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Saving the Soil

Lessons From the Long-Term Soil Productivity Experiment

Soil nourishes and sustains the forest, yet it's also one of the least understood ecosystem components. In a landmark experiment involving the Forest Services of both the United States and Canada, scientist Robert F. Powers leads the world's largest effort at understanding how to best manage this resource to improve the health and productivity of the forest.

As we walk through the forest, we often are moved by its greenery and serenity. But beyond aesthetic values, we rely on the forest for its vast resources, including clear and abundant water, wildlife, and the basic natural products that give us paper, furniture, and building materials, often taking these resources for granted. In fact, forests in many parts of the world are rapidly disappearing, unable to keep pace with the growing demand for resources as the human population expands, despite recycling and regulatory efforts in the developed nations.

Often overlooked is the vital role of soil, without which the forest would not exist. Soil is a rich chemical resource containing oxygen, nitrogen, carbon, and other nutrients central to sustaining plant and animal life. Forests and the soils beneath them hold about half of the land's carbon and are a major means of scrubbing carbon dioxide from the atmosphere to help control the greenhouse effect.

Researchers have known for some time that soil management is a key to sustained productivity. But soil, like the forest, is disappearing worldwide at rates that are hard to sustain, in part owing to erosion and uncontrolled deforestation. "Soil is the foundation of all other resource values," says Robert F. Powers, a researcher with the USDA Forest Service Pacific Southwest Research Station. "If you lose soil, you lose forests, wildlife and water."

In the United States, government regulations have been established to help sustain precious forest resources. Specifically, The National Forest Management Act of 1976 mandates that the U.S. Forest Service help manage forest resources to help ensure their health and long-term productivity. This implies optimizing soil management practices, which, for lack of a solid scientific foundation, have largely been based on speculation.

Powers and others have applied scientific research methods to the problem with the goal of identifying reliable guidelines for optimizing soil management practices. One of the key questions: "What is the best way to manage the soil?"

That line of inquiry led to the Long-Term Soil Productivity (LTSP) experiment, a landmark effort that began in 1989 to examine long-term consequences of soil disturbance on forest productivity. The project began as a grass-roots effort that has since grown to form partnerships and affiliations with public and private sectors in the United States and Canada, including major universities and the private forest sector. Today, LTSP is an international project that includes more

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From Science…

Major Themes

Soil productivity—The forest's soil is essential to its sustainability, yet it is one of the least understood components in the forest ecosystem.

Soil management—Without science-based guidelines, soil management practices in the past have largely been based on speculation.

Research Results

Timber harvesting—Findings indicate that removing forest biomass in thinning or final harvest operations have no noticeable impact on soil quality or the inherent productivity of the land.

Forest floor retention—A protective layer of organic matter on the soil surface reduces erosion caused by rainwater runoff, whereas the loss of the forest floor leads to early declines in nitrogen.

Soil compaction—Contrary to conventional wisdom, not all soil compaction is bad. When soils are sandy, a little soil compaction actually improves the availability of water to roots and growth is enhanced, particularly in dry climates.

Saving the soil is a complex problem, and finding out what works is an equally complex task. Many critics of forest management practices charge that activities that remove organic matter and nutrient capital and that alter soil physical properties invariably lead to collapses in the land's capacity to grow vegetation. International concerns have been raised that whole-tree harvesting removes ecosystem nutrients faster than they can be replenished. Such concerns are countered by skeptics who seek irrefutable proof that traditional management practices are harmful. Until recently, both criticisms and defenses were based on conjecture and anecdotal evidence.

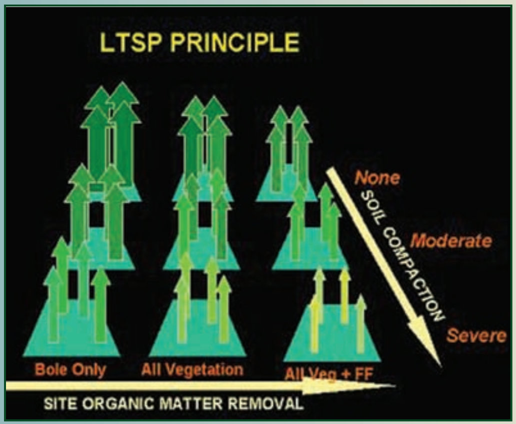
The LTSP program focuses on two key questions: (1) Is soil disturbance harmful? (2) How much soil disturbance is too much? To answer these questions, Forest Service researchers targeted two key properties directly affected by forest management operations: soil porosity (or soil density) and site organic matter (presence of leaves and twigs on the forest floor). These properties affect microbial activity, soil stability, water and gas exchange, and many other processes critical to forest health.

