THE WOODLAND WORKBOOK

FOREST PROTECTION

EC 1109 • Reprinted March 1998 $1.50

Soil Compaction on Woodland Properties

P.W. Adams

Contents

Soil compaction can happen whenever machinery, livestock, or people travel on the land. On woodlands, compaction is most likely to be caused by logging equipment such as crawler tractors and rubber-tired skidders. Compaction can greatly reduce the growth of seedlings and trees, and it can increase surface erosion problems.

Many possible forest practices, equipment, and site conditions can produce minor to severe compaction problems. If you expect significant compaction problems, you can use certain management practices to minimize them.

This publication will provide background on the nature and effects of soil compaction, how it can be recognized, and some management alternatives for reducing its impacts. This information can help you decide whether you have an existing or potential compaction problem that deserves attention, and it offers some ideas about what you can do to reduce compaction.

What is soil compaction?

A productive forest soil is a mixture of mineral particles, plant and animal matter, air, water, and associated nutrients. If you pick up a handful of this soil, usually less than half of what you hold is solid material. The rest is pore space containing water and air (Figure 1). Most of the pore space is either the tiny cracks and crevices found between soil particles and clods, or the channels left by animals, insects, and plant roots.

When a soil is compacted, the particles and clods are pushed closer together, reducing the amount of pore space and increasing the soil density (weight of a given volume of soil). Applying loads or vibration to the soil causes this packing of particles and clods. Even with wide tracks or tires, logging machinery and other vehicles produce some vibration and significant ground pressure, especially when traveling loaded over uneven or sloping ground surfaces.

Paul W. Adams, Extension forest watershed specialist, Oregon State University.

OREGON STATE UNIVERSITY EXTENSION SERVICE

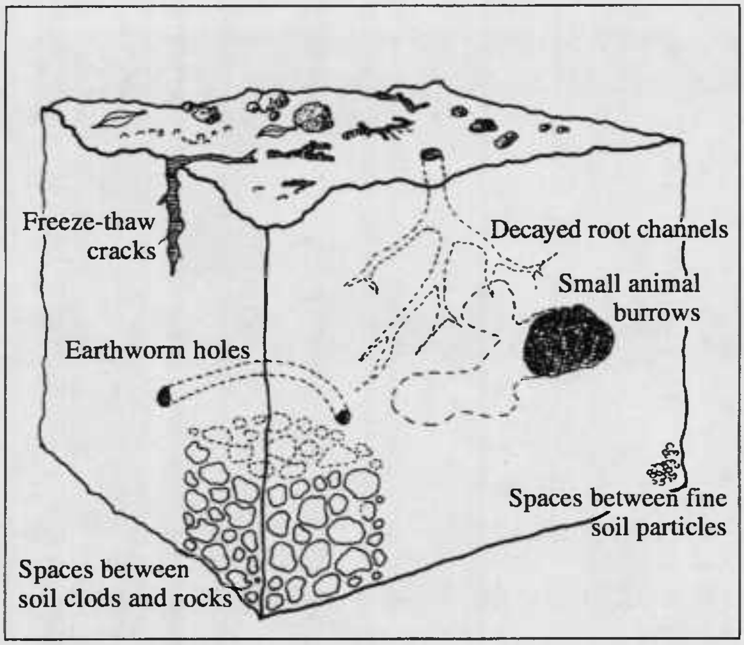

Figure 1.—Pore space and solids in a typical productive forest soil: total soil solids (mineral and organic matter) 45 percent; total soil pore space (ideally containing about equal volumes of air and water) 55 percent.

The pore spaces in the soil that are most easily affected by compaction are the larger channels or "macropores." These macropores are good sites for root growth, and they also provide efficient channels for soil drainage and aeration. Soil compaction reduces this large pore space, contributing to some important problems.

Why is compaction a problem?

A single logging operation with crawler tractors or rubber-tired skidders typically produces compacted soil on up to 20 to 35 percent of the area harvested. Multiple-stand entries for salvage, thinning, or final harvest can add similar percentages of compacted land area. Even more land area can be compacted after machine piling of slash or brush.

Reduced forest site productivity is a major problem caused by such widespread compaction on woodland properties. Research has shown that compacted soils are less favorable for good plant growth because of high soil density and hardness, reduced pore space, and poor aeration and drainage. Root penetration and growth is decreased in compacted soils because the hardness or strength of these soils prevents the expansion of roots.

Supplies of air, water, and nutrients that roots need are also less favorable when compaction decreases soil porosity and drainage. This is a particular problem in flat or low areas where water collects on or near the surface of slow-draining compacted soil.

