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Using Subsoiling To Reduce Soil Compaction



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Introduction

Soils can become deeply compacted in areas tracked by heavy equipment during timber harvesting, firefighting, fuel reduction, cultivation, or other forest management operations. Layers of compacted soil restrict the movement of water, air, and roots, reducing the survival and growth of trees and other plants.

Compacted layers typically develop 12 to 22 inches below the surface where conventional cultivators can't reach. These layers require special equipment called subsoilers, sometimes known as rippers (figure 1), to fracture them. This report offers some background on subsoilers and general guidelines on their use to break up compacted layers and return the soil's structure to a more natural state.

Highlights...

- Heavy equipment used in logging, firefighting, and other forest management operations can compact soils.
- Often, the compacted layers are 12 to 22 inches below the surface.
- Subsoilers can break up the compacted layer without destroying surface vegetation or mixing soil layers.
- This report contains information on subsoiling equipment and its use for land and forest managers who need to break up compacted soils.



Figure 1—This three-shank subsoiler attaches to a tractor's three-point hitch. It can fracture compacted layers 12 to 22 inches below the soil surface.

Subsoiling fractures compacted soil without adversely disturbing plant life, topsoil, and surface residue (figure 2). Fracturing compacted soil promotes root penetration by reducing soil density and strength, improving moisture infiltration and retention, and increasing air spaces in the soil.

How effectively compacted layers are fractured depends on the soil's moisture, structure, texture, type, composition, porosity, density, and, clay content. Success depends on the type of equipment selected, its configuration, and the speed with which it is pulled through the ground. No one piece of equipment or configuration works best for all situations and

soil conditions, making it difficult to define exact specifications for subsoiling equipment and operation. Adjustments will be required for most projects. A partial list of equipment vendors is included at the end of this report.

Research data and vendor information generally agree that three main factors contribute to effective subsoiling:

- Subsoiling works better during drier soil conditions.
- Winged tips on shanks improve soil fracturing.
- Heavy clay soils are very difficult to break up.

