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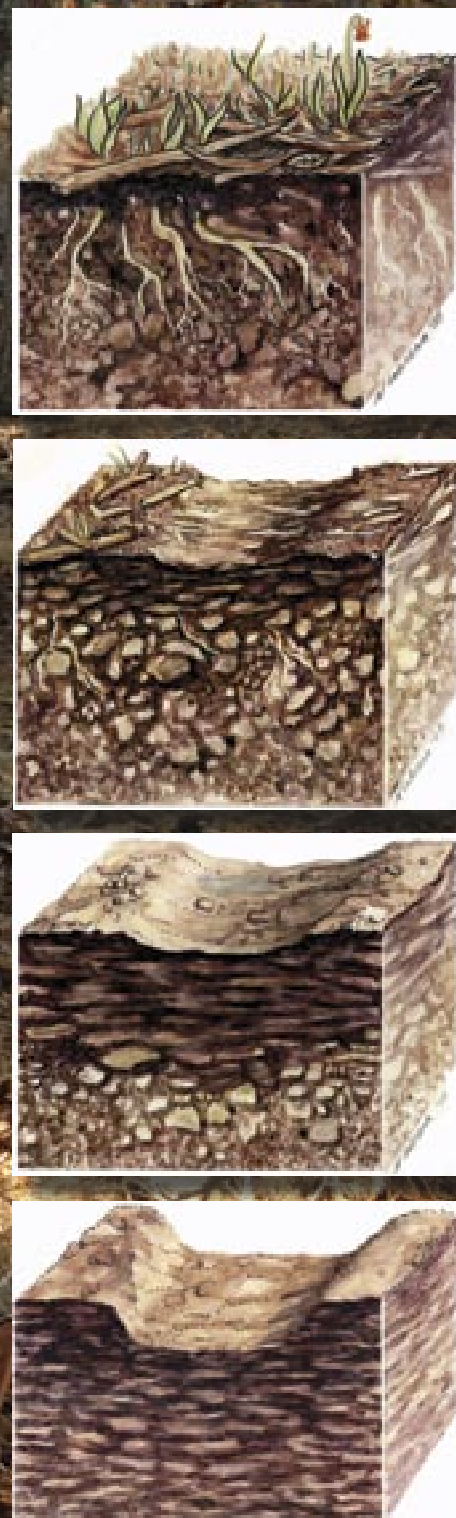
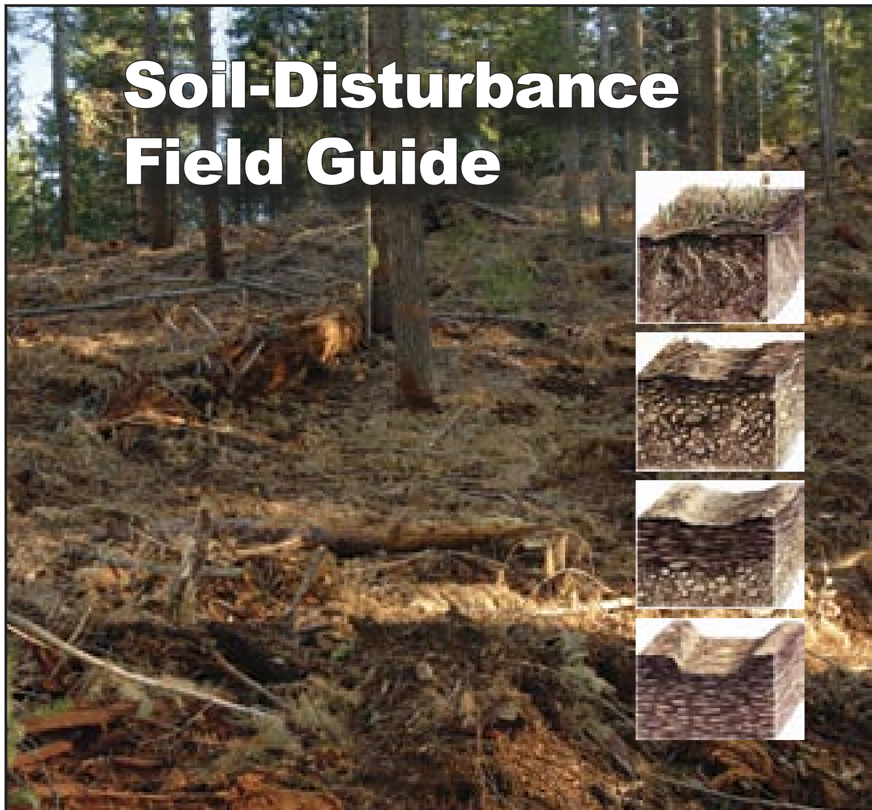
Soil-Disturbance Field Guide





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CHAPTER 1

Introduction

The San Dimas Technology and Development Center of the Forest Service, U. S. Department of Agriculture, developed the soil-disturbance field guide as a soil monitoring tool to identify soil-disturbance classes. The field guide provides detailed descriptions and photographic examples—over a wide range of climatic and vegetative conditions—of the undisturbed soil condition and the three soil-disturbance classes. The field guide is not only a training tool but also a tool for individuals, such as soil scientists, silviculturists, contract inspectors, fuel management specialists, and other resource managers to use when conducting field soil-disturbance assessments.

