United States Department of Agriculture

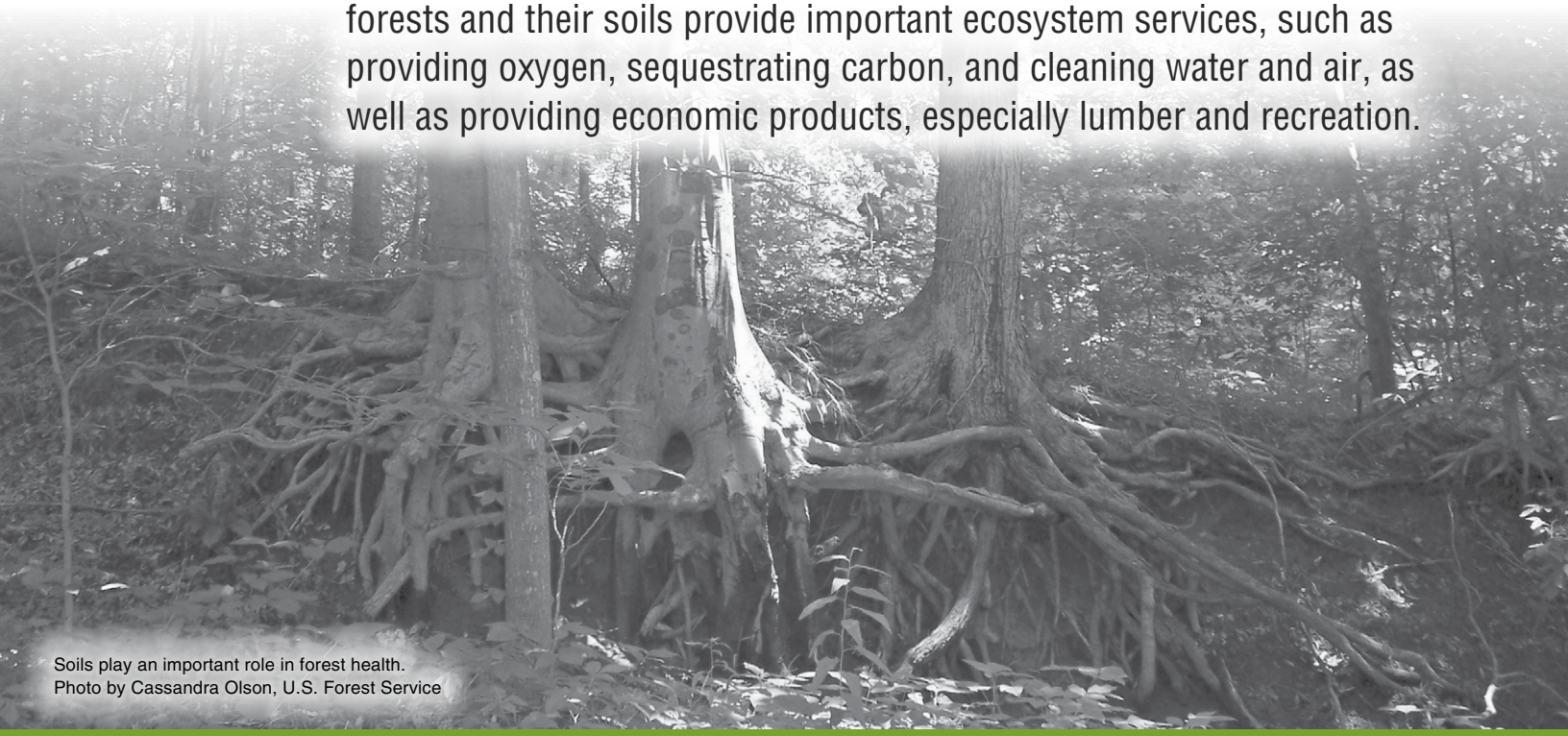
US FOREST SERVICE NORTHERN RESEARCH STATION

Research *Review*

2015 is the United Nations International Year of Soils:

Northern Research Station Science Provides Decades of Data on Forest Soils

Soil sustains life—all terrestrial plant life depends on nutrients and water from the soil, and all terrestrial animals, including humans, depend on the food web that is based on plants growing in soil. To emphasize the importance of soil and initiate new programs, the United Nations Food and Agriculture Organization has designated 2015 as "The International Year of Soils." As "the lungs of the earth," forests and their soils provide important ecosystem services, such as providing oxygen, sequestrating carbon, and cleaning water and air, as well as providing economic products, especially lumber and recreation.



