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SheFire: A New Tool for Measuring Soil Temperatures

Fire is complex and can transform forest ecosystems in ways that affect carbon storage, nutrient cycling, and ecosystem recovery. Methods for measuring the visible, aboveground characteristics of fire have substantially progressed in recent decades, but measuring the unseen, belowground effects of fire remains challenging. The increasing intensity and incidence of wildfire, particularly in the western United States, call for better understanding of the effects of fire on all aspects of the environment, including the soil.

Soil temperature can influence a variety of physical, chemical, and biological processes, but measuring the effects of fire on soil, such as soil heating, is difficult. The standard method for measuring soil temperature during fires involves digging a trench, placing and burying thermocouples (long, thin temperature-measurement devices and attached dataloggers) that record soil temperature data at various depths, and filling the trench back in.

An iButton stake that will measure soil depths 5, 10, and 15 cm when installed with the top of the stake 2 cm below the soil surface. USDA Forest Service photo by Matthew Dickinson

Researchers recently created a new field method to measure soil temperature during fire and developed a new model, SheFire, to describe soil heating during fires across depth and over time. The research was conducted by Matthew Dickinson, an ecologist at the U.S. Department of Agriculture, Forest Service, Northern Research Station, in collaboration with Mary Brady at the University of Nevada and other researchers from the U.S. Department of Agriculture, the University of Nevada, Michigan State University, Oregon State University, and Texas A&M University.

KEY MANAGEMENT CONSIDERATIONS

- The SheFire model is an open-source program that uses soil temperature to help researchers and land managers quantify and understand the effects of fire on soil health and seedling survival.
- Land managers and researchers can use iButtons arranged vertically on an iStake inserted underground to gather critical subsurface soil temperature data to feed into the SheFire model without disturbing the soil as much as conventional methods.
- iButtons and SheFire can be used to produce a temperature profile through the soil from the surface down to 15 cm.

New Method: iButtons and iStakes

The new method created by Dickinson and his collaborators is less disruptive to soil than the standard thermocouple method and is comparable in the temperature data it collects. It uses iButtons—small, self-contained temperature sensors and data loggers—to measure soil temperature. The buttons are mounted on iStakes—small wooden stakes that hold three iButtons—and inserted into the soil. “In soft soils, you can just push the iStakes in,” says Dickinson. “In hard soils, you have to use a steel bar to create the slot that the iStake goes into, but that disturbs the soil less than digging a trench.”

The iStake configuration tested by Dickinson and his colleagues uses wood, which has thermal properties similar to soil and thereby does not affect soil temperature. “Our method improves the accuracy of the measurements using the best technology available,” says Dickinson.

New Model: SheFire

Led by Mary Brady, the researchers also created an open-source model, SheFire (Soil Heating in Fire). This model uses a set of functions that can estimate soil temperatures at any depth and over time based on the temperature data from three depths measured by iButtons.

To test the accuracy of SheFire, the team ran a controlled laboratory study using a burn table. They inserted two iStakes, slightly offset from each other, into nine canisters of soil. One iStake had iButtons placed at 5, 10, and 15 cm, and the other had iButtons placed at 4, 7, and 12 cm. Next, the team set a fire over the canisters. They collected temperature measurement data from the 5, 10, and 15 cm iButtons over 350 minutes (almost 6 hours) to fit the SheFire model, and then used the model to predict soil temperatures at 4, 7, and 12 cm deep over time. They compared the predicted temperatures to the recorded temperatures by the 4, 7, and 12 cm iButtons. The test showed a close fit between the temperatures predicted by SheFire and actual temperatures. Accuracy tended to improve with depth.

Soil Heating and Soil Health

According to Dickinson, the SheFire model will be useful for understanding minor soil heating in a prescribed burn as well as more intense soil heating in a wildfire, particularly as heating relates to soil health. "The ecological rule of thumb is that if living tissue hits 60 °C, it's dead," Dickinson says. And although the rule holds if things get heated quickly, it doesn't necessarily apply when things are heated slowly, as in soils during fires.

SheFire can show how different soil heating patterns influence seed and tree root survival at different soil depths and potentially allow researchers to study the effects of fire on microbial communities. Researchers demonstrated the percent survival calculations in SheFire using an experimental fire and modeling the survival of partridge pea seeds and stem wood from Douglas fir (*Pseudotsuga menziesii*) and trembling aspen (*Populus tremuloides*). The nuanced information SheFire may be able to provide is vital, says Dickinson, "because hardly any data are available on how microbial communities respond to fire."

SheFire provides land managers and researchers with a way to quantify the effects of wildland fire, and soil heating in particular, on ecosystem processes and assess the ability of ecosystems to recover from fire. "With this model," says Dickinson, "I can look at soil temperatures at different depths and assess the impacts on microbial communities, tree roots, shrub stems, and so on. With better ways to measure soil heating, we can better predict the impacts of a given fire."

Initial attack on a fire south of Ashland, MT. USDA Forest Service photo

PROJECT LEAD

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FURTHER READING

Brady, Mary K.; Dickinson, Matthew B.; Miesel, Jessica R.; Wonkka, Carissa L.; Kavanagh, Kathleen L.; Lodge, Alexandra G.; Rogers, William E.; Starns, Heath D.; Tolleson, Doug R.; Treadwell, Morgan L.; Twidwell, Dirac; Hanan, Erin J. 2022. Soil Heating in Fire (SheFire): a model and measurement method for estimating soil heating and effects during wildland fires. Ecological Applications. 32(6): e2627. https://doi.org/10.1002/eap.2627.