Soil: The Foundation of the Ecosystem

Effects of Management Activities on Forest Soils: Can We Manage Better?

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INTRODUCTION

"The social lesson of soil waste is that no man has the right to destroy soil even if he does own it in fee simple. The soil requires a duty of man which we have been slow to recognize." (H.A. Wallace, 1938)

"In the old Roman Empire, all roads led to Rome. In agriculture, (forestry) all roads lead back to the soil, from which farmers (foresters/land managers) make their livelihood." (G.Hambidge, 1938)

Since Aristotle considered soil in relation to plant nutrition (348-322 B.C.), knowledge of soils has made tremendous strides. The way we view soils has evolved from a focus on agriculture to modern views of soil from multiple perspectives, including that of soils as natural bodies, partitioners of water, a medium for plant growth, soils as ecosystems and ecosystem components, and soil as engineering materials.

Our knowledge of soils and their roles in forest ecosystems is undergoing rapid change. In particular, knowledge of the composition and processes below ground is increasingly of interest to forest practioners. This is where most of the biotic diversity is and where annual carbon accumulation often is greater than above ground. Yet, too often the focus of forestry is on the vegetation rather than the soil system that regulates rates, quantities, and types of vegetative growth.

There has been much written, discussed, and debated recently about forest health, rangeland health, and watershed health. While each of these entities are important in their own right, the broader issue is one of "Ecosystem Health." And one cannot address ecosystem health without addressing "Soil Health." In particular, an understanding of management effects on soils is critical if we are going to provide healthy forests, healthy rangelands, healthy watersheds, or healthy ecosystems.

There is an expanding body of knowledge about the effects of management activities on forest soils. While there is much yet to be learned, our experience and knowledge do permit some general statements about management effects. The focus of my presentation is on the effects of some key management practices on soil properties, processes, and products derived from the soil.

Nature and Properties of Blue Mountain Soils

Before discussing specific effects of management, it is important to briefly review some of the variety of soils in the broad ecoregion of the Blue Mountains. This is important ecause the effects of management vary greatly among the various kinds of soils. I also hope to dispel some myths and perhaps false perceptions about the soils in this area.

Following are some important features of soils in the Blue Mountains:

- Most are influenced by volcanic ash from Mt. Mazama 6700 yrs. ago.
- Water-holding capacity is highly variable, but is highest in the soils from volcanic ash. Most soils with more than 14 inches of volcanic ash are dry for less than 45 days following the summer solstice.
- Soils dominated by volcanic ash usually are deep, or very deep (greater than 40 inches).
- Soil bulk density in the surface layer averages about 0.67 g/cc in the ash soils and about 0.9 to 1.0 g/cc for soils with minimal volcanic ash.
- The material below the volcanic ash is variable and affects the way the soil handles water. When clay subsoil is at shallow depths, overland flow can occur and cause accelerated erosion.
- Soil organic matter ranges from about 2 to 9% in the surface layer (0 to 6 inches) and usually is lowest in soils under lodgepole pine communities and highest under Engelmann spruce or grand fir communites. In the 6- to 12-inch depth, organic matter usually is 1 to 4%.
- The litter layer is highly variable, but thickness generally increases as soil temperature decreases and elevation increases.
- Quantities of soil nitrogen and available phosphorus vary widely. The surface 12 to 24 inches have relatively high contents, but at greater depths, amounts are very low.
- There is wide variability in soil properties and behavior.

Soil Quality Standards

Soils vary widely in their capabilities and resilience to management. Soil quality standards are a measure of acceptable limits of impact and a basis for defining detrimental conditions.

In 1977, the Pacific Northwest Region established soil quality policy, objectives, and standards. The general objectives are to plan and conduct management activities so that reductions in soil productivity and water quality are minimized and to maintain acceptable levels of nutrient capital.

