

# Maintaining Soil Quality in Woodlands

A Lake States Field Guide



Jeff Martin, DNR



Gerald A. DeBoer



## Maintaining woodland soil is a critical part of responsible forest management.

Many landowners – federal, state, county, industrial and private landowners – have committed to responsibly managing their woodlands. Their goal is to ensure that future generations will share the same benefits that they enjoyed as woodland owners. The benefits of woodland ownership are many, including collecting revenue from timber sales, hunting wildlife, picking berries and relaxing in front of a campfire.

Responsible forest management is based on landowner management objectives, site conditions, and sound silvicultural practices. This guide focuses on preserving soil quality during forestry operations. Many times we concentrate on the trees and what is going on above our heads, and we forget to look down, under our feet, and see what is happening there also.

Soil plays a critical role in our woodlands. It is the medium that trees and wildflowers grow in, the material that moles and salamanders root around in, and the sponge that water soaks into. When the quality of soil is compromised, there can be multiple effects on the surrounding landscape.

During forestry operations, soil may be disturbed – either by compaction, rutting or erosion. The most effective method for maintaining soil quality is to prevent and minimize these soil disturbances. Once soil is damaged, the effects can last for decades. Depending on the severity and location of soil disturbances, repair or mitigation may be an option; however, the costs are high in terms of time, money and future forest products when

Camen Wagner, DNR

# Threats to Soil Quality



There are three primary threats to soil quality – **compaction**, **rutting** and **erosion**. These soil disturbances can affect:

1. the *physical* properties of soil – texture, structure, porosity, density, drainage and hydrology
2. the *chemical* properties of soil – nutrient availability, nutrient cycling and acidity
3. the *biological* properties of soil – fungi, bacteria, worms and other organisms

compared to prevention. In many circumstances, repairs may be limited to aesthetic or safety concerns and the actual damage to the soil may not be corrected.

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*This guide will provide landowners, foresters and loggers with the information needed to identify sensitive areas and to develop a plan to maintain soil quality during forestry operations. If soil disturbances occur, options for repairing the damage are also discussed.*

**Compaction.** If you were to pick up a handful of undisturbed soil, usually less than half of it is solid material, like dirt, gravel, leaves and roots. The remainder is pore space filled with air and water. Pores are the tiny cracks and crevices between soil particles and the tunnels left by animals, insects and plant roots.

Soil can become compacted when heavy equipment moves over the ground during tree felling, forwarding and skidding. Soil can also be compacted by motorized vehicles, cattle and foot traffic. When soil is compacted, the individual particles of soil are pushed together, decreasing the volume of soil and increasing the density of soil.

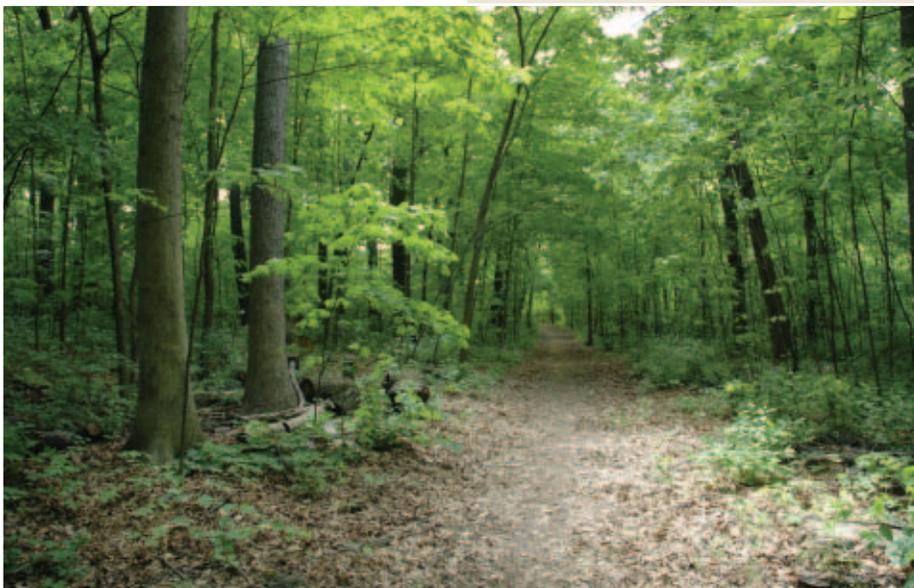
Compacted soil reduces plant growth because it:

- Makes it harder for plant roots to penetrate the dense soil
- Provides less air for the plant roots to “breathe”
- Allows less water to soak into the soil and be available for plants to use
- Slows the warming of soil in the spring

Plants are not the only things impacted by soil compaction. Healthy, uncompacted soil is rich with many varieties of insects, fungi, nematodes and bacteria. These organisms create large pores within the soil, improve soil texture and assist trees with nutrient uptake. When soil becomes compacted, populations of these organisms generally decrease.

In addition, when soil is compacted, runoff from rain and snowmelt is less likely to soak into the ground. Instead, the runoff flows over the ground, picking up sediment and carrying it into lakes, streams and wetlands.

Soil compaction primarily occurs on mineral soils, like sand, silt and clay. Organic soils, like peat and muck, are less likely to become compacted, but instead the soil is churned and mixed up, forming ruts.



Traffic from equipment, cattle and even people can compact soil.



Rich LaValley, DNR

Ruts can be created by just one pass of equipment under high risk conditions.

**Rutting.** When the soil is not strong enough to support the weight of a vehicle, long depressions or ruts form. Rutting generally occurs when the soil pores are filled with water, essentially causing the soil to “liquefy”. When rutting occurs, the soil is churned and pushed aside. The deep furrows created by ruts can damage and sever tree roots and trunks, resulting in:

- Decreased nutrient uptake and declines in tree growth
- Entry points for disease and insects
- Trees more vulnerable to wind throw
- Tree mortality, if the damage is severe enough

Rutting also compacts and displaces soil, reducing aeration of soil, decreasing infiltration of water and, ultimately, degrading the rooting environment for plants. These disturbances may also create an environment

that is more favorable to the introduction of weedy or invasive plants.

The hydrology or flow of water across a site can also be affected by rutting. If ruts cut across the natural flow of water, the soil may become saturated on the uphill side of the ruts, creating pockets of saturated soils or standing water. This may cause trees or other plants to drown out. Downhill from the ruts, vegetation may suffer from drier conditions. If the ruts follow the flow of water, they can act as ditches and water may be directed more quickly off of the site, draining the area. In this case, erosion and sedimentation are also likely to occur.

Rutting can occur on both mineral and organic soils. In wet conditions, ruts may be formed by only a single pass of equipment. Ruts can also be observed after multiple passes of equipment during dry conditions.

**Erosion.** Soil erosion is the movement of soil particles. It can occur when:

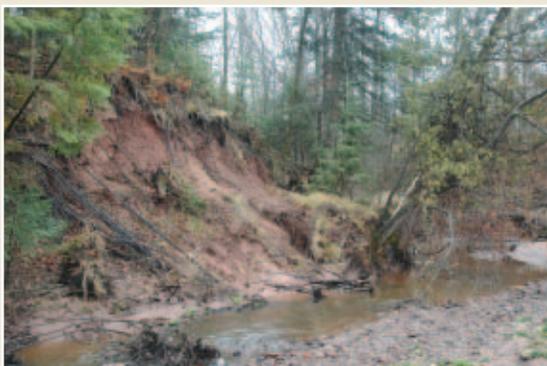
- Runoff from rain and snowmelt flows over the ground, picking up sediment
- Winds blow across bare ground, lifting up soil particles
- Gravity pulls down exposed slopes, causing chunks of land to slump away

As nutrient-rich top soil and organic matter are lost to erosion, plant growth can be reduced. Maintaining the top layers of soil are important for holding soil moisture and providing optimum growing conditions for plants.