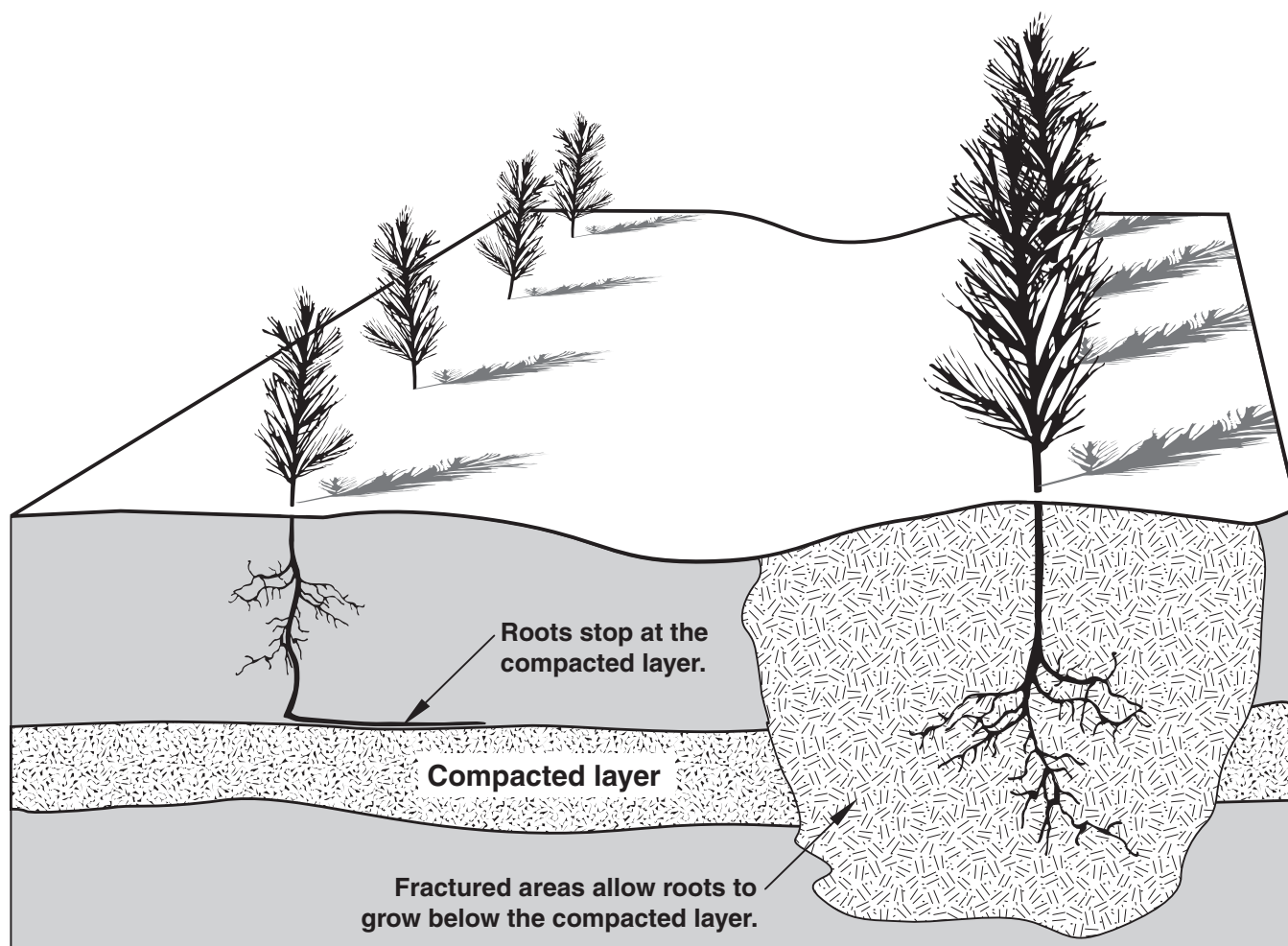


Figure 2—This illustration shows how fracture zones created by a subsoiler can help promote deep, healthy root systems. Ideally, the soil is fractured with minimal disruption to the soil surface and existing plant life.

Suitable Conditions for Subsoiling

Soils should be mostly dry and friable. If the soil is too wet, subsoiler shanks will slide through the ground without breaking up the soil. The shank can actually glaze the soil and compact it even more. If the soil is extremely dry, getting the subsoiler into the ground can be difficult, requiring larger, more powerful tractors to pull the shanks through compacted areas. Soils, especially those with more clay content, can actually break into large clods or slabs if conditions are too dry.

For most areas, ideal subsoiling conditions are during summer months before the soils are completely dry. Soils should crumble without sticking together, yet not be so dry and hard that they can't be broken up easily. The timing of ideal conditions will vary depending on the local climate. Contractors may prefer subsoiling wet ground because doing so is easier on their equipment and requires less fuel.



Subsoiling Equipment

Winged tips (points) cost more than conventional tips (figure 3a). Typical winged tips are 6 to 16 inches wide with 1 to 4 inches of lift, and a 40- to 60-degree sweep angle. Winged tips should be designed to fracture the soil uniformly without lifting or furrowing the surface excessively. If the surface is not being lifted slightly, the ground may be too wet or the winged tips may not have enough lift.

About 25 to 55 percent more horsepower is needed to pull shanks with winged tips, but often the shanks can be far-

ther apart. Winged tips set behind the leading edge of the shank improve efficiency and reduce the amount of horsepower needed to pull the subsoiler. If you consider the volume of soil loosened per horsepower, shanks with winged tips may be more efficient than shanks with conventional tips (figure 3b).

Subsoiler and shank tip equipment manufacturers have invested lots of money and time developing the most efficient subsoiler tips. They should be able to help define the best tip available for specific conditions in the field.