Measurements of seedling and tree growth (including Douglas-fir, western hemlock, ponderosa pine, and other important commercial species) on compacted soils show that these can experience significant growth reductions. Seedling height growth has been shown to be lowered between 5 and 50 percent.

Compaction from thinning operations has been found to decrease the diameter growth response of individual trees by as much as 40 percent. When averaged over an entire stand, with about 25 percent of the area in skid trails, compaction can reduce the overall diameter growth benefit from thinning by 5 to 15 percent.

Although some growth loss is expected from soil compaction, the exact amount depends on many factors. The most

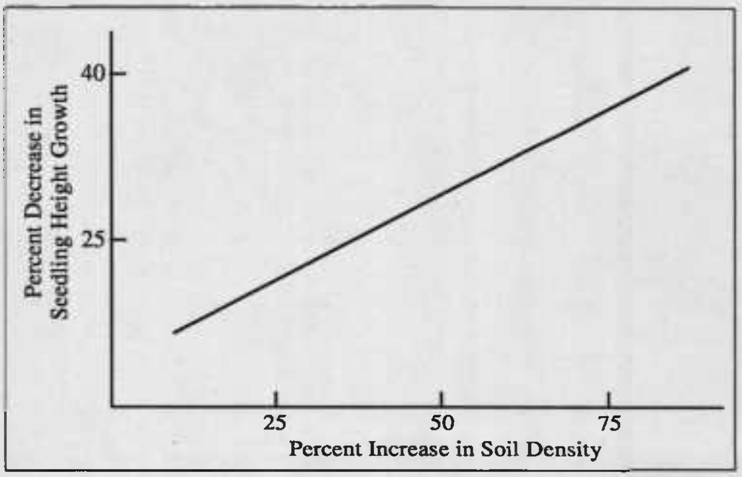

Figure 2.—The general relationship between increases in forest soil density and the height growth of tree seedlings (based on field studies of a variety of tree species, soil types, and locations).

important of these are the change in soil density, the area and depth of compacted soil, and the length of time that the soil remains compacted.

Seedling height growth losses, for example, have been found to increase with increasing soil density from compaction (Figure 2). For a given area of ground, the size of this increase depends on soil type, soil moisture content, equipment characteristics, and the number of vehicle trips that are made.

Because tree roots extend both downward and outward from the main stem, greater growth losses will occur when compaction extends deep into the soil over a large area of ground near the tree. In a thinned stand, for example, the greatest growth impacts are in residual trees that closely border major skid trails or that have had traffic on two or more sides of the stem (Figure 3).

The length of time that compaction lasts also determines whether growth impacts are short-lived or persistent. Unfortunately, research shows that growth impacts persist as long as several decades in the Pacific Northwest.

Besides the effects of soil compaction on seedling and tree growth, compaction also can increase surface runoff and erosion because of reduced water movement into and through the soil. Runoff can concentrate near existing woodland roads, adding to the stresses on the road drainage systems. Soil erosion can result when surface runoff becomes heavy and rapid enough to carry away soil particles.

Erosion can decrease forest site productivity from the loss of fertile surface soil, and the sediment produced can damage fish habitat and water quality for domestic and other uses.

Because of these potential problems, you're also legally required (through Oregon's Forest Practices Act) to minimize erosion caused by soil compaction on your property (see EC 1194).

Figure 3.—Tree likely to be moderately to heavily impacted by compaction in adjacent skid trails.

How can you recognize compaction?

You often can recognize heavily compacted soils on your property. These soils are difficult to dig up with a shovel, especially when they're dry. The individual clods that you excavate from a compacted soil also tend to be large and difficult to break up. When the clods are broken up, however, they often break into flat, platy pieces.

This platy structure is quite different from the granular or crumb structure

References to other publications

When you're referred to another OSU Extension Service publication, you'll find additional information in "For further reading," page 7.

observed. Resource managers and researchers use these tools to monitor and study soil compaction and its effects.

How can you minimize compaction problems?

Many approaches have been tried, to prevent or minimize soil compaction on forest lands. One has been to prohibit machinery operations on certain soil types or wet soils that seem particularly susceptible to compaction. Some soils appear to compact easily, especially at certain moisture levels, but it's difficult to estimate the amount of compaction that will result for the many soil and equipment conditions that are found in forest operations.

In addition, even a small change in soil density can produce a significant impact (Figure 2). Trying to manage compaction by soil type or soil moisture is not very practical.

Probably the best approach is to assume that most soils are "compactible" and to focus on techniques other than operations restrictions to minimize the degree, area, and depth of compaction.

