Working Papers in Southwestern
Ponderosa Pine Forest Restoration

Limiting Damage to Forest Soils During Restoration

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Ecological Restoration Institute
Northern Arizona University
P.O. Box 15017
Flagstaff, AZ 86011-5017
www.eri.nau.edu

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The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of southwestern ponderosa pine forests. These forests have been significantly altered through more than a century of fire suppression, livestock grazing, logging, and other ecosystem changes. As a result, ecological and recreational values of these forests have decreased, while the threat of large-scale fires has increased dramatically. The ERI is helping to restore these forests in collaboration with numerous public agencies. By allowing natural processes such as fire to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

Every restoration project needs to be site-specific, but the detailed experience of field practitioners may help guide practitioners elsewhere. The Working Papers series presents findings and management recommendations from research and observations by the ERI and its partner organizations.

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1: Restoring the Uinkaret Mountains: Operational Lessons and Adaptive Management Practices

2: Understory Plant Community Restoration in the Uinkaret Mountains, Arizona

3: Protecting Old Trees From Prescribed Fire

4: Fuels Treatments and Forest Restoration: An Analysis of Benefits

Introduction

In southwestern ponderosa pine forests, wildfires have become unnaturally damaging because of decades of fire exclusion and the increased density of forest stands. Large, severe fires are well known to be destructive to forest vegetation and wildlife, but an additional, often-unseen effect of fires is on and in the ground—the disruption of soil structure and properties that can have a cascade of effects throughout forest systems. Forest soils supply air, water, nutrients, and mechanical support for plants, and provide habitat for decomposers, nitrogen-fixing bacteria, and symbiotic fungi. Whether forest managers are looking to rehabilitate forests after wildfire or conduct restoration treatments intended to prevent severe wildfire, it is important to protect soils.

Fire Effects on Soils

Only about 10 to 15 percent of a fire's heat is typically directed downward (DeBano et al. 1998), but this can still cause considerable changes in soils. Beginning at 48 degrees Celsius (118 degrees Fahrenheit), heat destroys the biological components in soils, including microbes and plants. These effects are most obvious in the top centimeter or two of soil, and the most common result is the loss of top organic layers to erosion after fires. At higher temperatures, though, damage can result from the fire itself, especially during intense, stand-replacing fires.

When heat dries out organic components irreversibly, or they leach out to coat soil's mineral components, a *hydrophobic* (water-repellent) layer can form. This is most likely to happen when soil temperatures rise to between 176 and 204 degrees Celsius (350 to 400 degrees Fahrenheit). Soil temperatures can reach this level when thick layers of ground litter or accumulations of woody debris burn for long periods. Because it resists infiltration by rain, a hydrophobic layer puts the forest floor at risk of runoff and erosion.

When soils heat to temperatures between 200 and 500 degrees Celsius (390 to 900 degrees Fahrenheit), solid organic matter is destroyed. While this can provide ready nutrients for plants growing immediately after a fire, these conditions destroy soil structure. In the long run, this can affect archaeological or other cultural resources, nutrient cycling, and ecosystem productivity. Arid soils, such as those in some southwestern ponderosa pine forests, recover more slowly from these effects than soils in which organic matter is replaced more quickly.

Proactive Restoration Treatments Can Benefit Soils

Many of fire's negative effects on soils can be minimized with efforts to prevent catastrophic fires. Thinning and controlled burns can clear out accumulated brush and other fuels from forests. Then, when a fire does start, it is likely to burn cooler and with shorter duration in a forest that has undergone restoration treatments, thereby preventing many of the deleterious effects of prolonged, hot fires.

However, even prescribed burns and mechanical thinning projects introduce their own damage to forest soils, especially soil compaction. Compaction can reduce soil porosity and decrease the rate of water infiltration. These effects can lead to increased runoff and erosion similar to that seen following fires. Careful planning and treatment implementation can minimize these impacts.

Forest Restoration: Effects on Soils

Mineral soil can be lost during restoration thinning efforts in the same way as during traditional logging operations: directly through the removal of surface layers by mechanized equipment, or indirectly through compaction. Either type of damage can lead to erosion, retardation of plant recovery, and impeded root growth. Various factors affect the degree to which a particular soil type or site is vulnerable to soil compaction and loss (Selmants et al. 2003):

- Fine-textured soils are more at risk of compaction.
- Wet soils are more likely to sustain damage from both compaction and mechanical soil removal than dry soils.
- Organic matter and surface rock fragments can buffer soils from compaction.

The same factors can influence the speed at which soil recovers, although no studies to date have documented complete recovery from machine-induced compaction.

In addition, prescribed fires after restoration thinning can cause extensive soil heating and, when burning in thick litter, can damage roots and cause tree mortality (see *Working Paper 3: Protecting Old-Growth Trees From Prescribed Fire*). Slash pile fires can cause intense soil heating, destroying the soil seed bank and mycorrhizal fungi (Korb and Springer 2003). For these reasons, soil effects should be considered when planning post-thinning burns.

Minimizing Soil Loss and Compaction

Soil impacts should be considered during all stages of a restoration project: in the planning process, during implementation, and after thinning is completed. The following steps can aid in minimizing impacts.