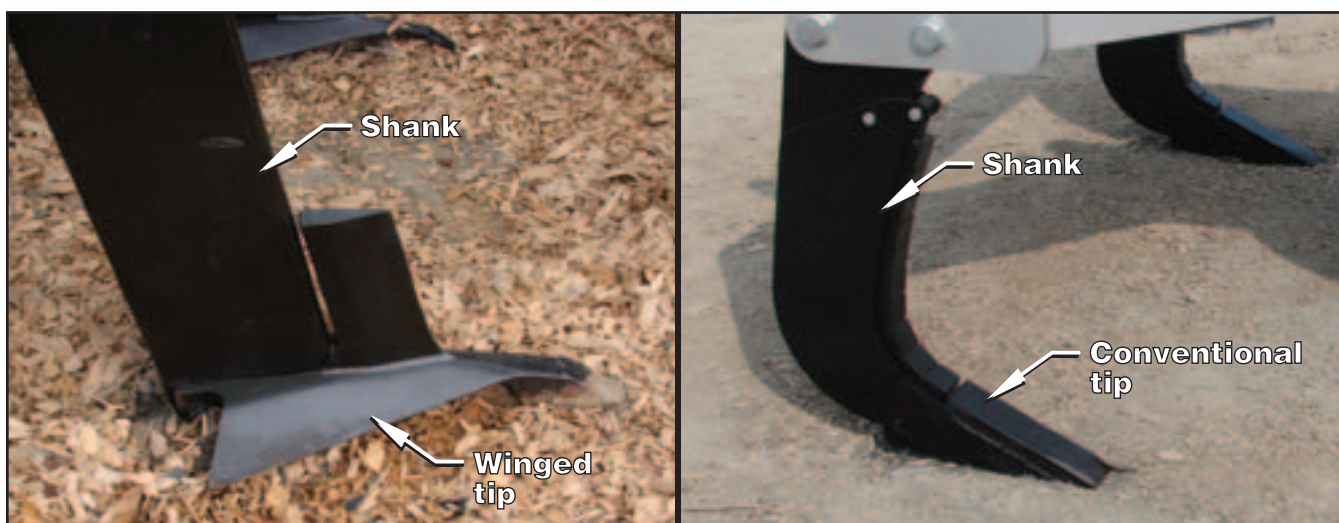


Figure 3a—Winged tips on subsoiler shanks (left) come in various shapes and designs. Conventional tips (right) are wedge shaped and are easy to replace.

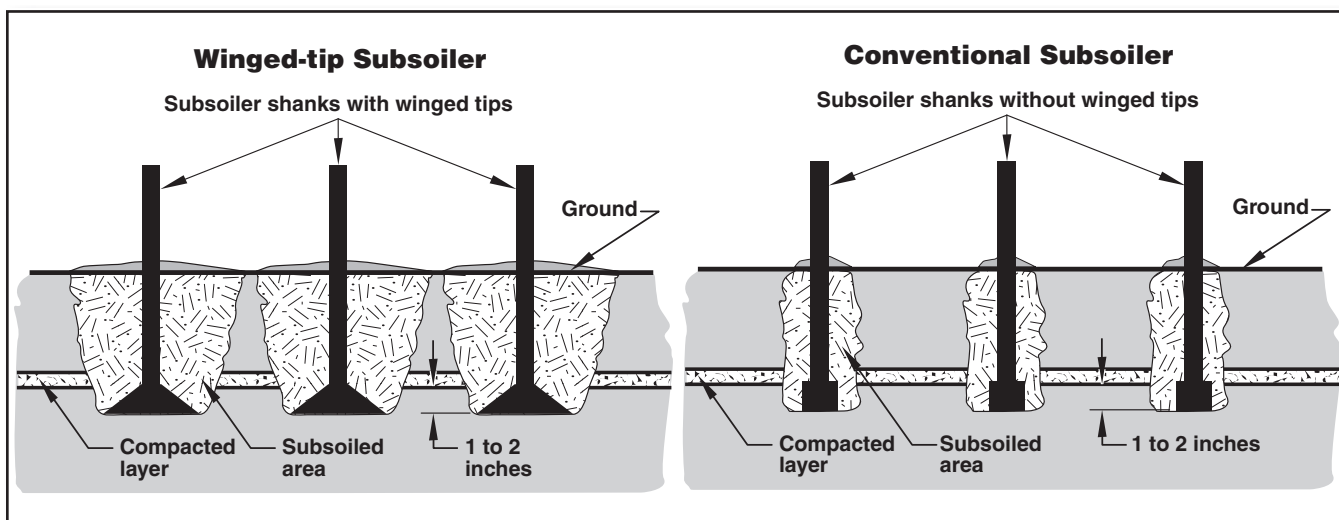


Figure 3b—Winged tips on subsoiler shanks (left) require more horsepower to pull through the ground, but typically fracture more of the soil than conventional tips (right).

Shank Designs

Parabolic shanks (figure 4a) require the least amount of horsepower to pull. In some forest applications, parabolic shanks may lift too many stumps and rocks, disturb surface materials, or expose excess subsoil. Swept shanks tend to push materials into the soil and sever them. They may help keep the subsoiler from plugging up, especially in brush, stumps, and slash. Straight or “L” shaped shanks have characteristics that fall somewhere between those of the parabolic and swept shanks.

