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INSIDE

"Science affects the way we think together."

Lewis Thomas

RED BUT NOT DEAD: EXAMINING MICROBIAL AND PLANT RECOVERY IN SEVERELY BURNED SOILS

Each separate dying ember wrought its ghost upon the floor.

—Edgar Allan Poe

Before the 2003 Booth and Bear Butte (B&B) Fire Complex in central Oregon, the floor of the mixed ponderosa pine and Douglas-fir forest was strewn with down wood. Afterward, although most of the fallen wood was gone, it was still possible to see where the larger logs had lain. The soil under them was now a distinctive red, leaving criss-crossing patterns across the otherwise bare, blackened ground. Prefire location of stumps was similarly identifiable by patches of red soil up to 3 feet across. Just as a good-sized log makes for a steady burning campfire, once ignited, large down wood and stumps smoldered for days, exposing the soil under and near them to intense, prolonged heat. The heating process volatilized soil nutrients and oxidized the top layer of soil, turning it various shades of red.

Doni McKay

Researchers found that soil severely burned during the 2003 B&B Fire in central Oregon was not sterile, contrary to conventional wisdom, although microbial communities were greatly reduced. They also learned that the relationship between severely burned soil and revegetating native or nonnative plants is more complex than originally thought.

Severe burning has long been thought to sterilize soil by killing the soil-dwelling fungi, bacteria, and other micro-organisms that comprise the soil ecosystem. In turn, it was thought that these red, severely burned soils were more susceptible to invasion by opportunistic nonnative plant species than less severely burned soil. Jane Smith, a research botanist with the Pacific Northwest Research Station, Cassie Hebel, then a Master's student in the College of Forestry at Oregon State University, and other collaborators decided to test these assumptions.

Their studies were the first to examine soil chemistry and soil microbial and plant communities in naturally occurring red soils after

IN SUMMARY

Soil exposed to prolonged intense heat during a wildfire turns a distinctive red color. The heat volatilizes soil nutrients and kills subterranean microbial communities. Patches of severely burned red soil are found most frequently in areas that were heavily covered with down, dead wood before the fire. It has long been thought that exposure to such heat sterilized soil, leaving it more susceptible to invasion by nonnative plant species than less severely burned soils.

Station scientists and collaborators initiated several soil-related studies after the 2003 B&B Fire Complex in the central Oregon Cascades to better understand the relationships among fire severity, soil microbial communities, and invasive nonnative plant species.

They found that, although soil nutrients and microbial abundance were greatly reduced, severely burned red soils were not sterile. They also found that growth of invasive plant species is limited by nutrient availability, rather than microbial diversity or mycorrhizal relationships. In the laboratory using soils from the study site, scientists found that nonnative species grew bigger than native species. However, nonnative plants grown in red soils were smaller than those grown in less severely burned black soils. Native plant growth did not differ in the red or black soil, raising questions about how nonnative and native plants will grow and compete long term in nutrient-limited environments.

a wildfire. Previous research had examined fire scars created by burning slash piles of logging debris. Those studies basically affirmed conventional wisdom, finding it takes longer for plants to regenerate when the soil has been subjected to fire for long periods, and that the colonization of nonnative plant species increased. One big difference, however, between a slash pile burn and a wildfire like the B&B Fire Complex is the amount of heat generated. The B&B Fire burned hotter than the slash piles, and thus reduced the nutrient availability in the soil even further. Smith's research team wanted to know if this made a difference in terms of ecosystem recovery.

Were the red soils formed during the B&B Fire Complex actually devoid of life? If they were not sterilized, what microbial communities were present? How vulnerable would these red soil patches be to invasion by nonnative species?

KEY FINDINGS

- The top 2 inches of severely burned red soil was highly nutrient limited, containing 71 percent less carbon and phosphorous and 69 percent less nitrogen than less severely burned black soil.
- Total microbial abundance was 60 percent less in red soils than in black soils.
- Vegetation surveys 2 years postfire revealed that the percentage of plant cover was more than 50 percent lower in red soils compared to black soils.
- Nonnative plants grew more rapidly than native plants in both red and black soils, but nonnative plants were smaller when grown in red soils. Native plant growth was the same in both soils.
- Nonnative plants were more nutrient dependent and therefore may be less competitive than native plants in nutrient-limited red soils.