Planning

- Make prescriptions reasonable for easier cutting. Leaving a few small trees where a dense doghair thicket stands, for example, makes it difficult for the logger to cut the rest down, resulting in more time needed for the job and greater impacts to soil. If a thicket is to be retained for wildlife habitat, it may be better to cut trees from its edge while retaining the thicket's integrity.
- Designate skid trails ahead of time. Use a pattern, such as a zigzagging line, that occupies as little surface area as possible (Garland 1997). Take advantage of areas least susceptible to compaction, such as areas with some surface rocks.
- Consider manual treatments such as hand felling, especially in ecologically sensitive areas.
- Consider a mosaic of treatments that leaves some areas undisturbed.

Implementation

- Work when soils are least sensitive. Avoid wet periods. One good option is to work when soil is frozen or dry. A layer of snow can provide an additional buffer against compaction.
- Maintain soil organic matter and keep surface soil, litter, and slash in place while harvesting. This can increase resistance to compaction and protect soils from erosion. The tradeoff is that this can also increase the severity of burns, controlled or otherwise, that follow mechanical treatments—so removing slash before burning may be a good idea.
- Use a cut-to-length (CTL) harvesting system that processes trees in the woods. The resulting slash can be disposed of in front of the machine and driven on to buffer soils from compaction. The use of a CTL system also reduces the need to drive to each individual tree by harvesting those within a set radius of the machine, as opposed to harvesting requirements for a drive-to-tree feller buncher.
- Use a forwarding system rather than a log skidding system in conjunction with a CTL harvester to collect logs piled in the woods by driving on the same slash mats. Later, the forwarder may be used to collect and remove the slash itself.

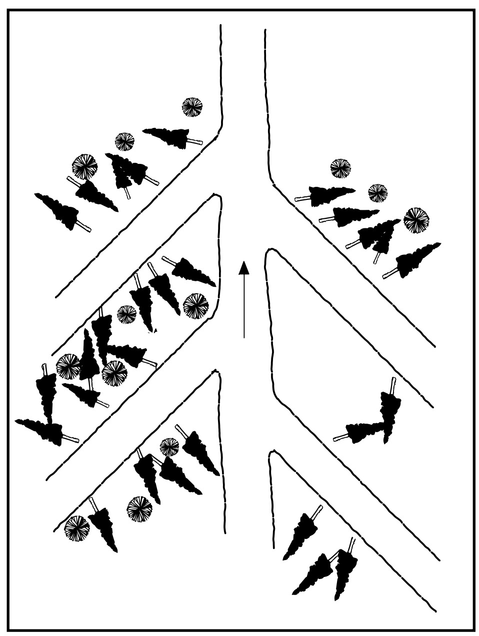

Figure 1. *Felling trees to skid trails can reduce the difficulty of winching and minimize soil impacts. Reprinted with permission from Garland 1997.*

- Fell trees to skid trails in order to minimize skidding distances, soil disturbance, and damage to vegetation (Figure 1; Garland 1997).

- Consider hot loading, or loading logs directly onto trucks rather than decking them first.
- Consider ripping skid trails to rehabilitate them after use.

After Thinning

- Burn slash where soil is already disturbed, such as on loading areas or roads.
- Lop and scatter slash before burning in order to prevent intense soil impacts under slash piles. The tradeoff is that excessive broadcast slash can greatly increase the intensity of prescribed fires and make them difficult to control. In particular, hot spots may occur under larger branches.
- Consider alternatives to burning slash. It can be removed for chipping, or transported to a biomass or pellet plant. If they are to be removed, slash piles should be placed along roads or skid trails for easy loading.
- One new approach that shows promise is remediation of severely disturbed areas—such as former roads and sites of slash pile fires—with native fungus. Spreading chipped wood and bark on such areas after inoculating it with fungi speeds the ecological recovery process and may help prevent the spread of noxious plants.
- Construct fire control lines with an eye toward minimizing soil compaction and erosion problems. Locate control lines away from erosive soils. Minimize the time control lines are in place, and rehabilitate them quickly after burning. Install water bars on steep slopes. Strike a careful balance between the straight control lines preferred by fire managers and zigzagging lines that may better prevent soil compaction and erosion.
- Seeding with native herbaceous plants can help stabilize soils after fire. Applying seed into the ash bed immediately after burning helps hold the seed in place, reducing the need to drill or otherwise disturb the surface.
- Carefully consider the frequency of future prescribed fires. They are crucial in maintaining forest structure but, if repeated as often as every two years, may cause declines in soil nitrogen available to plants (Wright and Hart 1997). Somewhat longer intervals may be preferable.

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For More Information

For information about forest restoration, contact the ERI at 928-523-7182 or **www.eri.nau.edu**.

To learn more about remediation of disturbed areas with fungus, contact Jim Bell at **composttrees@yahoo.com** or visit **www.fungi.com/mycotech/roadrestoration.html**.

Written by Anne Minard

Reviewed by Dennis Becker, Sat Sansar Best, Kevin Boness, Charlie Denton, Tori Derr, Tim Duck, Taylor McKinnon, Jeff Morton, Steve Overby, and Todd Schulke.

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www.eri.nau.edu

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