The field guide also is a tool to improve communication between land managers and contractors, equipment operators, and public interest groups. Much has been written (i.e., opinions and scientific data) about the potential effects of soil disturbance on vegetative growth and other ecosystem functions. In order to have a clear understanding of these interactions, it requires that everyone speak the same language to help develop a soil-management prescription.

Background

The Forest Service considers the sustainable production of natural resources and the maintenance of soil and water quality high priorities as it plans and implements management activities. Legislation, such as the Organic Administration Act of 1897, the Multiple Use and Sustained Yield Act of 1960, the National Environmental Policy Act of 1969, and the National Forest Management Act of 1976, speak either directly or indirectly about providing high-quality water, providing sustainable production of timber and forage, improving growth of forests and grasslands, disclosing impacts of proposed activities on soils, and not degrading the productive potential of the national forests. Little definitive direction was given on how to accomplish these goals.

In response to these laws, all Forest Service regions developed soil quality standards and implemented direction or guidance relating to maintenance and protection of soil productivity. Over the years, a wide array of monitoring protocols and definitions of detrimental soil conditions have been developed to determine if, in fact, agency management practices met this direction. These uncoordinated efforts, while well intentioned, created a number of problems. The most significant problem has been the inability to compare and/or share monitoring data across administrative boundaries because of (1) inconsistent or poorly designed sampling protocols, and (2) inconsistent descriptions of soil-disturbance categories and differing definitions of detrimental soil conditions.

The development of reliable monitoring protocols for assessing and comparing soil disturbance resulting from logging operations is a key component of an adaptive management process for forest soil conservation (Curran et al. 2005). Uniform and unambiguous definitions of soil-disturbance categories must be part of such protocols if accurate, consistent, and statistically sound assessments are to be made. Such categories must also relate to forest productivity and hydrologic function (Curran et al. 2007).

A proposed soil-quality protocol that incorporates both a statistically rigorous sampling protocol and definitions of visually observable soil-disturbance categories has been developed by the Forest Service and is available in the Forest Soil Disturbance Monitoring Protocol (Page-Dubroese et al. 2009a and b).

This field guide is a companion document to the national protocol (Page-Dumroese et al. 2009a and b), which also can be used on its own to identify disturbance classes and to monitor soil conditions before and after treatment.

Questions may arise regarding the accuracy and consistency of visual soil-disturbance assessments. Other forest management entities (Scott 2007, Curran et al. 2000) have found that such soil-disturbance observations work effectively if they are supported by a disciplined training program, frequent checking by experienced individuals, and training of observers. This field guide is intended to be used in such training efforts, and to help promote the high level of uniformity and consistency required when conducting visual soil-disturbance assessments. More importantly, it will improve the level of communication among all parties with an interest in forest soil-disturbance monitoring.

Field Guide Organization

Chapter 1 describes the role of a visual guide within the context of soil risk ratings and soil-quality monitoring, and evaluates the effects of soil disturbance. Chapter 2 defines and describes the visual attributes that determine a soil-disturbance class. Chapters 3 through 6 describe each disturbance class, its criteria, and where it may occur. Representational photographs also are included. By comparing photographs field personnel can determine which soil-disturbance class the management-induced disturbance falls within. Chapter 7 provides examples of mechanized equipment commonly used to implement harvest prescriptions.

Planning and Implementing Projects Using Visual Soil-Disturbance Classes

Onsite Investigations

One should follow a logical process when planning any ground-disturbing activity to ensure that soils and project-design features are considered when developing the desired conditions. Onsite investigations within a project area will determine the soils present and how the soils may have been impacted by past management activities. Soil-disturbance classes help to quantify the degree, extent, and distribution of existing impacts. Data collected as part of onsite investigations should be supplemented with other information, such as soil surveys, aerial photography, and management direction.

Soil Risk Ratings

Rating, or predicting the degree of risk of detrimental soil disturbance resulting from equipment operations, is a component of an adaptive management process for forest soils (Curran et al. 2005). Ideally, detrimental soil conditions are defined based on research designed to measure the effect of disturbance on specific soil types to subsequent tree growth. In the absence of such data, determinations are made about these cause-and-effect relationships.

Soil risk ratings are one way to look at specific soil types and their individual properties, and make determinations about how changes in these properties, brought about by equipment operations or fire, may affect site productivity and hydrologic function. This process is described in detail in Reynolds et al. (2008). A risk-rating model has been developed that, in brief, views each soil in terms of a bank account. Some assumptions include:

- Degree and extent of soil disturbance has a potentially greater effect on shallow or infertile soil than it does on deep or fertile soils.

- Soils supporting vigorous plant growth are less likely to be affected by soil disturbance than are less favorable soils.

- Soil impacts are more likely to reduce vegetative growth under stressful climatic conditions.

Soil-quality objectives for specific land-management projects can be established based on soil types and their corresponding risk ratings. For example, soils with low risk of damage by equipment operations may be able to sustain more class-3 soil disturbances than soils with a high degree of risk. Another consideration is that soils with a low degree of risk of damage from equipment operations may be able to withstand more equipment passes without incurring a class-3 soil disturbance. Many factors affect the risk rating, including soil texture, slope, and ecological setting. In the past, a single soil-quality objective was applied to all soils regardless of differences in properties or degree of risk. Using risk ratings and past monitoring information, if available, should allow for more flexibility in developing soil-quality objectives during the project-planning process.

Soil risk ratings can be generated by running the model on the National Soils Information System (NASIS) database (where soil surveys are available), or by using a field key and making onsite observations of soil properties.