The use of certain types of equipment for logging or other forestry operations can help reduce compaction problems. Soil impacts are often minor, for example, when cable or aerial logging systems are used. On gently sloping terrain, however, the costs of cable or aerial logging can be more than twice that of ground skidding.

We normally must look, therefore, at other alternatives for minimizing compaction while continuing to use ground-based systems. One of these is low-ground-pressure machinery. These vehicles have

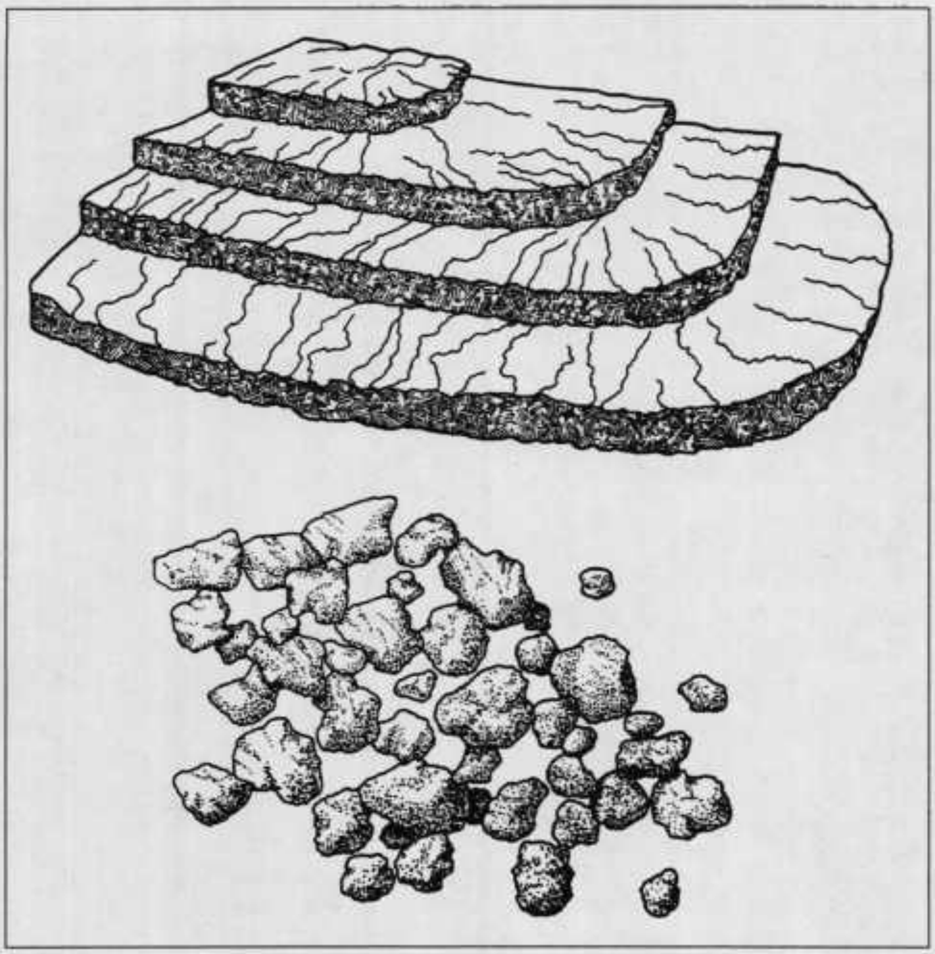

Figure 4.—Above: Platy structure often found in compacted soil. Below: Granular structure typical of the upper mineral horizon of productive forest soils.

commonly found near the surface of many forest soils (Figure 4).

Altered structure and reduced drainage in compacted soils also can result in surface runoff or standing water, which are normally uncommon on undisturbed upland forest soils.

The bare mineral soil often found in compacted areas like skid trails can be a good site for seed germination. Young plants and tree seedlings may be abundant in these areas, but compaction often reduces further plant development.

Therefore, another indicator of heavy compaction is the presence of stunted plants or tree seedlings. In second-growth forests, you can recognize skid trails used during logging years ago by looking for these growth differences.

Specialized equipment is available to detect soil compaction where it's not easily been found to produce somewhat less compaction than conventional equipment, but significant amounts still are likely to result.

One ground-based harvesting system that usually produces minor compaction problems is horse logging. Although horses' hooves produce substantial ground pressure, the ground area affected by horse travel in a logging unit is normally small and dispersed enough to be of little concern.

Horse logging thus can be a good option where site conditions allow an efficient operation. These conditions include small timber (generally less than 24" d.b.h.), gentle slopes, and short skidding distances (generally less than 500 feet).

