

Building Forest Resilience from the Ground Up

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Threats to our forests are changing. Wildfires are burning hotter and more often. Waves of pests and disease are similarly fueled by drought and overgrowth. Supercharged thunderstorms bring heavier, more intense rains, washing away fertile soil and creating dangers like flash floods and landslides. Human activities build threats as we continue harvesting precious resources and expanding urban interfaces with forested environments. As these stressors build, it's exceedingly important to recognize and monitor forest resilience; the inherent ability of the ecosystem to bounce back from disturbance. Forests exhibit resilience by surviving and even thriving through disturbance cycles. However, with more intense and frequent disturbances, there's a cause to be mindful of tipping points where forest resilience becomes insufficient. How far can forests be pushed? How many wildfires, how many droughts, and how many pests can a forest endure before it can no longer recover?

In response to these escalating threats, there is an urgent need to adapt forest management strategies. This requires developing novel tools and modifying traditional practices to focus efforts on building forest resilience. Scientific and technological innovations are critical for the success of adaptive land practice. While new approaches may present challenges to costs, workforce training, and logistics, the potential to bolster forest resilience through forward-thinking strategies is vital for long-term forest health and productivity.

Efforts to protect forest health often focus on above-ground vegetation, but our most significant opportunities to bolster forest resilience are through forest soils. Healthy forest soils provide a foundation for the entire ecosystem, providing essential services like water storage, nutrient cycling, and the growth medium necessary for organisms. Soils are much like the foundation of a building, where cracks weaken the entire structure. Thus, understanding how to protect and rehabilitate forest soil health is essential as land managers seek ways to enhance forest resilience and protect against threats facing our forested environments.

The Vitality of Forest Soils

Remember that forest soils are more than just dirt. They are a dynamic world, stocked with communities of microorganisms and essential resources needed to support the ecosystem. The abundant pore space in organic matter-rich forest soils absorbs and filters huge amounts of water, helping to protect against floods and erosion while providing clean water. Organic matter also feeds microorganisms, who recycle nutrients locked in plant matter which maintains aboveground health. These fundamental properties of healthy forest soils are the building blocks necessary for life. As Franklin D. Roosevelt said, "A nation that destroys its soils destroys itself. Forests are the lungs of our land; purifying the air and giving fresh strength to our people." In this modern era, as we search for ways to mitigate climate change, forest soils store vast amounts of carbon, and help to regulate the earth's climate.

The hidden life in forest soils serves as the tireless workhorse of a forest ecosystem. Bacteria, fungi, insects, earthworms, and other organisms have their place in society that underpins the entire forest. Consider this world's similarity to our own, with vast fungal networks shuttling resources to where they are needed most; predatory microbes serving as police officers, patrolling for harmful pathogens; and symbiotic organisms trading skills and resources, towards the benefit of all partners. Every leaf and root provide the underlying currency that keeps this powerful economy churning. It's through this bustling world that raw elements are refined into useful products and dead plant material is recycled to sustain the building blocks of a healthy forest.

(Insert photo 1)

Yet, like our forests, the health of this intricate below-ground world is increasingly under threat. The dangers to forest soils are abundant, whether due to logging operations that compact the soil or wildfires that consume the organic horizons to reduce water storage and nutrient availability. Moreover, climate change is amplifying many of these threats. Severe droughts put greater strain on soil microorganism communities, while higher-intensity rainfall can cause disastrous debris flows from degraded soils, such as those exposed by severe wildfires. This barrage of threats makes protecting and rehabilitating forest soils paramount for those looking to steward forest ecosystems through this era of unprecedented conditions.

Understanding Common Threats

In the Western U.S., mega-fires are turning organic-rich forest soils into nutrient-depleted landscapes. Some healthy, resilient forests can recover from severe wildfires. Yet, soils in forests with less resilience may require decades to regenerate to their previous condition, and in some instances, recovery may never occur. The heat of severe wildfire penetrates the soil resulting in substantial loss of organic matter, leaving nothing to hold the soil together. This makes post-wildfire soils far more susceptible to erosion. In addition, the combustion of organic material can leave a water-repellant residue on the soil surface, forming impenetrable sheets that prevent infiltration and speed water moving across the soil surface. This increases the potential for flash floods and debris flows. Extreme soil heat can also change forest soil's chemical composition.

In the Pacific Northwest, invasive plants such as Himalayan blackberry and Scotch broom form dense, almost impenetrable thickets, while diseases like sudden oak death devastate native trees. All these cause adjacent below-ground effects on nutrients and microbes, further degrading forest health and diversity. At the soil surface, pockets of invasive species steal light and nutrients from native species and often prevent large shrub and tree species from establishing. Some invasive species release chemicals that can harm soil microbes to increase their growth advantage. Over time, the lack of microbial diversity can disrupt the balance in the soil by altering organic matter inputs and microbial decomposition, reaching the point where native plants can no longer survive.