Erosion not only causes problems where the soil is removed, but also where the soil is eventually deposited. If sediment and other pollutants are carried by runoff into lakes, streams and wetlands, the results may include:

- Decreased water clarity as soil clouds the water
- Degraded fish and wildlife habitat as sediment settles on gravel spawning beds and buries aquatic vegetation
- Injured fish as sediment cuts their gills
- Reduced oxygen levels in water, stressing fish, as nutrients carried by the runoff fuel algae growth

During forestry activities, soil erosion is most likely to occur on forest roads and skid trails, especially at stream crossings. Erosion is less likely to occur in well-vegetated or flat areas. Soils with high percentages of clay, silt and very fine sand are most likely to erode, but any soil can start to erode as slopes becomes steeper.



Carmen Wagner, DNR

Streambank erosion can degrade water quality and lead to the loss of productive forest land.



Carmen Wagner, DNR

Long road grades are especially susceptible to erosion. Practices such as diversion ditches can be used to limit erosion.

# Identifying Sensitive Sites

Learning to recognize areas that are sensitive to soil disturbances allows landowners, foresters and loggers to put in place plans to avoid and minimize soil compaction, rutting and erosion. A site's susceptibility to soil disturbances may be related to specific site characteristics, such as soil or slope, or to events, such as rainfall or flooding.

Landowners, foresters and loggers can identify susceptible areas with a variety of resources – topographic maps, soil surveys and wetland inventory maps. In addition, these factors should be verified in the field before harvesting or road building. Field verification of sensitive sites is an important step that should not be overlooked. It is also important to remember that even on low risk sites, practices to avoid and minimize soil disturbances should be followed.



**Soil Moisture.** One of the keys to identifying sensitive sites is to understand the relationship between soil moisture and the risk of soil disturbance. The risk of soil compaction is highest when the large soil pores have been drained, because the remaining water lubricates soil particles so they can move and pack against one another. The potential for rutting, churning and displacement of soil is highest when soils are saturated with water because the water cannot be compressed. In

general, using heavy equipment on wet or saturated soils increases the risk of soil disturbances.

Across the landscape, soil moisture levels are affected by a number of factors, such as water tables and weather events. At the site level, you may also find areas that are wetter because of seeps, springs or local drainage patterns.

Soil Moisture Factors Affecting Risk of Soil Disturbances

Risk Factors	RISK LEVEL		
	High	Medium	Low
Soil Drainage Class	Poorly or very poorly drained soils	Somewhat poorly drained soils	Well or moderately well drained soils
Water Table	Within 12 inches of soil surface	Within 12 to 24 inches of soil surface	More than 24 inches below the soil surface
Rain Events	Within 4 days of last significant rainfall event	Within 5 to 10 days of last significant rainfall event	More than 10 days since last significant rainfall event

**Soil Texture.** The risk of soil compaction, rutting and erosion are all impacted by a soil's texture. Some soils like to hold onto water while others quickly drain. Soil texture also impacts how easy or difficult it is for that soil to start eroding.

in color and often you can still see plant parts in the upper layers of the soil.

You can easily identify a soil's texture by squeezing some moist soil between your fingers – if the soil is dry, simply add some water. Clay soils are sticky and form long ribbons when pressed between your thumb and forefinger. Silty soils feel like flour and form small flakes when squeezed. Sandy soils are gritty to the touch. Organic soils are black

It is important to consider a soil's texture in conjunction with other factors, such as soil moisture levels. Clay soils, when dry, are extremely strong and resistant to compaction. This is part of the reason why clay is well-suited to making bricks. However, under wet conditions, clay particles become surrounded by water and easily separate when force is applied, like the weight of harvesting equipment.

