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Seeing Our Future More Clearly: How One Peatland Study is Changing How We Think About Carbon

The World's Largest Climate Change Experiment

On a 20-acre bog in the Marcell Experimental Forest in northern Minnesota, 10 open-topped chambers rise more than 23 feet out of the peatland, connected by walkways that seem to float over a layer of *Sphagnum* moss. "Some people have compared it to the science fiction scene of an alien landing spot on planet Earth," says Stephen Sebestyen, a research hydrologist with the U.S. Department of Agriculture, Forest Service's Northern Research Station (NRS), and one of the scientists collaborating on this study. "In reality, what this turns out to be is, the world's largest climate change experiment."

With funding from the Department of Energy (DOE), and in partnership with DOE's Oak Ridge National Laboratory (ORNL) and expert scientists from around the world, Sebestyen and NRS research soil scientist Randy Kolka, the Forest Service lead on this experiment, with the help of NRS scientists Sue Eggert and Brian Palik, have spent the last 6 years testing the effects of climate change on carbon sequestration and storage in peat bogs. These bogs, formed over thousands of years as dead and decaying plant material and coprogenous earth accumulate, are natural sinks for carbon. While accounting for just 3 percent of the planet's landmass, peatlands hold a third of global soil carbon because the cool, wet, and acidic conditions slow decomposition.

The SPRUCE experiment's 10 open-topped chambers can be found on a 20-acre bog in the Marcell Experimental Forest in northern Minnesota. Photo by Oak Ridge National Laboratory.

KEY FINDINGS

- Peatlands make up 3 percent of the Earth's landmass yet store a third of global soil carbon because of the cool, wet, and acidic conditions.
- Research from SPRUCE, the first experiment to use whole-ecosystem manipulation to study the effects of climate change on peatlands, reveals that warmed bogs flip from carbon sinks to sources, releasing carbon at 5 to nearly 20 times the rate of historical accumulation.
- The warmest bog plots experienced the greatest carbon losses, with peat elevation decreasing by as much as 3.9 inches.
- Warming caused a dramatic shift in bog plant communities, with a near total loss of *Sphagnum* moss, a crucial keystone species for peatlands.
- The results from SPRUCE are being integrated into Earth Systems Models to help scientists better assess future climate scenarios and mitigation and adaptation strategies.

Yet, despite storing massive amounts of carbon, peatlands have not been represented in the global Earth Systems Models that scientists use to simulate carbon cycling processes and investigate future climate scenarios. The Spruce and Peatland Responses Under Changing Environments (SPRUCE) experiment is changing that. Research from the study informs the DOE's Energy Exascale Earth System land model (ELM), which is part of the ensemble of models used by the Intergovernmental Panel on Climate Change. "Getting any representation of peatlands in these models is a foundational change," says Sebestyen.

Warming Flips Carbon-rich Peatlands from Sinks to Sources

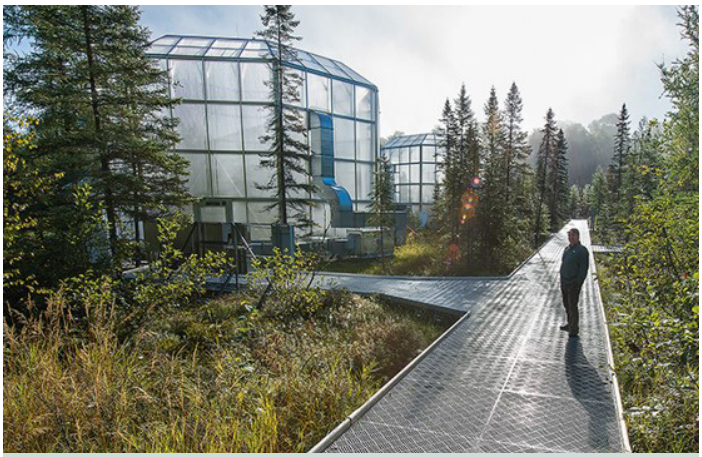
While various peatland experiments are conducted around the world, SPRUCE is the first ever to use whole-ecosystem manipulations to study the impacts of warming and elevated carbon dioxide on these crucial carbon sinks. Inside 8 of SPRUCE's 10 open-topped chambers, the air is heated by propane-fueled furnaces while the soil is heated, down to about 8 feet, by electric resistance heaters. The warming treatments increase both air and soil temperatures by 2.25 °C to 9 °C from outside temperatures. Elevated levels of carbon dioxide, ranging from 800 to 900 ppm, are also emitted into five of the chambers, allowing scientists to more fully mimic predicted future conditions, which are expected to be warmer and include higher concentrations of carbon dioxide in the atmosphere.

The findings from SPRUCE, recently published by lead author Paul Hanson (ORNL) in AGU Advances, are alarming: after only 3 years, even the experiment's most modestly warmed bog plots have flipped from carbon accumulators to carbon emitters, with rates of carbon loss ranging from 5 to nearly 20 times that of historical rates of accumulation. SPRUCE is the first whole-ecosystem experiment to document this phenomenon, foreshadowing a potential future in which peatlands, warmed by climate change, release massive amounts of carbon into the atmosphere. The warmest chambers saw the greatest carbon losses, with peat elevation decreasing by as much as 3.9 inches.

The plant communities within the warmed chambers also experienced significant changes. Longer growing seasons and more frequent false springs allow shrubs like Labrador tea (*Rhododendron groenlandicum*) to overtake *Sphagnum* mosses. According to Kolka, "These systems are turning into shrub factories at the expense of other communities." In the warmest chambers, ecosystem ecologist Richard Norby (ORNL) noted a near complete loss of *Sphagnum* moss, a keystone species for bogs that helps these peatlands preserve and accumulate organic matter. "I would estimate that 90 percent of the carbon buried out there is a result of *Sphagnum*," says Kolka. "The magnitude of the losses coming out of the warmest treatments is indeed alarming."

One Little Peatland in Northern Minnesota

The SPRUCE experiment, with participating scientists from over 15 universities and organizations, has been invaluable in providing Kolka, Sebestyen, and others with a clearer picture of what our future may hold. In the coming years, research from the experiment will continue to inform numerous Earth Systems Models as scientists begin to investigate a range of other conditions—from *Sphagnum* loss to changes in microbial communities—which can only be studied at SPRUCE. "This is a really diverse group [of scientists]," says Sebestyen of the team conducting research at SPRUCE. "It's fascinating to think about the amount of effort focused on one little peatland in northern Minnesota… What happens here matters to the entire planet."



Northern Research Station soil scientist Randy Kolka, the Forest Service lead on SPRUCE, stands on the raised walkway connecting the experiment's chambers. According to Kolka, "The magnitude of the losses coming out of the warmest treatments is indeed alarming." Licensed photo by Layne Kennedy, used with permission.

Project Leads

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FURTHER READING

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