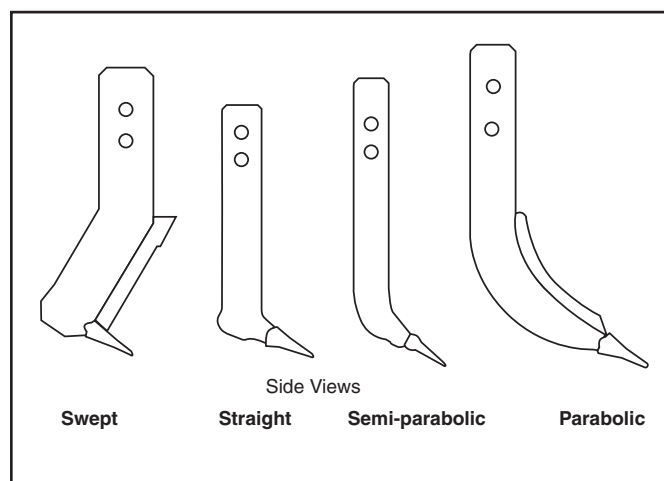


Figure 4a—Shank designs include: swept, straight or “L” shaped, semi-parabolic, and parabolic. Shank design affects subsoiler performance, shank strength, surface and residue disturbance, effectiveness in fracturing soil, and the horsepower required to pull the subsoiler.

Shanks should be designed to handle rocks, large roots, and highly compacted soils.

Shanks usually are from ¾ to 1½ inches thick. Thinner shanks are suited for agricultural use. Thicker shanks hold up better in rocky conditions, but require larger, more powerful equipment to pull them and disturb the surface more. Bent offset shanks, such as those found on Paratill subsoilers, have a sideways bend (figure 4b). Some testing has shown that bent offset shanks disturb surface residue less than straight shanks.

The typical spacing is 30 to 42 inches between shanks. Shanks should be able to reach 1 to 2 inches below the deepest compacted layer.

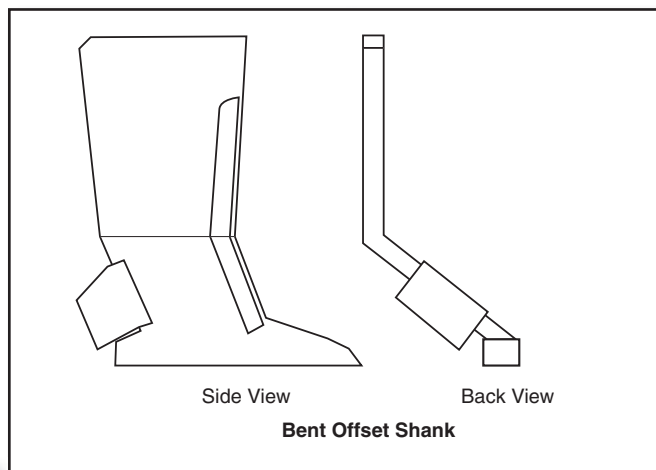


Figure 4b—Bent offset shank.

Shank spacing and height should be adjustable in the field. Towed subsoilers should have gauge wheels to control the shank’s depth. Conventional ripper shanks, typically found on dozer equipment, work reasonably well when winged tips are added and may be suitable for many jobs and locations.

Shanks With Shear Bolts

Shanks with shear bolts (figure 5a) are better suited for open ground with few rocks. If the shank strikes a rock or buried log, the shear bolt breaks, allowing the shank to swing



Figure 5a—Shanks need to be mounted to subsoilers so that the shank can survive if it runs into rocks or stumps. The shank above is protected by a shear bolt designed to break if too much force is put on the shank.

back. The subsoiler must be lifted out of the ground, the shank swung back into place, and the shear bolt replaced. Shanks with shear bolts typically are cheaper than shanks that reset automatically, but will cost the operator time in the field replacing shear bolts.

Shanks That Reset Automatically

Shanks that reset automatically (figure 5b) use a spring-loaded mechanism that allows the shank to hinge back when it hits objects in the ground. The shanks typically withstand 3,000 to 7,000 pounds of force before hinging. The shanks snap forward and reset after the subsoiler has passed the object.

Shanks that reset automatically are more expensive than those that rely on shear bolts, but require less repair time in the field. Some subsoilers use hydraulic systems with accumulators (hydraulic devices that store energy) to absorb force on the shank.



