Colder Soils in a Warmer World

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Colder soils in a warmer world? It doesn't sound intuitive, but it is a reasonable consequence of global climate change here in the northeast, and one that might have interesting effects on the composition of our forests, their ability to cycle nutrients, and the water quality of our lakes and streams.

Soils in northern New England forests do not typically freeze in winter due to the insulating effects of the snow pack, which acts as a blanket between the soils, warmed from the growing season, and the cold air. The future is less certain, however, as climate change scenarios for the northeast predict a less reliable snow pack, which would likely develop later and melt earlier. This would expose the soil to cold air and, ironically, increase the likelihood of its freezing. This could have implications for our forests, and research is now underway aimed at understanding just what changes when soils freeze in winter.

A few soil freezing events have been observed already in northeastern forests, and the changes in stream water chemistry that accompanied these events piqued the curiosity of researchers working at the U.S. Forest Service's Hubbard Brook Experimental Forest (HBEF) in Woodstock, NH. Watershed monitoring at the HBEF, combined with similar watershed monitoring in Maine, the Catskills, and the Adirondacks, recorded unusually high concentrations of nitrate in spring snowmelt after a winter (1989-90) in which the soils likely froze due to cold temperatures and thin snow pack. This nitrate loss has implications for both soil fertility and stream water quality. In addition, researchers in Canada have linked soil freezing to sugar maple decline. These observations suggested that something different happens to belowground processes when soils freeze and this change could influence both how our forests look and how they cycle nutrients. Given both the widespread nature of the effects of soil freezing (streams, soils, and trees) and the likelihood of it occurring more often, Hubbard Brook scientists decided they needed to know more. Just what was changing? Was it tree roots, soil microbes, or both? The nitrogen cycle flows through everything organic, so a very detailed look at things belowground was necessary.

Approaching this problem was not easy. For one, studying anything belowground is pretty difficult without disturbing it. Secondly, freezing forest soils is easier said than done. For good results, the researchers would need paired measurements of frozen and unfrozen forest plots where each conceivable link in the nutrient cycles could be measured to determine where the changes were taking place. In addition, they would need detailed weather, snow pack, and soil freezing measurements so they could interpret their results in the context of future climate predictions. Thus a group of snow pack experts, microbial ecologists, forest ecologists, and soil chemists came together and confronted their first problem: how could they freeze the soil in an area large enough for all of their research equipment?

Through the support of the National Science Foundation, the research team was able to design a study with 4 pairs of plots distributed in stands of sugar maple and yellow birch. Each plot was 10m x 10m and one of each pair was kept snow-free until early February in order to deprive the soils of the insulating effects of the snow pack. Plenty of high-tech equipment was used in this study, but snow removal was done the old-fashioned way: with a snow shovel. Within each plot, roots (growth and death), microbes (populations and activity), soil frost (depth), soil water chemistry, and gasses leaving the soil were measured.

This study was conducted in pairs of yellow birch and sugar maple plots in the winters of 1999-2000, and 2000-01, and is currently taking place in pairs of high and low elevation mixed species plots, all at the HBEF. From the first study, elevated nitrate in the soil water of the frozen plots was measured, indicating that it was in fact soil freezing that was causing the observed nitrate in the watersheds. There was significantly more root death in the frozen plots, but no difference between species. The microbial community did not seem directly affected, although it did respond to the increase in dead roots, which was a food source for some microbes.

The second round of this study is still underway and it will no doubt reveal more about the changes in the forest dynamics when the soils freeze. For now, though, it looks like the colder soils brought on by a warmer world will affect forests by damaging or killing tree roots. This means that there are fewer roots in the spring to take up available nitrate and thus more nitrate will enter the streams. This is a change in the nutrient dynamics of the soils that could affect streams and forests alike. Just how large the effect will be is unknown, because for now these regional, soil freezing events remain the exception.

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