Soil risk ratings are currently based on assumptions rather than on quantitative research. Therefore, they need to be verified or adjusted as part of the adaptive-management process. Soil-disturbance assessments, using visually observable disturbance classes, can provide some of the information needed to make these adjustments.

Desired Soil Conditions

Desired soil conditions for specific land-management activities can be based on the analysis of soil types, their characteristics, and their corresponding risk ratings. Desired soil conditions can be expressed as the allowable extent (usually expressed as a percentage of area occupied by each of the three soil-disturbance categories). However, there are other factors that contribute to the overall effect(s) of soil disturbance in a specific project area. These include:

Degree of disturbance. The amount of change in a particular soil property and the depth to which that change occurs (this is reflected in the soil-disturbance class).

Duration of disturbance effects. The length of time that the disturbance effects can be expected to persist. (This is also reflected somewhat in the soil-disturbance class and risk rating).

Distribution of disturbance. The pattern of soil disturbance across a project area or landscape. (For example, evenly spaced small polygons versus single large polygons or linear polygons). The pattern of soil disturbance across a project area is probably the single most important factor in determining potential effects.

Location of soil disturbance in relation to other resource values. The proximity of soil disturbance to other resource values, such as streams, riparian areas, critical habitat, heritage sites, etc., also can be an important consideration when determining effects.

Soil variability. Soil differences across a project area may necessitate a set of desired soil conditions and project-design features for a specific project.

These five factors need to be considered when establishing desired soil conditions and project-design features for each project. Applying a single set of soil-quality standards to all projects is no longer scientifically supportable.

Soil-Quality Monitoring

Soil-disturbance classes can be used quickly and easily to assess effectiveness of management activities in achieving desired soil conditions. If desired soil conditions are expressed in terms of soil-disturbance classes, then soil-quality monitoring following the national protocol can be used to determine if desired conditions have been met.

Quantitative physical indices of soil quality, such as strength, macropore-space distribution, or bulk density, can be assigned for specific soils. These indices can be related to specific soil types and disturbance classes. However, if meaningful data are to be obtained, many quantitative measurements need to be taken as part of controlled studies.

Describing or defining soil disturbance in terms of variables, such as soil strength, pore space, or bulk density, makes assessing change resulting from management activities difficult and expensive. Soil variability, and the variation in the pattern of equipment operations or burning, further complicates assessments. Other factors, such as climate (macro and micro), vegetation-management practices, genetics, and hazardous-fuels distribution also can affect the extent and degree of soil disturbance and its subsequent effects. However, they are often overlooked.

Sometimes several forms of soil disturbance can occur at one place, making assessments difficult. For example, forest-floor removal, displacement, and compaction often can occur in the same location. Most soils exhibit bulk-density increases with depth. In soils where displacement has occurred, natural-density increases can be confused with compaction.

One way to simplify soil-disturbance assessments is to use visual classes to describe the degree of change from the natural (or preproject) conditions resulting from the application of management activities. Soil-disturbance classes also allow soil scientists to communicate the desired soil conditions and to display the effects to contract administrators, other resource specialists, and the public. On the landscape, soil disturbance occurs in a continuum—from little or none to very severe. Disturbance classes allow an observer to divide the continuum into meaningful and describable segments.

Soil-disturbance classes attempt to combine important disturbance-type features into easily observable groups. Soil-disturbance categories described in this field guide should be used for descriptive use only. For the most part, effects of the various degrees of soil disturbance on the productive potential or hydrologic function are not yet known or have not been validated. However, assumptions based on existing research or personal experience can be made.

Summary

When planning and implementing management activities using soil-disturbance classes, this process may be helpful:

1. Collect existing information on the project area.
   - Review current and past aerial photography.
   - Obtain documentation of previous management activities (if available).
   - Review existing soil-survey information.
   - Determine soil-resource issues.

2. Conduct onsite investigations to determine soil characteristics and impacts of past management activities. Disturbance classes can be used to quantify management impacts on soils. (Follow the Forest Soil Disturbance Monitoring Protocol, volume 2.)

3. Determine the risk of soil disturbance resulting from planned management activities (equipment, fire) using current risk-rating models.

4. Establish desired soil conditions and develop project-design features needed to achieve them.

5. Conduct post-project monitoring following the national protocol to determine if desired soil conditions have been met.

6. Adjust soil risk ratings if needed.

7. Coordinate with the regional soil scientist on the need for more quantitative monitoring.

CHAPTER 2

Using the Soil-Disturbance Field Guide

The field guide is intended for individuals conducting field soil-disturbance assessments. However, before starting an assessment it may be helpful to review the available information on the project area. Background information on the soils within the units will help to prioritize sampling areas and to identify potential areas of concern. Numerous sources of information are available including:

- Watershed and landscape analysis.
- Management-activity records.
- Aerial photographs.
- Soil resource inventories.
- Soil risk ratings.
- Watershed improvement needs inventories.
- Soil-management prescription.

Field monitoring requires identifying specific soil attributes to determine the soil-disturbance class. A systematic method for observing soil conditions (physical, chemical, and biological) is necessary to make an accurate soil-disturbance-class determination.

The following list of attributes is from the National Soil Disturbance Monitoring Protocol, volume 2, included in appendix A. Soil scientists, silviculturists, and contract inspectors can determine accurately the overall disturbance-class rating by following a systematic review of key soil attributes. To ensure an accurate soil-disturbance rating, the reviewer should be thoroughly familiar with the undisturbed soil-condition attributes for the forest floor, surface, and subsurface.

