USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Rocky Mountain Research Station
Science You Can Use *(in 5 minutes)*
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# **Burning Insights:** How wildfires reshape the soil microbiome and impact soil health and forest regeneration

Archaea, bacteria, fungi, and viruses are organisms that comprise the soil microbiome and play a crucial role in the health of the world's forests. The soil microbiome is vital in cycling important nutrients needed by vegetation (e.g., nitrogen), stabilizing soil organic matter, and forming essential symbioses with plants, such as the ectomycorrhizal fungi (EMF) that are obligate symbiotic partners of the conifer tree species that dominate forests of western North America.

"Recent advances in microbiome research allow us to use powerful tools to help assess belowground diversity and soil processes to better evaluate impacts of disturbance and land management," explains Chuck Rhoades, a research biogeochemist with the Rocky Mountain Research Station.

Yet it wasn't until recently that researchers fully understood that human impacts weren't the only disturbance affecting the functioning of the soil microbiome or that trees weren't the only organisms being burned by wildfire.

"Though we know that a myriad of microorganisms inhabit the soil, we lack a clear understanding of how severe wildfires impact the soil microbiome," says Mike Wilkins, a Colorado State University (CSU) professor who specializes in the soil microbiome.

Recent studies published by RMRS scientists and university collaborators are using DNA sequencing tools to investigate changes within microbial communities following wildfire to close this knowledge gap. DNA extracted from burned and unburned soils

*Researchers analyze microbial DNA to determine the response of soil bacteria and fungi to wildfire. USDA Forest Service photo by Chuck Rhoades.*

was computationally pieced together to create the genomes of the bacteria and fungi remaining after fire. Amelia Nelson, a CSU Ph.D. student, describes the use of microbial genomes as "allowing us to see which soil bacteria and fungi are abundant, and also to sort out what they were doing following wildfire."

Analyses showed that key soil microbes and overall microbiome diversity and biomass decline proportional to increasing wildfire severity, and that these changes can last more than a decade. The scientists found persistent decreases in specific EMF symbionts (e.g., *Cenoccum geophilum*), which are crucial for lodgepole pine regeneration. However,

depleted levels of EMF symbionts were also found in forests impacted by recent bark beetle outbreaks. Together these findings suggest that the compound effects of bark beetle outbreaks and wildfires may reduce natural regeneration of lodgepole pine.

In contrast, "fire-loving" pyrophilous bacteria increased and became dominant members of the microbial community. These taxa are heat tolerant and can occupy soil niches following a wildfire and can grow on or consume fire-altered organic matter. These bacterial phyla contribute to soil organic matter degradation and stabilization, which is important following a wildfire to promote regeneration of trees and shrubs.

"Our studies of the complex links between forest vegetation and the microbiome will help to guide expectations about post-disturbance ecosystem responses and recovery and should provide important tools for designing and evaluating post-fire restoration," says Rhoades.

*An Engelmann spruce seedling planted at the base of a charred tree. Reforestation with nursery stock can help address the decline in soil ectomycorrhizal fungi that are important symbionts for many conifer species. Loss of these belowground partners can inhibit post-disturbance forest regeneration. USDA Forest Service photo by Chuck Rhoades.*

## KEY FINDINGS

- High-severity wildfire results in long-term (years to decades) decreases in soil microbial biomass and diversity.
- Loss of the soil ectomycorrhizal fungi that form symbioses with conifer trees after wildfire and bark beetle outbreaks may inhibit post-disturbance forest regeneration.
- Soil microbiology and microbiome DNA sequencing tools can help land managers assess the utility of various restoration treatments such as microbial inocula and organic soil amendments for speeding recovery of soil processes and plant communities.

## FURTHER READING


Nelson, Amelia R.; Narrowe, Adrienne B.; Rhoades, Charles. C.; Fegel, Timothy S.; Daly, Rebecca A.; Roth, Holly K.; Chu, Rosalie K.; Amundson, Kaela K.; Steindorff, Andrei S.; et. al. 2022. Wildfire-dependent changes in soil microbiome diversity and function. Nature Microbiology. 7(9): 1419–1430.

Caiafa, Marcos V.; Nelson, Amelia R.; Borch, Thomas; Roth, Holly K.; Fegel, Timothy S.; Rhoades, Charles C.; Wilkins, Michael J.; Glassman, Sydney I. 2023. Distinct fungal and bacterial responses to fire severity and soil depth across a ten-year wildfire chronosequence in beetle-killed lodgepole pine forests. Forest Ecology and Management. 544: 121160.

Rhoades, Charles. C.; Fegel, Timothy S.; Zaman, Tahir; Fornwalt, Paula J.; Miller, Susan P. 2021. Are soil changes responsible for persistent, slash pile burn scars in lodgepole pine forests? Forest Ecology and Management. 490: 119090.


## CONTRIBUTORS AND WRITER


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