Figure 5b— This photo shows shanks with springs that allow them to pull back when they strike an object, resetting themselves once they have cleared the object.

the subsoiler. Coulters for forest applications must be able to withstand forest conditions and impacts with rocks and stumps. Their height should be adjustable and they should be larger than the standard 20- to 24-inch diameter coulters, so the mounting frames clear residues on the forest floor and will not plug up the subsoiler. Coulters come in several designs, including straight and fluted.



Figure 6—Coulters help cut slash and other surface residues so they don't hang up in front of the shanks. The coulters can be straight (top) or fluted (bottom).

Coulters

Coulters (figure 6) are sharpened round metal disks that roll in front of the shank. They cut slash and surface residues so the materials don't jam on the front of the shank and plug

Frame and Toolbar Designs

Toolbars (figure 7) are configured in a straight line or in a V. Some subsoilers have a double straight toolbar to stagger shanks, allowing better clearance. V-shape designs are said

to require less horsepower to pull. Frames should have at least 32 inches of clearance under them when the shanks are sitting on the ground surface. This is especially important in forested or brushy areas.



Figure 7—Shanks can be attached to the subsoiler frame or toolbars in a straight line (top) or in a V-shape (bottom).

Using Subsoilers

Compacted layers are typically 12 to 22 inches deep. Ideally, the shank's tip should run 1 to 2 inches below the compacted soil layer. If the shank's tip is too deep, subsoiling may increase compaction because the compacted layer will not be fractured.

Shank spacing will vary depending on soil moisture, soil type, degree of compaction, and the depth of the compacted layer. Spacing should be adjustable so the worked area can be fractured most efficiently (figure 8). Horsepower requirements

depend on soil moisture, the depth and thickness of the compacted layer, and to a lesser extent, the soil type. Each shank may require from 30 to 75 horsepower.

Equipment speed can affect subsoiling. Travel speed that is too high can cause excessive surface disturbance, bring subsoil materials to the surface, create furrows, and bury surface residues. Travel speed that is too slow may not lift and fracture the soil adequately. Contractors may prefer to travel more quickly to improve their profit per acre.