Soil Texture Factors Affecting Risk of Soil Disturbances

RISK LEVEL FOR SOIL COMPACTION AND RUTTING			
Risk Factors	High	Medium	Low
Soil Texture	Organic soils Soils with an organic surface layer thicker than 4 inches	Clay soils Silt soils	Sandy soils
RISK LEVEL FOR EROSION			
Risk Factors	High	Medium	Low
Soil Texture	Fine sandy soils Silt soils	Moist clay soils	Dry clay soils Coarse sandy soils

**Topography.** The topography or terrain of a site also affects its susceptibility to soil disturbances. Moist soils are often found in narrow bands at the toe of steep slopes where groundwater seeps out of the soil. In rolling hills, pockets of wet soil can often be found in small depressions where water collects. The aspect or direction a slope faces can also affect a site's potential for soil disturbances. South-facing slopes receive more sunlight than north-facing slopes and dry much more quickly.

Topographic Factors Affecting Risk of Soil Disturbances			
	RISK LEVEL		
Risk Factors	High	Medium	Low
Slope	Slopes that are 15% or greater for 50 or more feet Slopes that are 25% or more for any length	Slopes that are 5%–15% Slopes that are 15%–25% for less than 50 feet	Slopes less than 5%
Location	Toe slopes with seepages	Ridgelines with shallow soils	
Aspect	North-facing slopes	East-facing slopes West-facing slopes	South-facing slopes



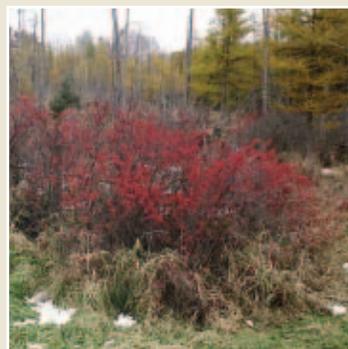
Keep equipment out of small depressions to protect soil and water quality.



Marsh marigold



Black spruce



Winterberry



Ash seedling

**Plant Communities.** Soil moisture, texture and topography are often expressed by the plants growing in an area. Recognizing which plants tend to grow in more sensitive areas can help you identify places to approach cautiously during forest management activities.

Plants Indicating Sensitive Sites	
Site Description	Indicators
Drainages and low-lying depressions	TREES – balsam poplar, black ash and white cedar SHRUBS – red-osier dogwood, speckled alder and willow GROUND LAYER – blue-joint grass, ferns, marsh marigold and sedges
Cedar and black ash swamps	TREES – black ash, tamarack and white cedar SHRUBS – speckled alder, willows and winterberry GROUND LAYER – bunchberry, creeping snowberry, ferns, marsh marigold and starflower
Forested bogs	TREES – black ash and tamarack SHRUBS – leather leaf and speckled alder GROUND LAYER – cotton grass, Labrador tea and sphagnum moss

# Planning Considerations

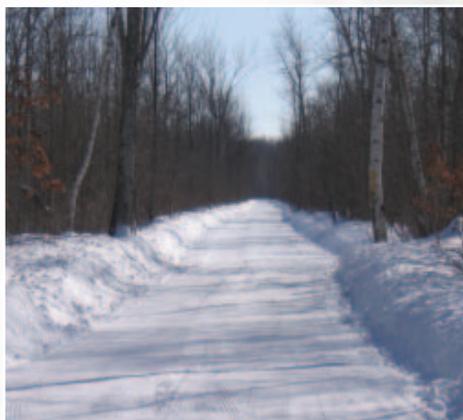
Information gathered about a site's sensitivity can be used for planning and scheduling forestry operations. Areas of concern should be noted on maps as well as located in the field. A discussion between the landowner, forester and logger can help identify what actions should be taken to avoid or minimize soil disturbances and when these practices should be implemented.