The study targeted forest types, age classes, and soil conditions common to active forest management, particularly in the context of timber harvesting. In general, the selected forest types were fully stocked, young-growth, even-aged forests, not "ancient forests" or nonforested openings.

Forest sites were then selected for experimentation, with each site measuring 1 acre, an area roughly the size of a football field. Treatments were imposed with the goal of creating extreme ranges in site organic matter and soil porosity, mainly to bracket the extremes in disturbance likely to occur under present or future management. Prior to treatment, vegetation and soil samples were taken to quantify biomass and nutrient levels in the untreated sites. In general, each experimental site was subdivided into nine plots, with each plot subjected to one of nine different combinations of organic matter removal and soil compaction.

The nine plots were arranged essentially in a grid pattern on the site to make treatment comparisons easy. To test the impact of modifications in site organic matter, each plot was subjected to one of the following conditions: conventional removal of tree stems, with tree crowns and the forest floor retained (minimal organic matter removal); all vegetation removed with the forest floor retained (moderate disturbance); or all vegetation and the forest floor removed with the bare soil exposed (severe disturbance). To test the impact of modifications of soil porosity, each of those plots was subject to one of the following treatments: zero soil compaction, moderate compaction, or high soil compaction.

Following treatment, the researchers focused on eight core measurements of climate changes, soil moisture levels, soil



LTSP principle — experimental setup.

Determining forest floor biomass before site treatment.

Determining forest biomass before site treatment.

chemistry, plant characteristics, and water infiltration. These measurements were generally taken every 5 years at each site.

The first LTSP site was established in 1990 in the Palustris Experimental Forest in the subtropical, moist pine forest type of the Louisiana Coastal Plain. The next year additional sites were established in the mixed-conifer forest of California's Sierra Nevada and in Minnesota's moist aspen forests. The LTSP program now includes 62 core sites encompassing a wide range of forest types throughout the United States and two Canadian provinces (British Columbia and Ontario). Coupled through partnerships with similar studies elsewhere, the LTSP study, which continues to expand, now includes data from over 100 sites across the United States and Canada. The earliest comprehensive LTSP results were published in 2005 and 2006. Findings from a decade of research showed, in general, that organic matter removal in whole-tree harvests does not degrade fundamental productivity, as some researchers had feared. Still, early findings must be validated through long-term study, according to LTSP Director Robert Powers. "Early findings do underscore the critical importance of protecting and maintaining the forest floor in saving the soil and ensuring forest sustainability," says Powers.

In particular, the study showed that the main method for reducing soil erosion is a protective layer of organic matter (leaves and twigs) on the soil surface. "A protective layer appears to be much more important than whether or not a soil is compacted. Organic matter reduces the dislodging force of raindrops and the speed by which water moves downhill across the soil surface, forces that normally enhance erosion," says Powers.

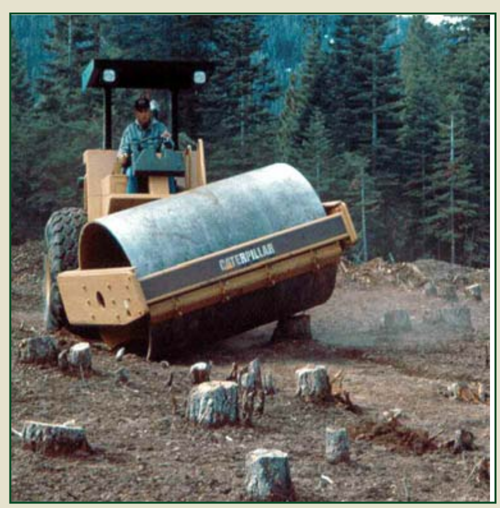
The study also found that the protective layer on the forest floor is important to sustained soil fertility. Removing the forest floor, a mix of fresh and decomposing plant residues, has far more of a detrimental impact on soil fertility than removing the living vegetation, Powers says. That's because this dead organic matter contains as much or more nitrogen than the living forest vegetation, he says. Removing the forest floor, lowers soil fertility in the first decade, but the importance of this effect and how long it lasts remains to be seen, he notes.

The LTSP study also showed that not all soil compaction is bad. If soils are mostly clay (dense), compaction reduces plant growth. But when soils are mainly sandy, a little soil compaction actually improves the availability of water to roots and growth is enhanced, according to Powers. This observation is particularly important in dry climates, where sandy soils equate to drought, he says.