A CLOSER LOOK AT RED SOIL

The effects of wildfire on soil ecosystems largely depend on how a fire develops, moves through a landscape, and duration of burn time. A crown fire burns quickly and can be lethal to the standing trees in its path, but it may not cause much damage to the forest floor. In contrast, a surface fire moving through accumulated fuel on the ground has the potential to smolder for days. Severely burned red soils generally are more prevalent in stands where large numbers of fallen trees were on the forest floor before the fire occurred.

Decades of fire suppression and other factors have resulted in accumulated surface fuel in many publicly owned forests throughout the Pacific Northwest. Conversely, previously burned forests also can accumulate large amounts of surface fuel relatively quickly: standing fire-killed trees are now beginning to fall across much of the 90,000 acres burned by the B&B Fire Complex on the Deschutes and Willamette National Forests. Understanding the short- and long-term role severely burned soil plays in shaping the postfire forest is critical to forest recovery projects.

Doni McKay

Crisscrossing patterns of red, severely burned soil show where logs lay before the fire.

Purpose of PNW Science Findings

To provide scientific information to people who make and influence decisions about managing land.

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Rhonda Mazza, editor; rmazza@fs.fed.us

Cheryl Jennings, layout; cjennings@fs.fed.us

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Jane Smith

Greater amounts of severely burned soil are found in areas where there had been large pieces of down wood before the fire.

Doni McKay

Shortly after the fire was contained, researchers found one species of fungus in the severely burned soil.

Hoping to learn more, Smith's research team took preliminary samples of freshly burned red soils shortly after the fire was contained in 2003 and found one species of fungus present. A year later, Hebel conducted more extensive sampling of red and black soils from adjacent study plots. She analyzed the samples to determine the abundance and variety of soil micro-organisms such as fungi, bacteria, and protozoa. The analyses revealed that, although the micro-organism communities that make soil a fertile growing medium were greatly affected by severe burning, the red soil was not sterile. The total microbial abundance was 60 percent lower in red soil compared to black soil. But, "the building blocks were there," says Hebel. "Numbers were reduced, but they were coming back."