## Specific recommendations for well-planned operations include the following:

- Avoid locating new roads and landings on high risk sites.
- Evaluate existing roads and landings on high risk sites for potential relocation.
- Designate skid trails before felling and logging. Reuse former skid trails when possible.
- Harvest areas targeted for skid trails first, then harvest from the back of the sale to the front, reducing trafficking outside of designated skid trails.
- Operate equipment only when soils are dry enough or frozen enough to support the load.
- Schedule yarding operations immediately after felling, especially on high risk sites, if reduced transpiration following harvest will increase soil moisture.
- To encourage frozen ground conditions, compact or blade the snow on roads and trails before harvesting begins. Opening the area around roads and trails will also help to lower air temperature at night.
- In the winter, skid on high traffic areas first to promote frost penetration and to prevent damage from future traffic.
- In spring, keep harvesting and skidding operations closely scheduled to avoid deteriorating conditions as the snow quickly melts under the opened canopy.
- On steep slopes, plan roads and trails so equipment climbs uphill while unloaded and descends when loaded.
- Be ready to stabilize bare soil with seed and mulch or other methods. Use native seed mixes when available.

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*If these techniques fail to minimize soil disturbances, forestry operations may need to be suspended.*



Carmen Wagner, DNR

Begin freezing down roads as soon as conditions permit, so that they will be ready when needed.



Jeff Martin, DNR

Plan your transportation network to avoid uphill climbs with loaded equipment.



Carmen Wagner, DNR

Use silt fences to prevent soil erosion until the site is vegetated.



Tom Salzman, DNR

Cross wet areas with timber mats to prevent rutting.



Scott Fischer, DNR

Place slash on skid trails to minimize soil compaction.



Nina Stensberg, DNR

Improve traction by using tracked equipment.

## Equipment Considerations

While equipment must be powerful enough to efficiently harvest timber, it should also be sized properly to minimize soil disturbances. It is important to match the size of the equipment to the size of the forest product. Decisions can be based on the equipment's static weight, loaded weight and ground pressure, but operator skill and local soil conditions also strongly impact the severity of soil disturbances.

### Based on equipment, some considerations during harvesting operations include:

- Accelerate and slow equipment gradually, rather than abruptly starting and stopping which can more easily tear up the soil.
- Choose a felling pattern that takes into account the terrain and equipment maneuverability when skidding timber.
- Winch logs from the stump to skidder rather than traveling to the stump.
- Place a cushion of slash on skid trails (perpendicular to traffic flow) to improve traction and to reduce soil compaction and rutting.
- If slash alone is inadequate to prevent rutting, use log corduroy or timber mats to support equipment.
- Avoid sharp turns with loaded equipment, especially at the base of hills.
- Avoid trafficking through depressions.
- Harvest sensitive areas when conditions are ideal. Move to less sensitive areas as conditions change.
- Do not overload equipment. On grapple skidders, the excess weight is shifted onto the rear axle. On forwarders, the excess weight offsets any advantages gained by using tracked equipment.
- Reduce loads carried by logging equipment or use low ground pressure equipment when crossing sensitive areas or if conditions are deteriorating.
- Reduce tire slippage by adding chains to tires or by using tracks – this will decrease soil compaction and rutting as well as increase machine productivity and decrease fuel consumption.

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*After working on the site for awhile, equipment operators develop a sense of the local conditions and how their machinery responds. If any sensitive areas are noted or questions arise, everyone should agree on what measures should be used to avoid and minimize any potential problems.*



Paul Pingrey, DNR

## Correcting Soil Disturbances

In the previous sections, methods to identify sites susceptible to soil disturbances and actions to avoid soil disturbances were discussed. This section provides guidance on techniques to repair and mitigate soil disturbances once they occur; however, keep in mind that the most effective strategy for reducing the impact of soil disturbances is to avoid and minimize soil disturbances in the first place, rather than relying on repairs after they occur. Avoiding soil disturbances is preferred over repairing them because:

- It is costly in time and money to implement and maintain practices that repair soil damage.
- Forest productivity is lost until the repair or mitigation occurs.
- It is probable that the soil damage may not be corrected and repairs will be limited to aesthetic and safety concerns.