Powers points out that many of these observations are merely the first effort at summarizing the main treatments from only about one-fourth of the LTSP experimental sites in the United States, mainly those that have reached 10 growing seasons. In most cases, at least a decade is needed to get a glimpse of longer-term results. "That's because a decade or more is needed for a forest to reach its maximum foliage potential or carrying capacity, an indication that the site is fully stocked," Powers says.

It is possible that trends may change once data from other LTSP installations become available, Powers notes. Nevertheless, LTSP findings are already helping government agencies to validate and improve soil quality monitoring standards. In turn, these results will help to set standards for sustainable forest management. "But many of the benefits of LTSP may not be immediately apparent for some time," Powers says. "This is one of the challenges of long-term research with a 'basic' angle."

Removing whole trees without soil compaction.



Compacting on a normal soil using a vibrating roller.

...To Management

A Conversation with Bob Powers

Q: ***What are the benefits of the LTSP program for consumers?***
The LTSP program seeks to achieve more sustainable forests, which in turn supply consumers with paper, building materials, furniture, and even electrical energy. "Waste products" such as wood chips are being used by some industrial plants to generate electricity through the controlled burning of forest residues. Because the wood burns very cleanly at high, controlled temperatures, the main emissions are carbon dioxide and water vapor. And because the carbon dioxide came from the atmosphere originally, there is no net increase in greenhouse gases. Thus, "biofueled power plants" can supplement electrical energy traditionally coming from such fossil fuels as coal, oil, and gas.

Here's a little-known but telling fact. The United Nations reports that the average person "consumes" the equivalent of about 21 cubic feet of wood annually (a volume slightly larger than a typical clothes drier). By "consumption" I mean the volume of wood it takes to supply us with energy, paper, and building materials. In many third-world nations—the ones supplying the industrialized world with wood—consumption is less than 4 cubic feet of wood per capita, and it's used mainly for cooking and heating. In industrialized nations like the United States, consumption is more than 90 cubic feet per person, and it's mainly in the form of refined products like paper, finished panels, and furniture. Per capita wood demand isn't apt to decline much, and projections to mid-century indicate that global population will rise more than 40 percent.

All of the world's citizens will want wood and the products it provides. We must find ways to protect our ability to grow wood domestically and abroad, and to improve growth where we can.

Q: ***Does your research have any bearing on global warming?***
Yes. Through photosynthesis, actively growing forests scrub carbon dioxide from the atmosphere and convert it to solid matter that can be stored for long periods of time in materials of immediate value (wood) and in less-obvious materials below ground (roots and soil). A byproduct of this photosynthetic process is oxygen that is released into the atmosphere.

Forests cover only a quarter of the Earth's land surface, but their vegetation and the soils beneath them hold nearly half of the land's carbon. This tremendous reservoir of carbon held by forests is more than the amount in the entire atmosphere. This means that healthy forests are a major means for scrubbing carbon dioxide from the atmosphere to help control the greenhouse effect and provide the air that we breathe. In other words, saving the soil may be a key to reducing warming trends.

Aerial view of an LTSP plot.

Major Themes

Scientific guidelines: Managers now have a scientific basis for addressing appeals dealing with soil quality and sustained productivity.

Risk models: By evaluating the data that affect soil productivity, scientists can now map and monitor risks to forest areas that may be threatened.

Decaying residues: Managing decaying residues of the forest floor may have a major impact on sustained forest productivity.

Soil compaction standards: Managers now know that clay soils require special care during ground-based operations, as they are at increased risk for poor soil aeration and increased hardness.

Competing vegetation: To ensure rapid forest growth, managers must implement early control of competing vegetation.

Bacteria and fungi: Microbial studies indicate that management practices have little lasting impact on soil bacteria and fungi.

LTSP plots after treatment.

Scientist Profile

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As leader and co-founder of The North American Long-Term Soil Productivity Research program, Powers has assembled an international team of public, private, and university forest researchers, managers, and scientists, in the world's largest effort at understanding how soil disturbances associated with forest management affect forest health and productivity. Knowledge learned from this unique, long-term project is now being adopted by scientists worldwide. Powers has led the project since 1989.

Powers is currently a Fellow in the Soil Science Society of America and an editor of the journal Forest Ecology and Management. He is also an affiliate faculty member in Oregon State University's Department of Forest Resources. As leader of the LTSP program, he continues to forge partnerships with private and public forest management groups in an effort to improve and strengthen the study.