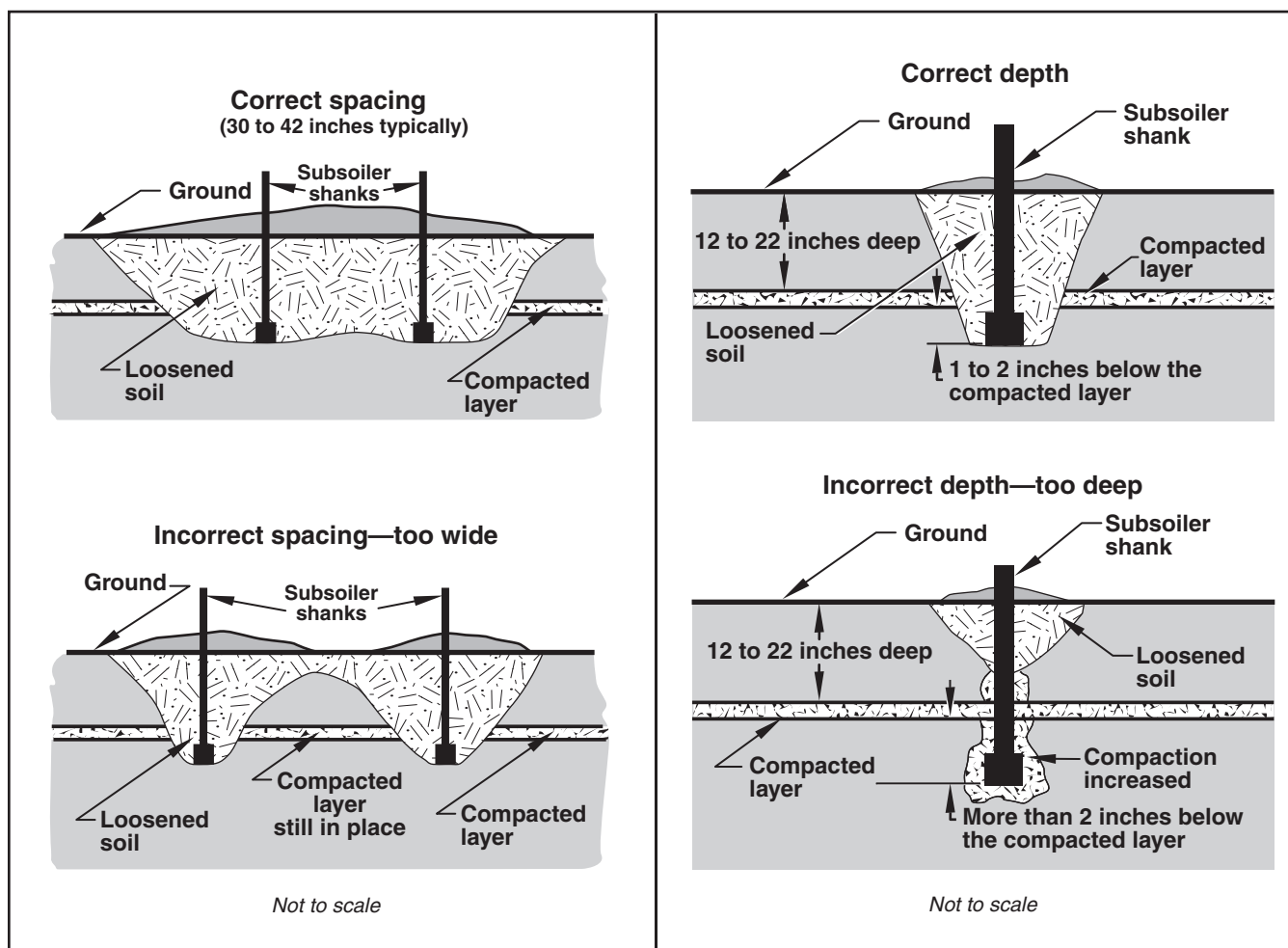


Figure 8—For most subsoiling operations, the shank tip should run 1 to 2 inches below the compacted layer of soil. The spacing and depth of the shanks can affect how completely and efficiently the soil is fractured.

Traffic Patterns

It is best to follow the ground contour whenever possible while subsoiling. This helps increase water capture, protect water quality, and reduce soil erosion, especially in burned areas or areas susceptible to erosion. Stay clear of waterways, ditches, and other areas where subsoiling could affect hydrology. Shanks should be lifted out of the ground frequently to clear stumps, rocks, and logs and to remove slash from the subsoiler.

It might be wise to consult your local silviculturist for advice on subsoiling next to trees and other established plants. Always be cautious of areas that might have buried utility lines, culverts, or diversion channels. Flag or mark such areas before subsoiling.

Tractor/Skidder Issues

The equipment used to pull subsoilers is heavy enough to create its own compaction problems. Make sure that the shanks on the subsoiler are spaced so that they run in the tracks of the tow vehicle. It may be best to specify smaller, lighter equipment to reduce ground pressure during subsoiling operations. Smaller, lighter equipment probably can't pull more than two to three shanks in most applications.

Excavator Subsoilers

Subsoiler attachments are available for excavators. They can be used in combination with buckets or rakes. A partial list of suppliers is included in the "Subsoiler Manufacturers" section.



Testing for Compacted Areas

The best time to check for compacted layers is when the soil is saturated. Several areas should be tested, especially areas such as logging decks or skid trails known to have been compacted by heavy equipment.

To test for compacted layers:

- Dig a test hole or ditch 24 to 30 inches deep in ground that is uniformly saturated.
- Probe down a face of the ditch's vertical walls with a nail or knife blade (figure 9). A small hand-held soil penetrometer can also be used to probe the face of the wall. If a backhoe or excavator is used to dig the ditch, probe the sides of the ditch, not the ends. Resistance to penetration indicates a compacted layer. If soil is compacted, you should be able to dig away the looser soils and leave a well-defined compacted layer.

- Note the depth and thickness of the compacted layer so the information can be included in contract specifications defining the subsoiling depth.

Soil penetrometers, designed to test soil strengths when a rod is pushed into the ground, can be used in some applications to identify compacted layers and how well subsoiling operations fracture the soil (figure 10).

Soil penetrometers are most accurate when soils are at their full moisture capacity. Penetrometers are difficult to use accurately in rocky soils or soils with a lot of roots, because it can be difficult to tell the difference when the penetrometer hits rocks or roots or a compacted layer.

The Missoula Technology and Development Center prepared a report on three models of penetrometers and their use. It is available at <http://www.fs.fed.us/t-d/pubs/html-pubs/htm05242837/> (Username: t-d, Password: t-d).