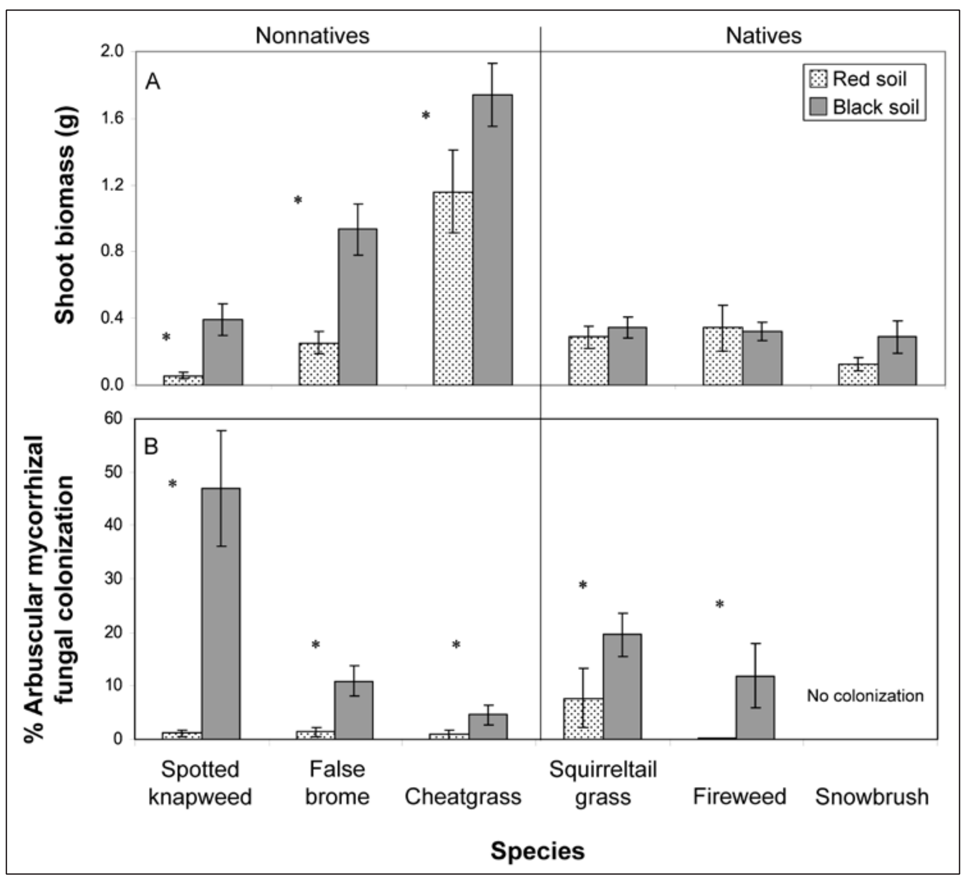
LOOKING FOR MYCORRHIZAL CONNECTIONS

The beneficial relationships between belowground mycorrhizal fungi and aboveground vegetation are well documented. Mycorrhizae connect with plant and tree roots, helping them absorb soil nutrients and water. In turn, the fungi obtain carbon and sugars from the plants and trees.

Other studies have found that increasing varieties of fungal species promote an increase in plant biodiversity, and therefore directly influence the structure of plant communities and ecosystem productivity. So what does this mean for vegetation regeneration in soils where the variety and numbers of mycorrhizal fungi have been greatly reduced?

"We hypothesized that if the microbial abundance and diversity were changed in red soil, one kind of plant or another would grow differently because of the presence or absence of mycorrhizae," Hebel says. To test this hypothesis, Hebel established controlled laboratory experiments that would yield information about the different growth rates of native and nonnative plants in red and black soil.

In the laboratory, Hebel grew three native plant species and three nonnative species from seed sources in or near the study sites. "We were controlling for the soil," she says. The three early successional native species studied were snowbrush, fireweed, and squirreltail



Nonnative plants grew better in black, less severely burned soil than they did in red severely burned soil. Native plants grew about the same in either soil. Researchers found no apparent relationship between abundance of mycorrhizal fungi and plant growth. Significant differences between means ($\alpha \leq 0.05$) are denoted with an (*).

grass. Nonnatives included three highly invasive species of concern in the area: cheatgrass, false brome, and spotted knapweed.

"We found that nonnative plants grown in the black soil were significantly bigger than plants grown in red soil, whereas native plants grown in black or red soil did not exhibit growth differences, explains Hebel. After analyzing plant roots for mycorrhizal fungi and finding no apparent relationships between abundance of mycorrhizal fungi and plant growth, they were stumped. "This result was surprising because we initially hypothesized that the native plants would be negatively influenced by the low abundance and diversity of soil microbes in the red soil," says Hebel.

"We needed to find what was driving the different growth responses of nonnative and native plant species in the red and black soils," Hebel says. "Once we compared soil nutrients and chemistry with nonnative plant growth, it became clear."

NATIVE ADVANTAGE?

Many invasive species are highly nutrient dependent, explains Smith. When soil nutrients are available, "strategies of the invasives allow them to rapidly colonize an area, grow big, and reproduce quickly," she continues. Native plants, on the other hand, do not respond as well to having more nutritional resources than they need. "They don't gobble up those nutrients the way the invasives do," says Smith.

In the soil samples from the B&B Fire Complex, the researchers found that the top 2 inches of red soil contained 71 percent less carbon and phosphorus and 69 percent less nitrogen than the less severely burned black soil. The nutrients were limited enough to dampen the aggressive tendencies of nonnative plants. That native plant growth was similar in both red and black soils suggests that at least some native species may be better adapted to regenerate in the severely burned red soils because they are less dependent than nonnative, invasive plants on the flush of nutrients after a fire, Hebel explains.

Doni McKay

Two years after the fire native plants had reappeared, but the percentage of plant cover was more than 50 percent lower in red soil than in black soil.

Two years after the fire, Hebel returned to the B&B study area and conducted an onsite vegetative study. Native snowbrush, fireweed, and trailing blackberry were growing on red soil plots, but the percentage of plant cover was more than 50 percent lower in the red soils compared to the less severely burned black soils in all plots. "The recovery rate of the red soil is much slower," she says.