Soil-Disturbance-Class Attributes

Forest-Floor Attributes:

- Forest-floor impacted.
- Live plant.
- Fine woody.
- Coarse woody.
- Bare soil.
- Rock.

Surface-Soil Attributes:

- Topsoil displacement.
- Erosion.
- Ruts – shallow.
- Ruts – moderate.
- Ruts – deep.
- Puddled conditions.
- Burning – low severity.
- Burning – moderate severity.
- Burning – high severity.

Subsurface Attributes:
- Compaction – shallow.
- Compaction – moderate.
- Compaction – deep.
- Platy structure.
- Massive structure.

Forest-Floor Attributes

The forest-floor material (litter, duff, live vegetation) includes all organic horizons above the mineral soil surface. Description of the forest floor provides valuable information of forest-floor nutrients (Page-Dumroese et al. 2000) and soil-cover presence is useful in applying erosion-prediction models. Figures 2-1 through 2-6 illustrate forest-floor attributes.

Figure 2-1—Live vegetation dominates this project area, and rapidly provides soil cover.

Figure 2-2—Fine-woody material is approximately the size of the 100-hour fuels.

Figure 2-3—Coarse-woody material left onsite after completing the harvest.

Figure 2-4—Coarse-woody material remains on the landing, and is dispersed throughout the treatment unit.

Figure 2-5—Bare soil is identified within the tape-measure boundary.

Figure 2-6—Soil cover is dominated by rock.

Soil Displacement

Surface-Soil Attributes

Topsoil (surface soil) primarily includes the mineral-soil A horizons, but if the A horizon is shallow or undeveloped, it may include other horizons. Soil-displacement involves the removal of soil material from one place to another. It often is the result of scraping with a blade, the turning of tracks or wheels, or the dragging of logs or whole trees. Surface soils, high in organic matter, are important to maintaining site productivity. They usually have high infiltration rates and absorb water readily. Subsoils tend to be more erodible than surface soil. Maintenance of surface soils is an important objective, especially in shallow soils, or where they are particularly thin. Soil displacement can occur over a large continuous area and is often more common than other types of soil disturbance. Figure 2-7 illustrates surface-soil displacement.

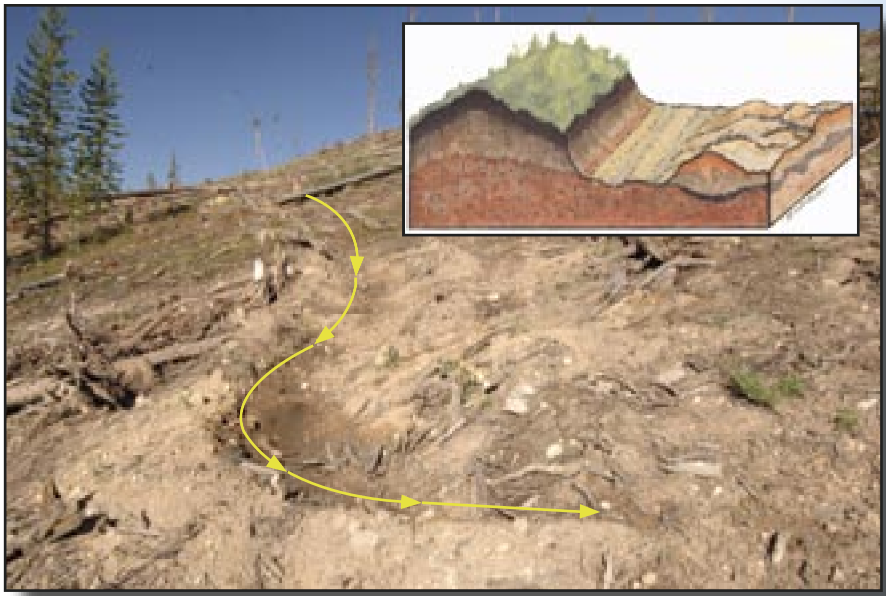

Figure 2-7—Displaced soil creates a berm along the skid trail by moving the topsoil (A horizon).

Erosion

Erosion is the detachment and movement of soil or rock by water, wind, ice, or gravity (Soil Science Society of America 2001). Erosion indicators include the presence of rills or gullies, pedestaling of rocks/plants, erosion pavement, and light-colored soil horizons exposed at the surface. Figures 2-8 through 2-10 illustrate erosion.

Figure 2-8—Rill erosion is prevalent on this cutslope due to lack of soil cover. Steep and long slope lengths without vegetation or soil cover are susceptible to accelerated erosion.

Surface-Soil Attributes (cont)

Figure 2-9—An example of pedestaling shows that the unprotected soil is washed away.

Figure 2-10—An area with erosion pavement shows that all the fine soil material has been removed.

Surface-Soil Attributes (cont)

Rutting

Ruts vary in depth, but are primarily the deformation of the soil from equipment operation during suboptimal moisture conditions or on soils with low bearing strength. Compacted ruts can channel water downslope causing erosion and slowing regeneration. Figures 2-11 through 2-14 illustrate rutting.

Figure 2-11—Shallow rutting is evident on the skid trail.

Figure 2-12—Moderate rutting on the skid trail, during suboptimal moisture conditions.

Surface-Soil Attributes (cont)

Figure 2-13—Moderate ruts from a single vehicle pass.

