly. However, study results indicated a more complex, varied response to disturbance. Credit: Doni McKay.

"These are complex ecosystems and there are no easy answers. Forest managers must balance the uncertainty about the impacts of fuel-reducing treatments with the probability of stand-replacing wildfire and future fire in fire-killed forests. These studies provide knowledge about the short-term impacts of mechanical disturbance after fire and about severe burning. How these scenarios play out over time remains to be seen. Because there is still so much to learn about the recovery of this complex ecosystem, soils and plant productivity should continue to be monitored in an adaptive management framework," stated Smith.

More ground to cover

Forest managers are faced with uncertainty. But with help from scientific studies such as the ones highlighted here, managers can obtain the valuable information they need to fine-tune management decisions and treatment methods. Furthermore, with a greater awareness of how soil microbes, soil nutrients, and vegetation respond to severe wildfire and post-fire salvage logging, forest managers can better determine which fuel-reduction treatments will be the most effective at maintaining critical soil processes.

Yet, to fully understand the impact of post-fire treatment methods on soils and soil recovery, further investigation is needed. Researchers suggest a continued exploration of the following:

- Salvage logging effects.
- Soil microbial communities and the role of nitrogen-fixing plants on soil recovery.
- The time required for soil nutrients to reach comparable levels in severely burned and less severely burned soils.
- Soil nutrients, soil changes, and seedling growth related to the different treatments over a longer period of time (beyond 2–4 years post-fire).
- Soil properties and vegetation between areas receiving frequent low severity fires and severely burned areas.
- Tree seedling growth on salvage logged areas to determine if seedlings planted in the subsoiled treatments continue to outperform seedlings planted in compacted or undisturbed soil treatments.

Management Implications

- Red soils are not completely sterile, but they can take longer to recover.
- Subsoiling has a positive effect on the growth of seedlings.
- Before employing post-fire salvage logging, consider the results from these studies as well as the recovery potential of a site and the risk of future fire in stands where the structure differs from historic conditions.
- Apply fuel treatments that produce a low-density stand structure and retain large, fire-resistant pines in the overstory.
- Use care when performing fuel treatments to limit soil disturbance.
- Continue monitoring soils and plant productivity within an adaptive management framework.

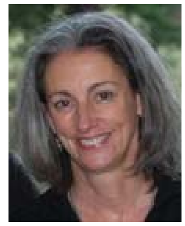
Further Information: Publications and Web Resources

Hebel, C.L., J.E. Smith, K. Cromack, Jr. 2009. Invasive plant species and soil microbial response to wildfire burn severity in the Cascade Range, Oregon. *Journal of Applied Soil Ecology*, 42: 150-159. http://www.firescience.gov/projects/05-2-1-44/project/05-2-1-44_2009.Hebel_Applied-Soil-Ecology.pdf

Oliver, M. 2010. Red but not dead: examining microbial and plant recovery in severely burned soils. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. http://www.fs.fed.us/pnw/sciencef/scifi124.pdf

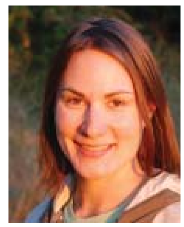
Trappe, J.M., R. Molina, D.L. Luoma, E. Cázares, D. Pilz, J.E. Smith, M.A. Castellano, S.L. Miller, M. Trappe. 2009. Diversity, ecology, and conservation of truffle fungi in forests of the Pacific Northwest. Gen. Tech. Rep. PNW-GTR-772. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. http://www.firescience.gov/projects/05-2-1-44/project/05-2-1-44_2009.Trappe_Truffle.PNWGTR772.pdf

Scientist Profile



A Research Botanist, **Dr. Jane E. Smith** has been with the USDA Forest Service, Pacific Northwest Research Station since 1987. She received a BA in Botany from Humboldt State University, and an MS in Forest Ecology, and a PhD in Botany and Plant Pathology from Oregon State University.

Jane can be reached at:
Pacific Northwest Research Station
3200 Jefferson Way, Corvallis, OR 97331
Phone: 541-750-7387 • Fax: 541-750-7329 • Email: jsmith01@fs.fed.us



Cassie L. Hebel earned a BS in Biology/Zoology from Eastern Washington University and an MS in Forest Ecology from Oregon State University. She currently works as a spatial analyst for Watershed Sciences, a Corvallis-based remote sensing company.

Cassie can be reached at:
517 SW 2nd St., Suite 400, Corvallis, OR 97333
Phone: 541-752-1204 • Email: chebel@watershedsciences.com

Tara N. Jennings earned a BS in Biology with a minor in Chemistry and an MS in Forest Ecology from Oregon State University. She currently works as a biological science technician for the USDA Forest Service, Pacific Northwest Research Station in the genetics team.

Tara can be reached at:
Pacific Northwest Research Station
333 SW First Avenue, Portland, OR 97204
Phone: 541-750-7301 • Email: tjennings@fs.fed.us

Since 1989, **Doni McKay** has been with the USDA Forest Service, Pacific Northwest Research Station. She earned an AS in Horticulture from Linn Benton Community College and a BS in General Agriculture from Oregon State University.

Doni can be reached at:
Pacific Northwest Research Station
333 SW First Avenue, Portland, OR 97204
Phone: 541-750-7392 • Email: dmckay@fs.fed.us

Collaborators

Kermit Cromack, Jr., Department of Forest Ecosystems and Society, Oregon State University
Bruce Caldwell, Department of Botany and Plant Pathology, Oregon State University
Douglas Shank, Willamette National Forest
Peter Sussmann and **Brian Tandy**, Deschutes National Forest

Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

The information in this Brief is written from JFSP Project Number 05-2-1-44, which is available at www.firescience.gov.

An Interagency Research, Development, and Applications Partnership

JFSP *Fire Science Brief* is published monthly. Our goal is to help managers find and use the best available fire science information.

Learn more about the Joint Fire Science Program at *www.firescience.gov*

John Cissel
Program Manager
208-387-5349
National Interagency Fire Center
3833 S. Development Ave.
Boise, ID 83705-5354

Tim Swedberg
Communication Director
Timothy_Swedberg@nifc.blm.gov
208-387-5865

Writer
Sheri Anstedt
sanstedt@comcast.net

Design and Layout
RED, Inc. Communications
red@redinc.com
208-528-0051