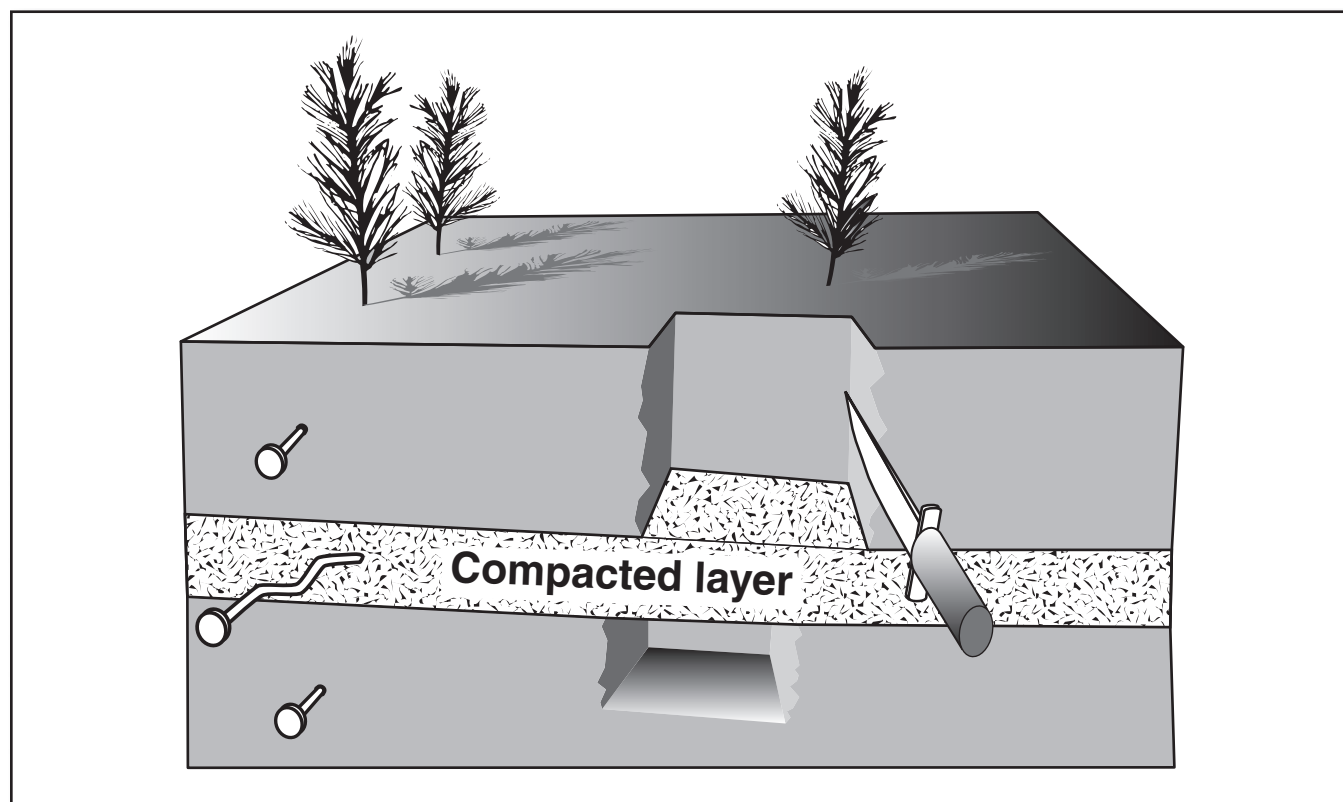


Figure 9—To test for compacted soil, dig a test hole or ditch 24 to 30 inches deep. Push a nail or knife blade into the soil along a face of the ditch walls. Resistance to penetration indicates a compacted layer.



Figure 10—Soil penetrometers can be useful when determining whether soil layers have been compacted or when checking to see how well areas have been fractured by subsoiling. Penetrometers don't work well in areas with lots of rocks or roots.

Expected Results After Subsoiling

Under ideal conditions, subsoiling should be 75 to 80 percent successful in breaking up compacted layers. In some cases, two passes at an angle to each other may be required to completely fracture compacted soil.

The ground should be lifted slightly and remain relatively even behind the subsoiler, without major disruption of surface residues and plants. No more than a little subsoil and a few rocks should be pulled to the surface. If large furrows form behind the subsoiler, the shanks may not be deep

enough, the angle on winged tips may be too aggressive, or the travel speed may be too high.