Soils play an important role in forest health.
Photo by Cassandra Olson, U.S. Forest Service

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DECADES OF SOIL RESEARCH AND RESULTS

The significance of soils to the restoration and resiliency of healthy forests has prompted many decades of research on soils and on the effects of management and disturbances on them. The U.S. Forest Service is the leading source of information on how forests affect and are affected by soils, with wide-ranging and long-term research activities. Current soil research by the Northern Research Station (NRS) involves studies of the following topics:

1. Belowground processes controlling carbon and nutrient cycles
2. Soil effects on biomass growth on aboveground and belowground parts of trees
3. Community structure, functions, and interactions of forest soil organisms, and their effects on ecosystems
4. Distribution of soil carbon, and its response to forest disturbance and climate change

In particular, NRS scientific studies focus on the effects of disturbances such as fire, timber harvest, acidic deposition, and silvicultural treatments on soil nutrients and compaction, and the resulting effects on forest growth, species composition, and stand dynamics. Most studies on soils require long-term institutional commitments of large areas, time, personnel, and funding, making the 23 NRS experimental forests (EF) sites key players in long-term national programs. The NRS Forest Inventory and Analysis (FIA) unit has added soil data to its regionwide forest monitoring operations, collecting information over its 24-state area for more than 20 years.

National Long-Term Soil Productivity Network

Controversy over soil health after forest harvesting has made scientific information vital for knowledge-based decisionmaking and restoration efforts. Harvesting has two main effects on soils: 1) compaction by equipment, and 2) removal of organic matter (branches, logs, and leaves) and the nutrients they contain. Because it examines a range of woody biomass removal (from stems-only to everything aboveground), the Long-Term Soil Productivity (LTSP) study has become a key source of information for developing sustainable harvesting of woody biofuel stocks from forests. The LTSP study, begun in the 1980s in response to needs for scientifically based information, has produced many decades of data. Five NRS experimental sites are part of the LTSP network: Fernow (WV) and Bartlett (NH) EFs; Shannon County, Missouri; and the Ottawa and Huron-Manistee National Forests (MI). When 10-year data from all sites were analyzed and published, the research team, led by the late Felix Ponder of NRS, found that for many of the site types and species investigated, harvest-related organic matter removal and soil compaction (excepting aspen vegetative reproduction) did not result in large decreases in stand biomass 10 years after harvest. Most stands, however, had not yet reached canopy closure, and treatment effects may continue to evolve. The LTSP information is also valuable to the restoration work on thousands of acres after harvesting, fire, surface mining, compaction from machinery, bark beetle infestations, excessive herbivory by deer overpopulation, and disturbances from nonnative invasive species, both insect and plant.

At the **Missouri LTSP installation in Shannon County, Missouri**, John Kabrick studies compaction and biomass removal treatments on white oak, northern red oak, and shortleaf pine. Kabrick found that soil compaction increased the growth of planted trees on coarse-textured soils. This effect was associated with improvements to soil physical properties, particularly to increased soil moisture and temperature. The only growth reductions attributable to compaction treatments occurred on sites with fine-textured soils, which generally are more vulnerable. To date, the network of LTSP study installations has provided great insight into the short-term effects of harvest-related site and soil disturbances on productivity across broad ecological gradients. Continued monitoring will provide a greater understanding of the longer-term effects that will occur during different stand development stages. Kabrick is also part of a long-term, landscape-scale study examining the effects of thinning, burning, and the combination of the two on soil carbon and nutrients.

In the **Fernow Experimental Forest (WV) Watershed Acidification Study**, Mary Beth Adams is using ammonium sulfate fertilizer to follow acidification of an entire forested watershed. This long-term experiment, in its 25th year, is a National Science Foundation Long-Term Research in Environmental Biology (LTREB) site and has fostered many graduate and undergraduate research projects. It is one of two whole-watershed acidification studies in the United States.

MONITORING AND STUDYING THE CONDITION OF FOREST SOILS

Interest in sustainable management has expanded the definition of "soil health" to recognize the broader role that soils play in regulating key forest ecosystem functions. Forest soils can affect many aspects of tree health, species diversity, and forest types. Forest Service Research and Development supports geographically diverse forest soil inventories and comparison studies.

Crew inserting stakes at the Kissena Corridor Park in Queens, New York. Photo by U.S. Forest Service.