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The standards are:

Leave at least 80% of activity area in acceptable condition for plant growth (including roads; 85% excluding roads)

Detrimental conditions:

Soil Compaction (for non-volcanic soils)
- 15 % increase in bulk density
- 50% decrease in macro pore space
- less than 15% macro pore space

Soil Compaction (for volcanic ash or pumice soils)
- 20% increase in bulk density

Soil Displacement
- Removal of 50% of A and/or AC horizons from 100 ft.[2] area

Soil Puddling
- Loss of soil structure by rutting at greater than 6-inch depth

Burning
- Top layer of mineral soil changed in color to red, next 0.5 inch blackened

Soil Erosion
- Leave a specific amount of effective ground cover according to the soil erosion hazard

Effects of Management on Soil

Management activities affect soils in many ways. Effects can be beneficial as well as detrimental, physical, chemical, biological, or combinations of these. Of course it is also true that the kind of soil affects the kind of practice or activity that is appropriate for achieving long-term sustainability of the land and water resources. Use of the land is continually evolving and the nature, degree, and extent of effects changes accordingly. As population pressures increase, the demand for goods, services, and values from the land also increases. While technology changes to adapt to changing land uses, the tendency has been for bigger, faster, and more automated equipment that has the potential to affect the soil in greater degrees. The application of technology must be based on an understanding of the soil capabilities and resilience if we are to manage for long-term sustainability of forest and rangeland ecosystems. From an organism perspective, it is a matter of managing stress conditions to optimize organism function.

Effects of Harvest Activities on Soils

For this discussion, I include harvest and site preparation activities required to establish a new stand. Operation of heavy equipment can have significant effects on soil properties. Research and monitoring studies in the area have found that detrimental soil conditions normally occur on from 10% to more than 70% of an activity area.

Lower disturbance may be due to fewer entries compared with other sites. The majority of the soil damage was from soil compaction. Only a small percentage was from soil displacement.

One study also found that total nitrogen and organic matter were reduced by 17 and 26%, respectively, when comparing low and high disturbance areas. Average soil bulk density increased by 24%.

The low natural bulk density of the Blue Mountain soils derived from volcanic ash contributes measurably to their relatively high productivity. The high porosity that accompanies low bulk density results in soils with relatively rapid infiltration and high water storage capacities. These properties also mean that the soils have relatively low erosion from rainfall.

Effects of Harvest Activities on Tree Growth

The question then is, so what? Studies in Northern Idaho, found significant reductions in height and diameter growth of lodgepole and ponderosa pine stands related to soil compaction, defined by penetration resistance classes, and to displacement. Volume reductions were as much as 44% on high resistance classes. Similarly, a study in Northeast Orego volcanic ash soils found reductions of 2 and 24%, respectively, for height an diameter growth when comparing hig disturbance with low disturbance areas

Effects of Fire on Soil Properties an Organisms

Effects of fire are dependent on dur tion and intensity of the fire as well as th condition of the soil, including moistu content, when burned. There is gre variability in effects on the soil and o vegetation. One can find beneficial c adverse effects, depending on which stud one cites.

Element	°C
C	200
N	>300
P	750-800

Table 1. Temperatures at which selecte elements are volatilized

Carbon and nutrients can be volati ized at temperatures of 200°C and high (table 1). Fires can affect soil processe including nutrient availability. Cool fir can increase availability of some nut ents for a few years (table 2). Wat repellency can increase when tempe ture is about 170°C and higher. That c cause increased runoff and accelerate e sion. This often happens in areas of h burns. That is, fires of high intensi long duration, or both.

Soil Process	Effects
Cations Released (Ca, Mg, K)	Deposited as oxides and salts
Ammonification	Enhanced for few years
Nitrification	Enhanced for few years
Water repellency	Intense at temps above 176 °C Peaks at 270 °C Common at 204 to 370 °C

Table 2. Some effects of fire on selected soil processes

Soil organisms can be killed w relatively cool fires. When soils are w organisms are killed at lower tempe

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Organism		Temperature °C Wet	Dry
Bacteria		110	210
Fungi		60	120
Roots	1.0 cm	<100	—
	2.5 cm	—	<100

Table 3. Temperatures at which soil organisms are killed by fire

tures than when dry (table 3).