Figure 2-14—Deep ruts formed in soils with a high water table.

Soil Burn Severity

This field guide focuses on soil disturbance from mechanized equipment. However, once an area has been mechanically treated, a secondary follow-up treatment may include burn piles or prescribed burning to achieve resource objectives. In recognition that these conditions may exist when post-treatment monitoring is conducted, the values of low, moderate, and high burn severity are included in the guide. Evaluating soil burn severity can determine if increased erosion or the amount of remaining forest-floor nutrients is a concern from the treatment. Figures 2-15 through 2-17 illustrate the burn-severity classes.

Surface-Soil Attributes (cont)

Figure 2-15—Low soil burn severity. Pile burning of forest residues shows no evidence of soil heating. Black ash and incomplete combustion of materials on the surface indicates low soil burn severity.

Figure 2-16—Moderate soil burn severity. Dark ash is prevalent but the soil structure is intact, and water repellency is discontinuous.

Figure 2-17—High soil burn severity. Ash may be white or reddish. The soil structure is loose and powdery (structureless).

Subsurface Attributes
Soil Compaction

Soil compaction is an increase in the soil bulk density, and a concomitant decrease in the soil porosity, by the application of mechanical forces to the soil (Soil Science Society of America 2001). There are three levels and depths of compaction: shallow (0 to 4 inches), moderate (up to 12 inches), and deep (over 12 inches). Figures 2-18 through 2-20 illustrate soil compaction.

Figure 2-18—Compaction shallow. Increased resistance and compression is evident but the rocky soils ameliorate the depth and severity of compaction.

Surface-Soil Attributes (cont)

Figure 2-19—Compaction moderate. Increased resistance is evident to approximately 8 inches.

Figure 2-20—Compaction deep. Increased resistance is greater than 12 inches in depth on this main skid trail.

Surface-Soil Attributes (cont)

Platy/Massive Soil Structure

A platy soil structure is evident with flat-lying or tabular structure in the mineral soil. Massive indicates no structural units are present, and soil material is a coherent mass. A puddled soil condition results from both shearing and compactive forces, which destroys natural structure and results in a condition of greatly reduced pore space (Soil Science Society of America 2001). Visual attributes are defined as shallow (to 4 inches in depth), moderate (extends 12 inches deep), and deep (greater than 12 inches). Figures 2-21 through 2-24 illustrate platy, massive, and puddled conditions.

Figure 2-21—A puddled soil condition shows the effect of both a structureless condition and an impaired hydrologic function.

Figure 2-22—Shallow platy structure is evident in the top 4 inches, as the area recovers from previous harvesting.

Surface-Soil Attributes (cont)

Figure 2-23—Massive (structureless) is found in this skid trail.

Figure 2-24—Deep platy structure is evident in the main skid trail.

Undistrubed Soil Condition

The soil-disturbance continuum extends from undisturbed to increased levels of disturbance. Visual attributes help select the soil-disturbance class ranging from 0 (undisturbed) to 3 (highly disturbed). Once a systematic method is completed for observing soil conditions, the correct soil-disturbance category is applied to that point. Figures 2-25 through 2-28 illustrate the undisturbed soil condition and the three soil-disturbance classes.

Soil-disturbance Class 0 – Undisturbed

- No evidence of past equipment.
- No depressions or wheel tracks.
- Forest-floor layers are present and intact.
- No soil displacement evident.
- No management-generated soil erosion.
- No management-created soil compaction.
- No management-created platy soils.

Figure 2-25—Soil-disturbance class 0, undisturbed.

Soil-Disturbance Class 1

- Wheel tracks or depressions evident, but faint and shallow.
- Forest-floor layers are present and intact.
- Surface soil has not been displaced.
- Soil burn severity from prescribed fires is low (slight charring of vegetation, discontinuous).
- Soil compaction is shallow (0 to 4 inches).
- Soil structure is changed from undisturbed conditions to platy or massive albeit discontinuous.

Figure 2-26—Soil-disturbance class 1, faint wheel tracks, forest-floor intact, no signs of displacement or increased compaction.

Soil Disturbance Class 2

- Wheel tracks or depressions are evident and moderately deep.
- Forest-floor layers are partially missing.
- Surface soil partially intact and maybe mixed with subsoil.
- Soil burn severity from prescribed fires is moderate (black ash evident and water repellency may be increased compared to preburn condition).
- Soil compaction is moderately deep (up to 12 inches).
- Soil structure is changed from undisturbed conditions and may be platy or massive.

Figure 2-27—Soil-disturbance class 2, wheel tracks are evident, forest-floor layers are missing, soil-displacement is evident, and soil compaction is increased (up to 12 inches).

Soil Disturbance Class 3

- Wheel tracks or depressions are evident and deep.
- Forest-floor layers are missing.
- Surface soil is removed through gouging or piling.
- Surface soil is displaced.
- Soil burn severity from prescribed fires is high (white or reddish ash, all litter completely consumed, and soil structureless).
- Soil compaction is persistent and deep (greater than 12 inches).
- Soil structure is changed from undisturbed and is platy or massive throughout.

Figure 2-28—Soil-disturbance class 3, wheel tracks are evident, forest-floor layers are missing, signs of surface-soil removal are evident, and soil compaction is increased (over 12 inches in depth).

Temporal and spatial effects of mechanical disturbance need to be considered as a component of the monitoring effort. Different treatment prescriptions and equipment will yield different effects and must be matched to the area soil prescription.