No invasive nonnative plants were found in the study area. Smith conjectures that this is because there were limited seed sources for the nonnative plants, and the team did not directly address that question in this small-plot study. "This doesn't mean that the invasive plants can't colonize now" she says. "If the seed source is there for the invasives, they're likely to move in." In 2005, Smith did notice a few thistles growing outside the study plots.

Only time and more study will reveal the balance of power between native and nonnative species in these severely burned soils. Hebel points out that individual plant species react differently to soil biota in various ecosystem types, so it is important not to generalize about which variables influence nonnative plant species invasions. It does appear that calling red soils "detrimentally burned," as they have been referred to in the past, is a misnomer as they may provide a benefit by creating the potential for plant and microbe diversity. Even so, large percentages of severely burned red soil appear to negatively impact forest recovery.

"Our results suggest that although burned soils in general promote growth of nonnative invasive plants, these species may be less competitive in severely burned sites where organic matter, soil nutrients, and microbes are reduced due to severe heating," Hebel explains. It seems the patchiness of different burn severities may help enhance biodiversity across a postfire landscape.

Researchers continue to investigate recovery of the red and black soils in the B&B Fire Complex. The red soil has darkened in color over the last 4 years, but they still see differences in the microbial communities and nutrients of the red and black soils. "It's such a fascinating study; the length of time for recovery of severely burned soils is unknown," Smith says.

These unknowns lead to a host of postfire management questions that remain to be answered. Smith is conducting a related study on the effects of salvage logging on soil microbes and soil nutrients. It would also be valuable to know how native and invasive plant species compete with one another in disturbed environments with low nutrients.

LAND MANAGEMENT IMPLICATIONS

- Although burned soils in general may promote the growth of nonnative, invasive plants, these species may be less competitive in sites where organic matter, soil nutrients, and microbes are reduced after exposure to intense heat.
- Plant cover is slow to return to severely burned soils.
- Where substantial areas of land have large amounts of down, dead wood before a fire, the potential for severely burned soils increases.

"We've scratched the surface," Smith says, "but haven't fully answered the many biodiversity questions surrounding long-term soil and forest recovery after severe wildfire."

Plants are the young of the world,
vessels of health and vigor…
— Ralph Waldo Emerson

Doni McKay

Trees killed by the 2003 fire are now beginning to fall and likely will become surface fuel for the next fire.

Tara Jennings

On a field trip to the red and black soil study sites on the Deschutes National Forest, participants discuss postfire management questions.

FOR FURTHER READING

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WRITER'S PROFILE

Marie Oliver is a science writer based in Philomath, Oregon.

Science FINDINGS

U.S. Department of Agriculture
Pacific Northwest Research Station
333 SW First Avenue
P.O. Box 3890
Portland, OR 97208-3890

SCIENTIST PROFILES

JANE E. SMITH has been a research botanist with the PNW Research Station since 1987. She earned a B.A. in botany from Humboldt State University and an M.S. in forest ecology and Ph.D. in botany and plant pathology from Oregon State University. She has looked at the diversity of fungi in old-growth and young managed stands of Douglas-fir, and the response of soil fungi to restoration thinning and prescribed fire in ponderosa pine forests. She is currently investigating belowground ecosystem dynamics and soil recovery after fire and salvage logging in forests east of the Cascade Range in Oregon.

Smith can be reached at:

USDA Forest Service
Pacific Northwest Research Station
Forest Sciences Laboratory
3200 SW Jefferson Way
Corvallis, OR 97331
Phone: (541) 750-7387
E-mail: jsmith01@fs.fed.us

CASSIE L. HEBEL earned an M.S. in forest ecology from the Department of Forest Science at Oregon State University in 2007. Her research investigated postfire soil microbial communities and invasive plant species. She currently works as a spatial analyst for Watershed Sciences, a Corvallis-based remote sensing company.

Hebel can be reached at:

Watershed Sciences
257B SW Madison Ave
Corvallis, OR 97333
Phone: (541) 752-1204
E-mail: chebel@watershedsciences.com

COOPERATORS

Kermit Cromack, Jr., Department of Forest Ecosystems and Society, Oregon State University

Douglas Shank, Willamette National Forest