He received his B.S. in Forest Management from Humboldt State University in Arcata, California, and earned his Ph.D. in Physiological Forest Ecology from the University of California, Berkeley. He has been employed by the USDA Forest Service since the mid-1960s.

A recipient of numerous awards and honors, he was the first U.S. Forest Service employee to be selected as a fellow in the Soil Science Society of America.

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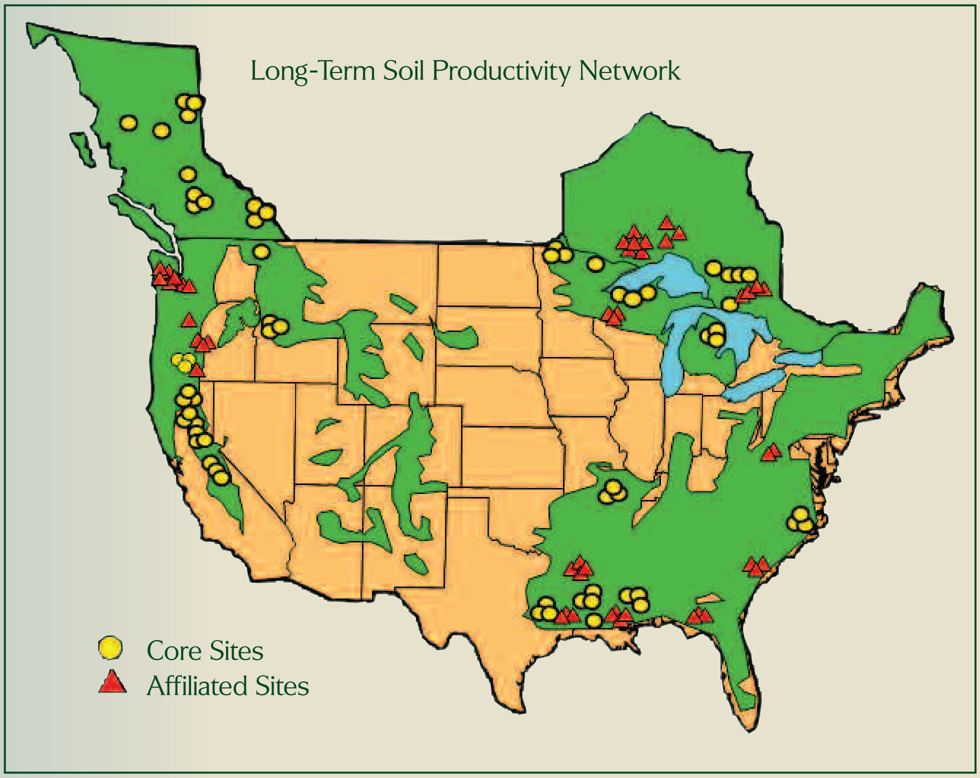
than 100 experimental sites across North America. Collectively, these sites represent the world's largest coordinated research network addressing basic and applied science issues related to soil science and forest productivity.

The LTSP program developed the first scientific indices and guidelines for monitoring and managing soil quality. Scientists now know that the keys to sustained productivity involve interactions between soil porosity, site organic matter, and soil fertility within the constraints of regional climate. Lessons learned from the ongoing LTSP effort will not only help sustain valuable forest resources in the United States and Canada, but will prove useful in maintaining forest productivity throughout the world.



LTSP network with core and affiliated sites.

Writer's Profile: Mark T. Sampson holds a B.S. in biology from Washington & Lee University in Lexington, Virginia, and an M.S. in journalism from Columbia University Graduate School of Journalism in New York. A member of the National Association of Science Writers, he currently resides in Alexandria, Virginia.

What's Next

One looming question concerns the impact of intensive forest management on carbon sequestration. Forests store roughly one-quarter to one-third of their biomass below ground as roots. Current thinking is that as management improves growing conditions, the amount of carbon going to roots is diminished. Put simply, trees don't need to invest so much in roots if the soil is fertile enough to provide abundant water and nutrients to the tops. If true, this suggests that intensive forest management (thinning, fertilization, genetic improvement) leads to less carbon being stored below ground and more going to tops, according to Powers. And from this it follows that intensive management to grow more wood faster may be working against the value of forests in carbon sequestration, the researcher says.

But Powers points out that this conventional wisdom has not been tested rigorously. The LTSP and related studies offer a good way to find out once and for all, he says. A better understanding of this process may lead to new strategies for controlling greenhouse gases and reducing global warming trends, he notes.

For Further Reading

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Web Resource:
http://www.fs.fed.us/psw/programs/ecology_of_western_forests/projects/ltsp/ (10/29/2007).

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