CHAPTER 3
Defining Soil-Disturbance

Class 0 – Undisturbed Soil Surface

The soil-disturbance class 0 is defined by the following characteristics:

- No evidence of past equipment.
- No depressions or wheel tracks.
- Forest-floor layers are present and intact.
- No soil-displacement evident.
- No management-generated soil erosion.
- No management-created soil compaction.
- No management-created platy soils.

Soil-disturbance class 0 may be found throughout the landscape. Steep hillslopes, riparian- or streamside-management zones, and some research-natural areas may have little to no management-induced disturbance. Review aerial photographs and available stand-level data if the area was previously treated. Aerial photographs help identify untreated areas adjacent to monitoring locations. Undisturbed areas are beneficial for monitoring calibration. Stand records have considerable data, such as when entries were made, treatment prescription, and follow-up treatments implemented. Soil-specialist reports identify the soil type within the project area and address risks and mitigation requirements.

Soil-Disturbance Class 0

- The forest floor is intact, no indications of past equipment operation.
- Surface litter includes fine and coarse woody material and may have plants.
- Deep organic material covers the A horizon.
- Both large and small roots extend throughout the soil profile.
- Surface soil structure is generally granular.
- No resistance to penetration with a shovel.

Figure 3-1—Soil-disturbance class 0 – undisturbed.

Figures 3-2 through 3-12 illustrate soil-disturbance class 0. The Ecomap information throughout this publication is taken from a 1994 USDA Forest Service document, which is included in the references. The figure captions also include the photo location.

Soil-disturbance Class 0 – Undisturbed

- No evidence of past equipment.
- No depressions or wheel tracks.
- Forest-floor layers are present and intact.
- No soil displacement evident.
- No management-generated soil erosion.
- No management-created soil compaction.
- No management-created platy soils.

Figure 3-2—Vegetation: Sitka spruce and western hemlock. A thick organic layer including feather moss covers the mineral soil surface. The surface soil texture is a gravelly silt loam. Ecomap Section M245C - Southern Alexander Archipelago, Tongass National Forest, Alaska Region.

Figure 3-3—Vegetation: Grand fir and Douglas fir. The soils are influenced by volcanic ash from Mount Mazama. The surface soil texture is silt loam. Ecomap Section 332G - Blue Mountains, Umatilla National Forest, Pacific Northwest Region.

Figure 3-4—Vegetation: Douglas fir and mixed conifer. The surface soil texture is sandy loam. Ecomap Section M261E - Sierra Nevada, Lake Tahoe Basin Management Unit, Pacific Southwest Region.

Figure 3-5—Vegetation: Grand fir and Douglas fir, western spruce fir, and western ponderosa forest. The surface soil texture is loamy sand. Ecomap Province M332A - Idaho Batholith, Idaho-Panhandle National Forest, Northern Region. Undisturbed areas are often found adjacent to previous timber-harvest units, as in this case.

Figure 3-6—Vegetation: Longleaf pine and slash pine. The surface soil texture is sandy loam. Ecomap Section 232B - Coastal Plains and Flatwoods, Conecuh National Forest, Southern Region.

Figure 3-7—Close-up view of the undisturbed soil structure in the unit. Vegetation: Longleaf pine and slash pine. The surface soil texture is sandy loam. Ecomap Section 232B - Coastal Plains and Flatwoods, Conecuh National Forest, Southern Region.

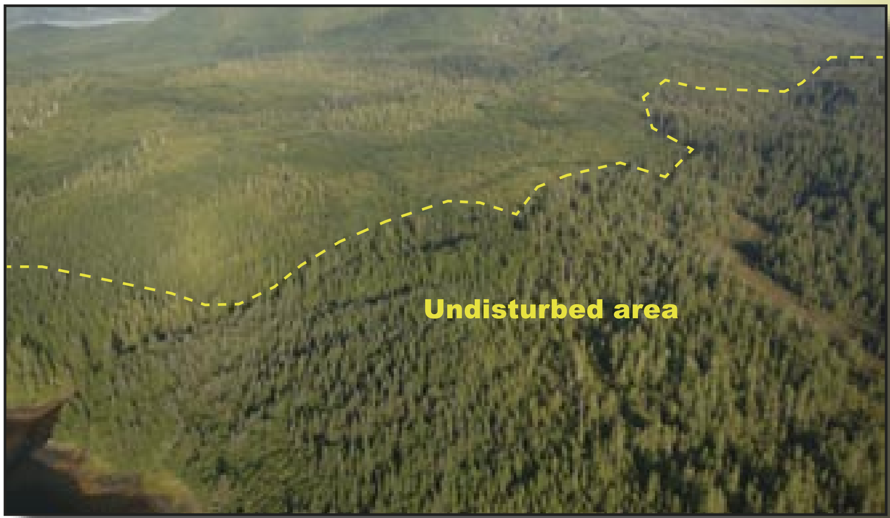

Figure 3-8—Vegetation: Sitka spruce and western hemlock. The surface soil texture is a gravelly silt loam. Ecomap Section M245C - Southern Alexander Archipelago, Tongass National Forest, Alaska Region. Undisturbed areas can be found adjacent to previously harvested areas.

Figure 3-9—Vegetation: Northern hardwoods. The surface soil texture is sandy loam. Ecomap Section 212H - Northern Great Lakes, Hiawatha National Forest, Eastern Region.