Options for correcting soil disturbance can be discussed based on where the damage occurred – in the harvest area, skid trails, or forest roads and landings. If repairs are not made, site productivity may decline, the lifespan of structures may be reduced, erosion and sedimentation may occur, and safety hazards may be created.



Carmen Wagner, DNR

Soil disturbances have the most potential to damage future timber production in the general harvest area of a timber sale.

**Harvest Area.** In the general harvest area, soil disturbances should be avoided at all costs and should not get to the point where corrective actions are needed. It is crucial to protect the soil in these areas to ensure future high quality timber production. If a problem is detected, there are some corrective actions that can be considered. Unfortunately, in most instances, trying to correct a problem may result in more damage to surrounding trees or to the site. In these instances, repairs may be simply for aesthetic or safety reasons rather than trying to repair the soil damage.

If soil compaction is observed, tillage may loosen compacted surface soils. In the woods however, tillage is an expensive and difficult procedure. Generally, practices such as fertilization and competition control can produce greater growth than tillage, but these results are short-lived because the inherent damage to the soil is not addressed. Slash or chipper residue can also be used to mulch fine-textured soils and encourage the development of pore space by worms and other creatures.

If rutting occurs, the ruts may be filled or graded level. Care should be taken to avoid creating new problems while trying to correct others. For instance, ruts may need to be left as is if grading will only cut more tree roots increasing the potential for tree damage or even tree mortality.

Erosion is most likely to occur when the soil is bare and unvegetated. If bare soil is observed, apply seed and mulch to help hold the soil in place. Use a seed mix appropriate for expected moisture and light levels. Be sure to use seed mixes that are free of invasive and non-native plant species. Additional information on preventing soil erosion is available in *Wisconsin's Forestry Best Management Practices for Water Quality Field Manual*.



Carmen Wagner, DNR

Damage to individual trees in the harvest area cannot generally be corrected. Repairs to ruts in this area will primarily address aesthetic and safety concerns.



Kristin Shy, DNR

At the completion of a timber harvest, repairs should be made, as needed, to skid trails and other parts of the timber sale.

**Skid Trails.** Skid trails are areas of concentrated traffic used to harvest trees and transport logs to landings. When managing for even-aged stands like aspen, regeneration is expected to occur in the skid trails and it is important to minimize soil disturbances. When managing for uneven-aged stands like northern hardwoods, the skid trails may be designated for multiple entries into the stand. In this case, regeneration in the skid trails is less likely and some soil compaction may be tolerated; however, ruts and erosion should still be avoided. Implications of soil disturbances should be placed in the context of management objectives.

Generally, minimal maintenance should be needed for skid trails as compared to forest roads. Designated skid trails may occasionally need to be back-bladed to level the trail surface. If weather and soil conditions are suitable, this can simply be part of an end of the day routine. If ruts or other problems become severe enough, other corrective actions may be needed. Depending on the severity of the problem, use of the skid trail may need to be suspended until weather and soil conditions improve.

If skid trails are severely compacted and regeneration is expected in these areas, tillage may be used to improve the rooting zone for trees. Ripping in combination with disking is usually the most appropriate treatment for most skid trails that are compacted during harvesting. If earth moving is required to improve drainage, the trail should be ripped or disked before bedding. Combination plows can be a practical and economical method for ripping, disking and bedding in one pass. In addition, grading, seeding, and erosion control structures may also be needed to prevent erosion and sedimentation.



Carmen Wagner, DNR

Soil compaction is often evident in pine plantations.

**Forest Roads and Landings.** Forest roads and landings are heavily used by equipment. By their very nature, they are compacted surfaces. On forest roads and landings, a greater tolerance for ruts may be permitted because generally these areas are part of a dedicated transportation network, rather than productive forestland. However, repairs should still be made as soon as site conditions allow to prevent soil erosion and impassable road conditions.