If you must use tractors, skidders, and other machinery capable of causing significant soil compaction, there are still alternatives and information that you can employ to minimize compaction problems. Soil duff layers (twigs, needles, and other organic debris on the soil surface), for example, can act as a cushion against the forces of heavy machinery.

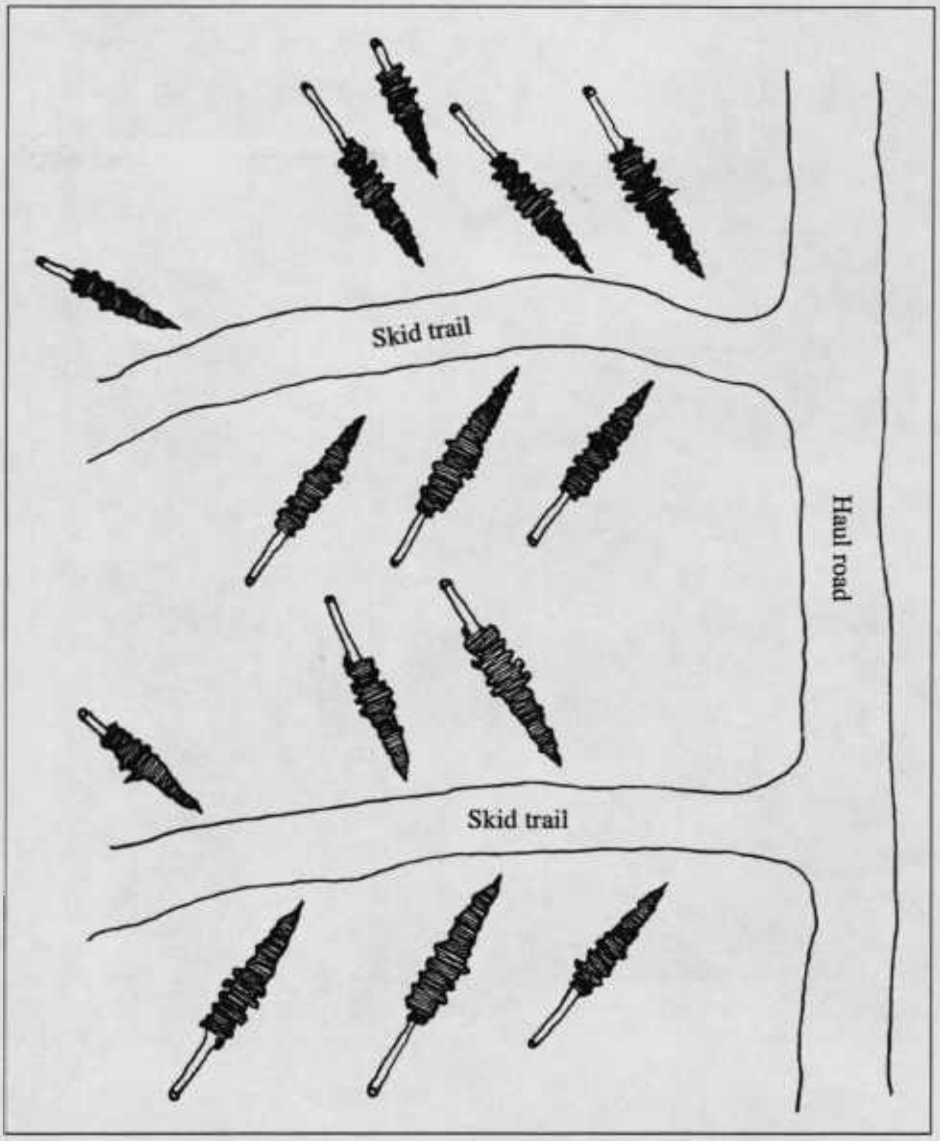

Figure 5.—Designated skid trail system with trees felled toward the lead of the trails.

You can reduce compaction of the mineral soil if you leave these layers in place where vehicles travel, although you can expect some traction and puncture problems with rubber-tired vehicles.

Frozen soils or soils covered with several inches of snow also can be relatively resistant to compaction, and it may be possible to schedule machinery operations to take advantage of this characteristic.

One of the most promising alternatives for minimizing soil compaction caused by logging is the use of designated skid trails to limit the area of compacted soil (see EC 1110). With this approach, the skid trails are clearly marked before the logging activities begin. Trees then are felled so they can be winched readily to tractors or skidders that remain on the established trails (Figures 5 and 6).

This technique can restrict compaction to less than 10 percent of the land area, which is considerably lower than the 20 to 35 percent compacted trail area often found after conventional ground-based logging operations.