Tests showing that a subsoiling project has been successful include:

- The force required to push a soil penetrometer into the ground, known as the soil index reading, should drop.
- A sharpened steel rod with a handle should be easier to push vertically into the ground.
- Soil bulk density (the weight of a soil sample divided by its volume) should drop after subsoiling.



Vendor Listings

A large variety of equipment is available for subsoiling. Some subsoilers are mounted to tractors with a three-point hitch; others are wheel mounted and pulled with a drawbar. Subsoilers designed for agricultural use may be suitable for rangeland, but they may be too wide and not sturdy enough for forested areas. The market for subsoilers designed specifically for forestry applications is limited.

Manufacturers have designed and operated rippers with vibrating shanks, but they are used mostly for trench ripping when laying cables. A new design from Soilworks California incorporates a vibrating wing that moves up and down as the shank is pulled through the soil (figure 11). Designs and options change often and can be customized. Call the manufacturer for the latest updates and options. A partial list of subsoiler and shank point vendors follows.



Figure 11—The wing on this subsoiler moves up and down with a hydraulic ram mounted behind the shank.

Subsoiler Manufacturers

Bigham Brother, Inc. (Shear Bolt Paratill)
Lubbock, TX
Phone: 800-692-4449
Web Site: <http://www.bighambrothers.com/subsoiler.htm>

Brillion Farm Equipment
Brillion, WI
Phone: 800-409-9749
Web Site: <http://www.brillionfarmeq.com>

Forest Soil Restoration (Forest Cultivator)
Sandy, OR
Phone: 503-668-4405

Great Plains Manufacturing, Inc.
Salina, KA
Phone: 785-823-3276
Web Site: <http://www.greatplainsmfg.com>

John Deere Co.
Moline, IL
Phone: 309-765-8000
Web Site: <http://www.deere.com>

Krause Corp.
Hutchinson, KS
Phone: 800-957-2873
Web Site: <http://www.krauseco.com>

Savannah Forestry Equipment, LLC
Savannah, GA
Phone: 912-964-2214
Web Site: <http://www.savannahglobal.com/savannahforestry/>

Soilworks California
Templeton, CA
Phone: 805-434-2044
Web Site: <http://www.soilworks.net>

Thurston Manufacturing Co.
Thurston, NE
Phone: 800-658-3127
Web Site: <http://www.blu-jet.com>

Unverferth Manufacturing Co., Inc.
Kalida, OH
Phone: 800-322-6301
Web Site: <http://www.unverferth.com>

Excavator Subsoiler Manufacturers

Leading Edge Attachments Inc.
Jefferson, MA
Phone: 866-928-5800
Web Site: <http://www.leadingedgeattachments.com>

Rockland Manufacturing Co.
Bedford, PA
Phone: 800-458-3773
Web Site: <http://www.rocklandmfg.com>

Shank Point and Winged Tip Manufacturers

John Deere Co. (LaserRip Points)
Moline, IL
Phone: 309-765-8000
Web Site: <http://www.deere.com>

Nichols Tillage Tools, Inc.
Sterling, CO
Phone: 877-519-2771
Web Site: <http://www.nicholstillagetools.com>

Shield Agricultural Equipment
Hutchinson, KS
Phone: 800-798-1968
Web Site: <http://www.shieldag.com>

About the Authors

Gary Kees joined MTDC in 2002 as a project leader. Gary works in the reforestation and nursery, forest health, and GPS programs. His current projects involve laser guidance systems, ATV and backpack sprayers, nursery seeders, and remote weather stations. Gary, who has a degree in mechanical engineering from the University of Idaho, worked for 10 years as a mechanical and structural engineer, project manager, and engineering group leader for Monsanto Co. in Soda Springs, ID.

Library Card

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Heavy equipment can compact forest soils. Often, the compacted layers are 12 to 22 inches below the surface. A special piece of equipment, known as a subsoiler, can break up the compacted layer without destroying surface vegetation and residue or mixing soil layers. This report contains information on subsoiling equipment and its use. It also includes lists of vendors selling the equipment. Forest managers should find the report helpful if they need information about breaking up compacted soils.

Keywords: equipment, forest management, how to, rippers, specifications, soil compaction, soil structure, tilth, vendors

Additional single copies of this document may be ordered from:

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<http://fsweb.mtdc.wo.fs.fed.us/search/>

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