Road surfaces should be graded only as needed to maintain a smooth, stable running surface and to retain the original surface drainage. Excessive grading can result in increased wear, loss of surface materials and can lead to erosion.

Grading should cut deep enough into the surfacing material so that loosened material will mix, compact, and bind with underlying materials. If deep potholes or ruts cannot be graded out, the surface can be ripped and then graded and re-compacted to achieve proper binding. Otherwise, holes and ruts that are just filled or patched will quickly reform in the same locations.

Rocks and other oversized material that is brought to the surface during grading should be moved off the road. Berms that form along road edges from grading concentrate road runoff and create poor road conditions. In most cases berms should be removed either by grading or by hauling the material away.



Carmen Wagner, DNR

Forest roads and landings can typically tolerate more soil disturbances than other parts of timber sales.



Carmen Wagner, DNR

Well vegetated road surfaces are unlikely to experience erosion.

Over a prolonged period of use and maintenance, surfacing materials gradually break down or are lost to the side of the road. Steep road segments and curves experience the highest rate of surface material loss. Eventually, the road will not match its design standard. At that time, it is necessary to add surfacing material in order to bring the road back to its intended standard.

All temporary roads should be closed when the activity they were constructed for is completed. Road closure can be accomplished either by the installation of a gate or by the construction of a physical barricade. Keep in mind that gates can be a high maintenance item, while barricades or berms require extra effort to open when access is needed for maintenance or other management activities.

Fully closing a road or “vacating” a road involves removing all stream crossing structures and revegetating the road surface so it is in a condition where erosion is unlikely. Road vacating is a semi-permanent/permanent technique that, if done properly, completely eliminates the need to maintain a road. This option is typically more suitable for temporary roads.

**The most effective method  
for maintaining woodland  
soil quality is to prevent  
and minimize disturbances.**



## Additional Sources of Information

Sources for additional information on the topics discussed in this publication are listed below. WDNR publications are available from your local WDNR Service Center or by calling (608) 267-7494.

- A Landowner's Guide to Building Forest Access Roads, USDA Forest Service Publication #NA-TP-06-98:  
<http://na.fs.fed.us/spfo/pubs/stewardship/accessroads/accessroads.htm>
- Forested Wetlands: Functions, Benefits and the Use of Best Management Practices, USDA Forest Service Publication #NA-PR-01-95:  
[http://na.fs.fed.us/spfo/pubs/n\\_resource/wetlands/index.htm](http://na.fs.fed.us/spfo/pubs/n_resource/wetlands/index.htm)
- Wisconsin's Forestry Best Management Practices for Water Quality Field Manual, WDNR PUB-FR-093:  
<http://dnr.wi.gov/forestry/usesof/bmp/bmpfieldmanual.htm>
- Sustaining Minnesota Forest Resources: Voluntary Site-Level Forest Management Guidelines for Landowners, Loggers and Resource Managers, Minnesota Forest Resources Council:  
<http://www.frc.state.mn.us/FMgdline/Guidebook.html>
- Sustainable Soil and Water Quality Practices on Forest Land, Michigan Department of Natural Resources and Michigan Department of Environmental Quality
- Preventing Soil Damage in the Boreal and Acadian Forests of Eastern Canada: A Practical Guide for Forest Operations, Forest Engineering Research Institute of Canada
- USDA Natural Resources Conservation Services Web Soil Survey:  
<http://websoilsurvey.nrcs.usda.gov/app/>



### A publication of the Wisconsin Department of Natural Resources

The purpose of this publication is to inform, not to advise. It is recommended that you seek professionals knowledgeable about the specifics of your woodland and applicable regulations prior to implementing any forest management activities on your property.

This publication is available from Wisconsin Department of Natural Resources, Division of Forestry, PO Box 7921, Madison, WI, 53707.

For additional information, call (608) 267-7494 or visit our web-site at: [www.dnr.wi.gov/forestry/](http://www.dnr.wi.gov/forestry/)

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