Costs of logging with designated skid trails can be comparable to "logger's choice" systems, and in some situations these actually may be cheaper because of increased skidding efficiency.

You should be aware that designated skid trails may result in fewer planting sites

Figure 6.—To reduce the area of compacted soil, the logger pulls line to the log (above) and then winches it to the vehicle on the designated skid trail (below).

Figure 7.—You can reduce compaction problems after logging by tilling major skid trails and landings with implements like these rear-mounted "winged" ripper teeth.

or seedbeds—you may need brush control or burning for adequate reforestation (see EC 1188). Remember, too: The soil benefits you gain from designated skid trails may be wiped out if you use heavy equipment for brush control or slash piling.

Where designated skid trails are impractical or where widespread compaction already exists, you can use soil tillage to lessen the compacted condition. This practice has been applied successfully on agricultural lands for many years, and benefits can be expected from properly applied tillage of compacted forest soils also.

Tillage of compacted areas like skid trails and landings usually involves the use of a small- or medium-sized crawler tractor outfitted with implements such as rear-mounted ripper teeth or agricultural discs, or a front-mounted brush rake. Rear-mounted teeth can be particularly effective in loosening compacted soils when they include a "wing" attachment near the bottom of each tooth (Figure 7).

Brush blades and agricultural discs can be useful in areas with relatively shallow compaction and limited debris, but they're considerably less effective on sites with deep compaction and abundant debris.

Some other important site conditions that can reduce the efficiency and effectiveness of general tillage operations include steep slopes, rocky soils, and limited turning space. Tillage of wet soils, especially those with a significant amount of clay, also can be ineffective.

No single method for minimizing compaction problems can be equally effective and economical for the many possible combinations of soil, site, equipment, and land management activities.

Probably the best approach is to determine first where and when you are likely to have existing or potential compaction problems. Then, for each situation, evaluate the advantages and disadvantages of the alternatives available for minimizing these problems. This procedure should go a long way towards helping you to protect your forest investment and our valuable soil and water resources.

For further reading

OSU Extension publications

Garland, John J., *Designated Skid Trails Minimize Soil Compaction,* EC 1110 (reprinted 1997). $1.50

Fitzgerald, Stephen A., *Site Preparation: An Introduction for the Woodland Owner,* EC 1188 (revised 1996). $1.50

Adams, Paul W., *Oregon's Forest Practice Rules,* EC 1194 (revised 1996). $1.00

To order copies of the above publications, or additional copies of this publication, send the complete title and series number, along with a check or money order for the amount listed, to:

Publication Orders
Extension & Station Communications
Oregon State University
422 Kerr Administration
Corvallis, OR 97331-2119
Fax: 541-737-0817

We offer discounts on orders of 100 or more copies of a single title. Please call 541-737-2513 for price quotes.

You can access our Educational Materials catalog and many of our publications through our Web page at *eesc.orst.edu*

OSU Forestry publications

Andrus, C.W., and H.A. Froehlich, *An Evaluation of Four Implements Used to Till Compacted Forest Soils in the Pacific Northwest,* Oregon State University Forest Research Laboratory, Research Bulletin 45 (Corvallis, 1983). No charge for single copy; order from Forestry Publications Office, Oregon State University, 227 Forest Research Laboratory, Corvallis, OR 97331-7401.

Audiovisual programs

Purchase or 5-day rentals available from Forestry Media Center, Oregon State University, 248 Peavy Hall, Corvallis, OR 97331-5702. Phone 541-737-4702.
Fax 541-737-3759. E-mail address: forestrm@ccmail.orst.edu
Web address: http://osu.orst.edu/Dept/fmc

Adams, Paul W., and Tom Luba, *Recognizing and Managing Forest Soil Compaction Problems,* slide-tape or video transfer #823. 15 min.

Adams, Paul W., and others, *Soil Compaction on Forest Lands,* videotape or 16mm film #850. 32 min.

Adams, Paul W., and others, *Tilling Compacted Forest Soils,* slide-tape or video transfer #876. 25 min.

Adams, Paul W., and others, *Designated Skid Trails,* slide-tape or video transfer #903. 25 min.

The Woodland Workbook is a collection of publications prepared by the Oregon State University Extension Service specifically for owners and managers of private, nonindustrial woodlands. The Workbook is organized into separate sections, containing information of long-range and day-to-day value for anyone interested in wise management, conservation, and use of woodland properties. It's available in a 3-ring binder with tabbed dividers for each section.

For information about how to order, and for a current list of titles and prices, inquire at the office of the OSU Extension Service that serves your county.

This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.

Revised November 1990. Reprinted March 1998.