Fires that consume the forest floor biomass and change soil color to red usually will have significant adverse effects on nutrient supply and result in soil erosion. But where prescribed fire is properly applied to moderately deep and well developed soils, the benefits should outweigh the drawbacks.

Can We Manage the Soil Resources Better?

I think the answer is an unqualified yes! The question really is, how can we manage better? First, our approach should be to prevent damage as much as possible. This can be done in a number of ways. For harvest and site preparation, our goal is to reduce the amount of area affected, operate when conditions are favorable, such as when soils are dry or when the ground is frozen or depth of snow is sufficient to cushion the impact, use cable or helicopter systems where needed, and minimize the number of entries. In order to reduce the number of entries, it is important to begin by considering the silvicultural prescription. For example, even-age management requires fewer entries than uneven-age management. Therefore, even-age management systems may result in less effect on the soil, and it may provide more opportunities for applying cultural practices, such as tillage, that can begin the process of restoring compacted soils.

Some practices that minimize adverse effects from fire include doing broadcast burning within prescription, selective use of underburning within prescription to reduce fuel loads, crushing residues in lieu of burning where appropriate, and selectively piling fuel for burning.

These are some specific examples for reducing effects. Many already are used to varying degrees. The key to managing the soil resources better is to have knowledge of the soils and their behavior in response to management practices. Another important step is to have clearly defined soil quality standards and design prescriptions to meet those standards as well as meeting other management objectives. Finally, a sound monitoring program that includes management feedback is essential for improving soil management.

One of the principal and critical steps we have taken to gain the understanding about the complex interactions of the soil-vegetation-landscape system, is through a cooperative stressed-sites administrative study. Dr. Mike Geist is the principal scientist. There are three parts to this effort: development of effectiveness monitoring methods, stressed sites guides, and diagnostic and treatment studies. In order to continue and develop better management models, this effort needs to have additional support.

Cultural Practices to Improve Soil Conditions

There are a number of practices that can improve soils that have been degraded from management or can improve soil quality where inherent properties are such that soil quality is low. Subsoiling is a common practice to alleviate compacted conditions. Winged subsoilers that fracture the soil without leaving deep furrows or turning over the soil can be effective. It requires careful operation by skilled equipment operators. Rock rippers and scarification with brush blades usually are ineffective for soil restoration and should not be used as a general practice. When subsoiling, it is very important to clearly define objectives, including depth of tillage. Then, use the right equipment under the right conditions to meet those objectives.

Nutrient capital, especially nitrogen, varies widely in Blue Mountain and other northwest soils. However, availability in forms that plants can use also is a critical factor. Frankly, we don't have a good understanding of nutrient availability in most of our forest ecosystems. While we have some information about what species respond to added fertilizer on some soils, we don't usually know why some respond and why others don't.

Forest fertilization may be a means of improving the nutrient status of soil and vegetation. Fertilization studies are being conducted in parts of the Blue Mountains by the Intermountain Tree Nutrition Cooperative at the University of Idaho. Both ponderosa pine and Douglas-fir are being studied. The results are inconclusive. While some gains in growth have been measured in Northeast Oregon, they are less than in central Washington and northern Idaho, for example. There are confounding influences such as limits of nutrients other than those added. Sulfur and phosphorus may be limiting on volcanic ash soils. Also, fertilization may lead to increased mortality by insects and root diseases.