Wood Decomposition on the Forest Floor

Organic matter decomposition is an index of forest management effects (both positive and negative) in long-term soil productivity studies. In addition, projected climate change and changes in land use can profoundly affect soil organic matter decomposition rates. Mary Beth Adams, Rich Hallett, John Kabrick, Daniel Lindner, Brian Palik, and Ian Yesilonis (NRS) plus Deborah Page-Dumroese (Rocky Mountain Research Station); Marty Jurgensen (Michigan Technological University); Megan Lang (University of Maryland); and Mark Bradford and Alex Felson (Yale University) have begun a new network to study the belowground decomposition in diverse ecosystems. The NRS projects are located in Long-Term Soil Productivity sites in Michigan, Minnesota, Missouri, and West Virginia and others at the Baltimore Ecosystem Study, a Long-Term Ecological Study (LTER) in both urban and non-urban forests; on a hydrologically restored forested wetland near Somerset, MD; and in Kissena Corridor Park in Queens, NY.

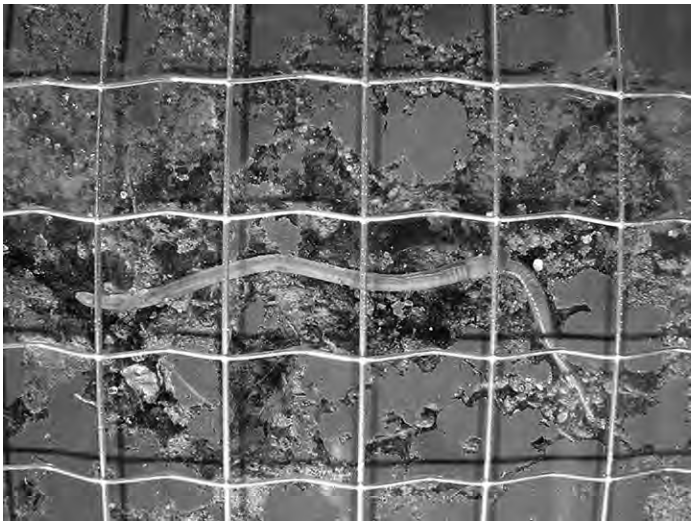
U.S. National Forest Soil Indicators.

Starting with the 1999 annual inventory, FIA added soils to the list of attributes they sample across the nation's forested landscape. Important measurements include soil carbon, primary nutrients, and significant pollutants. Soil carbon typically represents the largest fraction of carbon stored in forests. Charles "Hobie" Perry is collaborating with colleagues to use the soil indicator data to improve the estimates of soil carbon provided to the United Nations Framework Convention on Climate Change. The soil nutrient information is being used to examine the impacts of atmospheric nitrogen deposition on forest growth and mortality; the results will define "critical loads" of nitrogen for forest ecosystems. Finally, he is collaborating with the U.S. Geological Survey and Forest Service scientists to create an accurate inventory of forest soil mercury, a pollutant that accumulates in forests through atmospheric deposition. Forest fires release mercury into the atmosphere when the forest floor is consumed, while mercury concentration in the mineral soil may be unaffected. As industrial emissions are increasingly regulated, the contribution of forest fires to the mercury budget is an increasingly significant unknown.

Long-Term Impact of Liming on Growth and Vigor of Northern Hardwoods

Sugar maple, a keystone species in northern hardwood forests, has experienced health declines in portions of its range over the past 50+ years from acid precipitation. Acid rain depletes soil base cations (primarily calcium and magnesium), which affects soil pH and aluminum levels in the soil. This decline became widespread in the mid-1980s in sugar maples growing on the unglaciated Allegheny Plateau in northern Pennsylvania. In a long-term liming study (1985-2008), NRS scientists Robert Long and Steve Horsley (emeritus) and T.J. Hall (Penn State) found that liming (one-time application of 10 tons/acre of dolomitic limestone) reduced acidity in four northern hardwood stands in northwestern Pennsylvania. Soil, soil water, and sugar maple foliage chemistry were significantly altered by liming and the changes in soil and foliage chemistry persisted as long as 21 years. Sugar maple in limed plots had greater diameter growth, better crown health, greater survival, and larger seed crops than in un-limed plots.

Dolomitic limestone being applied by a tractor with a hopper-spreader in fall 1985. Photo by U.S. Forest Service.



An earthworm tunnels through an organic-rich mineral soil layer. The photo was taken in the rhizotron. Photo by U.S. Forest Service.