Figure 3-10—Close-up view of the surface soil texture found in figure 3-9.

Figure 3-11—Vegetation: Western spruce and fir forest with spruce dominating the overstory, and subalpine fir in the understory. The surface soil texture is sandy loam. Ecomap Section M331A - Yellowstone Highlands, Shoshone National Forest, Rocky Mountain Region.

Figure 3-12—Close-up of the soil structure from this undisturbed area in figure 3-11. Notice the abundance of roots throughout the sample.

CHAPTER 4
Defining Soil-Disturbance Class 1

The soil-disturbance class 1 is defined by the following characteristics:

Soil surface:
- Faint wheel tracks or slight depressions evident.
- Forest-floor layers present and intact.
- Surface soil has not been displaced and shows minimal mixing with subsoil.
- Low soil burn severity. Litter slightly charred or partially consumed. Duff largely intact. Water repellency is similar to pre-burn conditions.
- Soil compaction is shallow. [Compaction in the surface soil (top 0 to 4 inches) is slightly greater than observed under natural conditions.]

Soil physical conditions:
- Change in soil structure from granular structure to massive or platy structure; restricted to the surface soil.
- Platy structure is noncontinuous.

Soil-disturbance class 1 can be found throughout the landscape in both recent and older treatment units. Depending on the recovery time, look for soil-disturbance class 1 on secondary or tertiary skid trails, winter-logged units, single-pass trails, and low-severity, broadcast burn areas.

Areas that were managed 20 to 30 years ago may still show indications of soil disturbance. Surface characteristics may be masked by pine needles and accumulated litter, but it is not uncommon to note slight depressions from equipment or greater penetration resistance on major skid trails, access roads, or landings. Areas monitored that demonstrate attributes of previous activity should be categorized as class-1 disturbance.

Soil-Disturbance Class 1

- Wheel tracks or depressions evident but faint and shallow.
- Forest-floor layers are present and intact.
- Surface soil has not been displaced.
- Soil burn severity from prescribed fires is low (slight charring of vegetation, discontinuous).
- Soil compaction is shallow (0 to 4 inches).
- Soil structure is changed from undisturbed conditions to platy or massive albeit discontinuous.

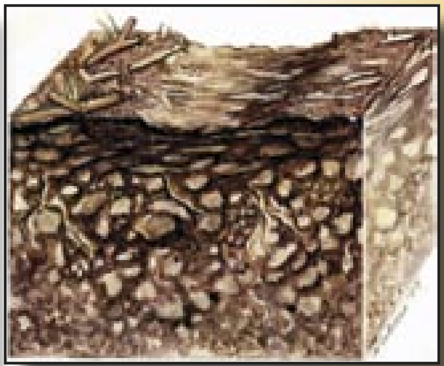

Figure 4-1—An illustration of soil-disturbance class 1.

Figures 4-2 through 4-39 provide photographic examples of class-1 soil disturbance from all regions of the country.

Figure 4-2—The thinning operation in this unit was completed 1 month prior to this photograph. The skid trail is evident, but the forest-floor layers are present and intact with no signs of soil displacement.

Figure 4-3—Vegetation: Longleaf pine and slash pine. The surface soil texture is sandy loam. The treatment prescription was to reduce fire risk with a biomass removal of pine and hardwoods. A tracked feller-buncher and rubber-tired skidders yarded whole trees to the landing for processing. The photos were taken within 1 month of treatment (February 2007). Ecomap Section 232C - Atlantic Coastal Flatlands, Francis Marion and Sumter National Forest, Eastern Region.

Figure 4-4—Vegetation: White fir and ponderosa pine. The surface soil texture is gravelly sandy loam. These photos were taken during an active thinning (November 2006) to reduce fuels using cut-to-length logging equipment. A rubber-tired feller-buncher and a forwarder were followed by an excavator with a mowing head to reduce ladder fuels. Ecomap Section M261 E - Sierra Nevada, Lake Tahoe Basin Management Unit, Pacific Southwest Region.

Figure 4-5—The soil-disturbance class 1 is identified after removing the cut-to-length logs and chipping the residual vegetation. Slight wheel tracks are evident but operations over slash with low-ground-pressure equipment reduce soil impacts.

Figure 4-6—Vegetation communities include Douglas fir, white fir, ponderosa pine, and mixed-hardwood forest. The surface soil texture is sandy loam. These photos illustrate a thinning to promote tree growth by reducing competition. Treatment was implemented within the past 3 months (November 2006). Ecomap Section M261B - Northern California Coast Range, Shasta-Trinity National Forest, Pacific Southwest Region.

Figure 4-7—Using an available cutslope, the soil scientist identifies the soil type, structure, and natural soil resistance prior to monitoring the unit.

Figure 4-8—Vegetation: Jeffrey pine forest. The surface soil texture is gravelly sandy loam. The treatment is a fuels-reduction prescription designed to create defensible space adjacent to main transportation corridors. This was an active-thinning project using a feller-buncher and grapple-skidder to yard whole trees to the landing (photo November 2006). Ecomap Section M261G -Modoc Plateau, Lassen National Forest, Pacific Southwest Region.

Figure 4-9—A closeup of the results of a single equipment pass, which leaves the litter layer intact.