Another way of increasing nitrogen status is by encouraging growth of nitrogen-fixing plants. Though nitrogen-fixing species are not abundant in some areas of the Blue Mountains, some sites support non-leguminous plants such as ceanothus, shepherdia, purshia, cercocarpus, alnus, and others that fix nitrogen. Leguminous plants include lupinus, astragalus, and thermopsis. Management of these species can enhance the nitrogen status of soils, and nitrogen usually is the most limiting nutrient. Management of soil organic matter and woody residues is important for total nutrient management. Woody residues provide sites for non-symbiotic nitrogen-fixation and they are important for maintaining mycorrhizal fungi.

Summary Recommendations to Maintain and Improve Soil Quality

Maintenance of soil quality is crucial for sustaining productivity and favorable hydrologic functions. Good soil quality is essential for reducing stresses on vegetation. A few key points are worth considering. First, know your soils and how

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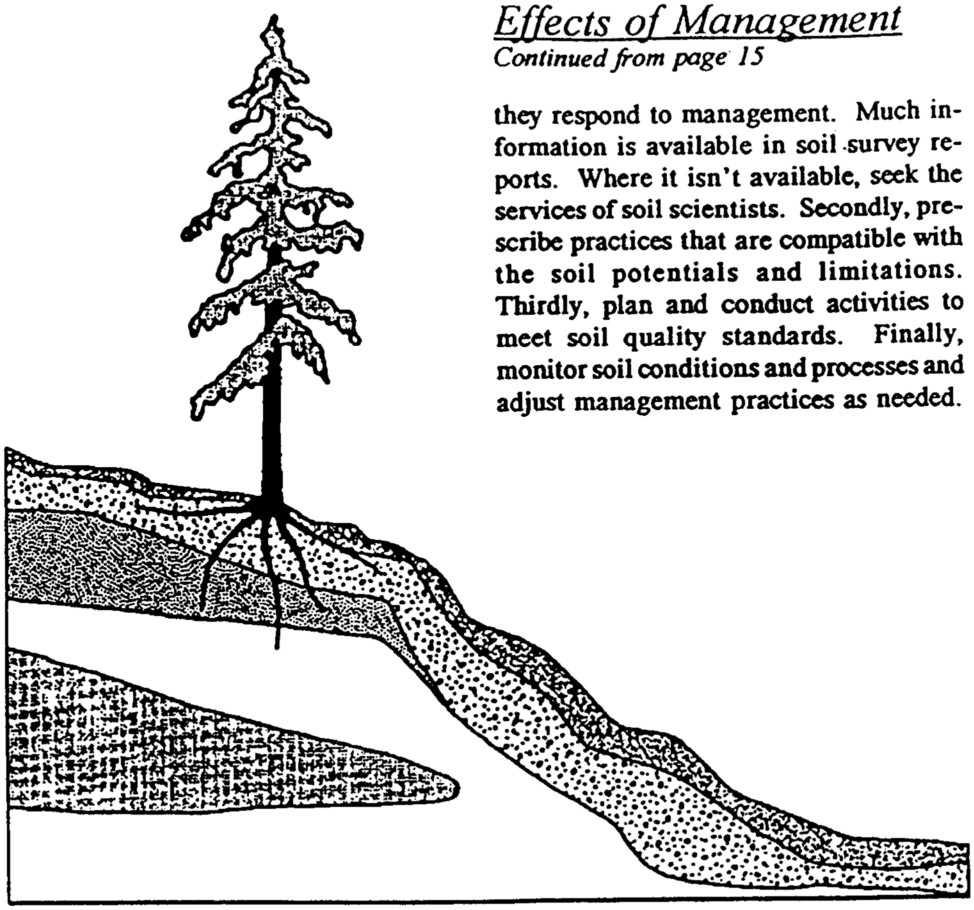

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they respond to management. Much information is available in soil survey reports. Where it isn't available, seek the services of soil scientists. Secondly, prescribe practices that are compatible with the soil potentials and limitations. Thirdly, plan and conduct activities to meet soil quality standards. Finally, monitor soil conditions and processes and adjust management practices as needed.

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