Rhizotron

At the Houghton, MI, NRS facility, Erik Lilleskov and partners use a 75-foot-long tunnel with 24 windows—called a rhizotron—to observe and monitor belowground ecological processes, including activities in the chemically active zone near roots, without disturbing the soil or soil organisms. Tree roots, mycorrhizae (symbiotic fungi that help tree roots obtain nutrients), and other life in forest soils are essential for healthy and productive forests and provide valuable forest ecosystem services, including supplying water and nutrients to trees; providing structure to support trees and prevent soil erosion; purifying surface and groundwater; sequestering carbon from the atmosphere; and serving as habitat for a variety of soil organisms. Using the rhizotron, Lilleskov has studied a broad-range of topics—root growth and death; the interrelationships of soil organisms, especially invasive European earthworms, aka "night crawlers"; and nutrient effects. Lilleskov and colleagues found that night crawlers are moving into formerly worm-free forests in the north-central and northeastern United States, areas that were scraped clean of soil during the last glacial period. Although generally considered to be "good for gardens," earthworms in these forests rapidly consume the organic materials of the forest floor, often removing leaf litter within several years of invasion. The scientists are studying ecosystem responses to a range of earthworm species in maple- and hemlock-dominated forest systems; changes in soil carbon, nutrients such as nitrogen and calcium, soil microclimate, hydrology, soil organisms, and plant community assemblages can be attributed to these earthworms. Lilleskov found that although earthworms are widespread, they have not yet saturated the landscape in the northern forests, so we can expect continued expansion over the next several decades.

BIOGRAPHIES

Mary Beth Adams is a research soil scientist in the "Ecology and Management of Invasive Species and Forest Ecosystems" in Morgantown, WV. She has a PhD in soil science and forestry from North Carolina State University (1986). **John Kabrick** is a research forester in the "Sustainable Management of Central Hardwood Ecosystems and Landscapes" unit in Columbia, MO. He has a PhD in soil science from the University of Wisconsin (1995). He is a member of the NRS LTSP team and is continuing the work of the late Felix Ponder, who was the LTSP coordinator for many years. **Erik Lilleskov** is a research ecologist in the "Climate, Fire, and Carbon Cycle Sciences" unit in Houghton, MI. He has a PhD in ecology from Cornell University (1999). **Robert P. Long** is a research plant pathologist in the "Sustaining Forests in a Changing Environment" unit in Irvine, PA. His PhD is from Pennsylvania State University. **Brian Palik** is a research ecologist in the "Center for Research on Ecosystem Change" unit in Grand Rapids, MN. He has a PhD in forest ecology from Michigan State University (1992). **Charles "Hobie" Perry** is a research soil scientist and eastern U.S. Soils Indicator Advisor for NRS Forest Inventory and Monitoring in St. Paul, MN. His PhD in forestry is from the University of Minnesota (1998).

Be it deep or shallow, red or black, sand or clay, the soil is the link between the rock core of the earth and the living things on its surface. It is the foothold for the plants we grow. Therein lies the main reason for our interest in soils.

Roy W. Simonson, USDA Yearbook of Agriculture, 1957

RESOURCES AND REFERENCES

Web Resources:

USDA Forest Service, Research & Development: www.fs.fed.us/research/water-air-soil/basic-processes.php

USDA Forest Service, Northern Research Station (NRS): www.nrs.fs.fed.us/disturbance/pollution/ www.nrs.fs.fed.us/inventory_monitoring/inventory/ www.nrs.fs.fed.us/sustaining_forests/conserve_enhance/biodiversity/ltsp/ www.nrs.fs.fed.us/sustaining_forests/monitoring_assessment/decomposition/

USDA Natural Resources Conservation Service: www.nrcs.usda.gov

Forest Inventory & Analysis: www.nrs.fs.fed.us/fia/topics/soils/default.asp

Long-Term Soil Productivity Network: www.fs.fed.us/psw/topics/forest_mgmt/ltsp/

Rhizotron: www.nrs.fs.fed.us/clean_air_water/carbon_sequestration/rhizotron

Soil Science Society of American: www.soils.org

UN International Year of Soils: www.fao.org/soils-2015/en/

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US Forest Service
Northern Research Station
359 Main Road
Delaware, OH 43015

Contact the Northern Research Station
www.nrs.fs.fed.us

Michael T. Rains
Station Director
11 Campus Boulevard #200
Newtown Square, PA 19073

610-577-4017
mrains@fs.fed.us

Rebecca G. Nisley
Writer and Editor

203-230-4338
rnisley@fs.fed.us

For additional printed copies or to receive this publication in electronic format, email nrspubs@fs.fed.us or call 740-368-0123.

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There are 111 NRS scientists working at 20 field offices, 24 experimental forests, and universities located across 20 states, from Maine to Maryland, Missouri to Minnesota.

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