Forest harvesting can be sustainable, but when logging activities disrupt soil properties there can be long-term consequences to both forest and soil health. Understanding potential logging impacts and adjusting harvests to protect

soil health is important. Activities that retain large-diameter woody residues and surface organic horizons protect nutrients, reduce erosion, and protect microbial populations, including important networks of mycorrhizal fungi. These fungi form symbiotic relationships with tree roots and help bring nutrients and water to trees. These relationships are so important that when disturbed, they can reduce tree growth and the long-term productivity of the forest.

(Insert photo 2)

Drought conditions across many regions of the western U.S. are more frequent and long-lasting, which increases wildfire risk, and hurts plant growth and microbial communities. Sudden swings between drought conditions and intense rainfall events increase the threat of erosion. Climate change also favors the expansion of pests and diseases, as warmer temperatures and stressed trees create ideal conditions for outbreaks.

Forest Management Pathways to Resilience

Threats facing our forests may seem overwhelming, but sound and adaptive management strategies can protect forests and soils from disturbance and bolster their resilience. The critical element is soil organic matter. Keeping enough organic matter in forest soils helps maintain fundamental processes even during stressful conditions.

Restoring forests and rebuilding soil health after disturbances often requires replanting native species, installing erosion protection measures, and managing invasive plants. Novel research focuses on avenues to jumpstart microbial communities in disturbed soils, increase nutrient cycling, and promote the regeneration of native plants. Soils with diverse microbial communities and sufficient nutrients are better equipped to regenerate native species after a disturbance, as well as withstand droughts, pests, and disease outbreaks.

To build resilient soil after harvesting, it is important to maintain surface organic horizons to limit the extent, duration, and intensity of compaction. Placing a layer of branches and needles on skid trails can buffer the soil from mechanical damage while also enhancing water and nutrient supplies as the stand begins to regenerate. Combining this practice with other methods to minimize heavy machinery and retaining a diverse mix of tree species and age, forest harvest operations can proceed with no lasting effects on forest health. Informed practices safeguard forest soil health and ensure pathways for sustainable resource production, while simultaneously protecting and promoting forest resilience.

Forest management also plays a vital role in addressing climate change. Thinning crowded stands and fostering diversity help to reduce the risk and severity of fires and their impact on soils. Wildfires release tremendous amounts of carbon dioxide, the most abundant greenhouse gas. Further, wildfires are among the most abundant sources of more potent greenhouse gases, like methane and nitrous oxide. Climate-smart land practices that build more fire-resilient forests can help reduce these harmful emissions. Altering tree spacing and species composition, to include more fire-adapted species, reduces the potential for catastrophic, high-severity burns. Seizing on opportunities to make our forests carbon sinks, rather than carbon sources, is vital to climate mitigation efforts.

The Biochar Opportunity

Overhauling current practices for reducing forest slash presents opportunities to generate a useful product, enhance soil health, and sequester carbon. Biochar is a charcoal-like substance produced through the combustion of organic materials in a low-oxygen environment (pyrolysis). Forest slash is an ideal feedstock for biochar production. Rather than the traditional practice of burning this material, converting it to biochar yields a valuable product that sequesters a portion of the carbon that would otherwise be released into the atmosphere. As a soil amendment, biochar improves water retention, nutrient holding capacity, and benefits microbial activity. While often used in agriculture, biochar has immense potential in forest management. It can be incorporated into soils during restoration activities, providing long-term benefits for re-planted trees and regenerating soils. Additionally, biochar holds promise for remediating contaminated soils, such as those found in mining sites common across western U.S. forests. With proper production methods and application rates, biochar presents a multi-faceted opportunity to turn a waste product into benefits for forest resilience and soil-dependent industries.

Investing in Forest Soil Health: Benefits Beyond the Forest

Investments in forest soil health pay dividends that extend beyond the forest ecosystem. Healthy soils underpin productive and resilient forests, opportunities for sustainable timber harvests, and other long-term economic benefits for forest-dependent communities. In an era of new climate extremes, there is increasing value in maintaining healthy forest soils, especially regarding water. Healthy forest soils protect the well-being of countless species, including our own, by filtering water, reducing flood risk, and supporting a robust food web. Protecting the carbon-storage capacity of forest soils is critical for mitigating the rise of greenhouse gas concentrations in the atmosphere. Nurturing tree growth and healthy forest soils helps capture carbon and provides raw materials for innovative, climate-smart products like cross-laminated timber. This highlights the exciting potential of sustainable forest management to cultivate new resources and contribute to positive climate action.

Forest health is inextricably linked to soil health. Understanding this often-overlooked foundation is critical to proactive, climate-smart land management. While the threats facing forest soils are considerable, further use of innovative and informed practices helps ensure the survival of our forests through this era of climate-fueled disturbances. By learning more about sustainable forest management, supporting local forest projects, or simply pulling an invasive plant from your favorite trail, we can find a way to protect our forest ecosystems. A commitment to adaptive practices that promote healthy forests, and the soils that support them, is essential to ensuring the natural resources we enjoy and rely upon.