Figure 4-10—Vegetation: Ponderosa pine. The surface soil texture is gravelly sandy loam. The treatment is part of a larger project (Metolius Basin Project Area), with the objective of reducing fuel loading within wildland-urban interface zones. A couple of years after the areas are thinned, the bitterbrush is mowed using a small, tracked, all-season vehicle with a mower attachment. The mower makes a single pass over the entire unit (photo July 2007). Ecomap Section M242C -Eastern Cascades, Deschutes National Forest, Pacific Northwest Region.

Figure 4-11—Closeup of the soil structure in the unit. The forest floor is intact after mowing, with some soil displacement where the equipment turned.

Figure 4-12—Vegetation: Ponderosa pine. The surface soil texture is gravelly sandy loam. The treatment was a green-tree thinning using a harvester/forwarder in 2007. The skid trail is rated as a class-1 disturbance based on shallow wheel tracks that are present, soil that has not been displaced, and compaction that is not evident (photo July 2007). Ecomap Section M242C - Eastern Cascades, Deschutes National Forest, Pacific Northwest Region.

Figure 4-13—Closeup of the soil structure from the skid trail in figure 4-12, showing no signs of increased compaction.

Figure 4-14—Vegetation is dominated by grand-fir and Douglas-fir forests. The soils in the area are heavily influenced by a mantle of volcanic ash from Mount Mazama. The surface soil texture is silt loam. The treatment in this unit is part of an ongoing thinning project using cut-to-length with a harvester and forwarder. Soil impacts are within disturbance class 1. The combination of flat topography and operating on dry soil over surface litter reduces potential adverse impacts to soils (July 2007). Ecomap Section M332G - Blue Mountains, Umatilla National Forest, Pacific Northwest Region.

Figure 4-15—A typical wheel track from the forwarder as it operates over surface litter.

Figure 4-16—Vegetation is subalpine fir forest. The surface soil texture is loam. The unit was harvested in 2005 (photo August 2007) to remove insect mortality. The soil prescription was to operate over snow to reduce impacts to the soil. Prior to this treatment the area had not been entered since 1977. Ecomap Section M331A - Yellowstone Highlands, Shoshone National Forest, Rocky Mountain Region.

Figure 4-17—Closeup of the fine roots found throughout the soil sample of figure 4-16.

Figure 4-18—Forest vegetation is juniper-pinyon woodlands and saltbush-greasewood. The surface soil texture is loam. The treatment is to remove juniper with a small, tracked, rubber-tire tractor with a mulching head attachment. The treatment objective is for wildlife improvement and hazardous fuels reduction. The area was initially treated in the 1960s using two dozers dragging a chain. As the dozers worked cross slope the vegetation was removed, which created openings for wildlife movement. Now a less disturbing method uses a track-laying bobcat with mulching head. Mulch provides cover and reduces erosion. Treatment implemented in 2006 (photo June 2007). Ecomap Section 341C - Utah High Plateaus and Mountains, Dixie National Forest, Intermountain Region.

Figure 4-19—It is important to dig into the soil profile to check for signs of increased resistance and depth of soil compaction.

Figure 4-20—Closeup of soil structure in the treated area below the mulch layer.

Figure 4-21—Closeup of the soil structure in the main skid trail.

Figure 4-22—Vegetation is western spruce fir forest. The surface soil texture is gravelly clay loam. The unit is part of an insect salvage harvest of Engelmann spruce. The soil-prescription recommended use of preexisting trails and winter logging to reduce and avoid adverse impacts to soils. The logs were skidded over snow with rubber-tired skidders with chains and a D-5 track-laying dozer during the winter of 2006-2007. Compaction in the surface soil is only slightly greater than observed under natural condition. Ecomap Section M341C - Utah High Plateaus and Mountains, Dixie National Forest, Intermountain Region.

Figure 4-23—Vegetation includes northern hardwoods on moraines and stratified ice-contact hills. The surface soil texture is fine sandy loam. This unit was part of a salvage logging prescription to remove trees damaged after a windstorm in 2006 (photo September 2007). Ecomap Section 212H - Northern Great Lakes, Hiawatha National Forest, Eastern Region.

Figure 4-24—Vegetation: Lodgepole pine. The surface soil texture is sandy loam. The treatment prescription was to thin the unit over snow during the winter of 2005. Harvesting equipment included 3-wheeled shears and rubber-tired skidders. The soils are shallow to moderately deep and at high risk of erosion with removal of ground cover (photo August 2007). Ecomap Section M331H - North-Central Highlands and Rocky Mountain, Arapaho-Roosevelt National Forest, Rocky Mountain Region.

Figure 4-25—Closeup of the unit in figure 4-24 with no indications of compaction as a result of the winter-logging operation.

Figure 4-26—Vegetation: Lodgepole pine. The surface soil texture is sandy loam. The thinning unit was conducted over snow during the winter of 2005. Equipment included 3-wheeled shears and rubber-tired skidders. Soils are shallow to moderately deep and at risk of accelerated erosion with loss of ground cover (photo August 2007). The low soil burn severity should not increase erosion because of limited areal extent and depth in the mineral soil. Ecomap Section M331H - North-Central Highlands and Rocky Mountain, Arapaho-Roosevelt National Forest, Rocky Mountain Region.

Figure 4-27—Several trees show signs of equipment operating in the area.

Figure 4-28—Vegetation is silver fir, Douglas-fir, and fir/hemlock forest. The soils are dry for a significant portion of the summer due to rain-shadow effects on the east slope. Soils have low bulk density and organic-matter rich topsoil. The loss of topsoil from wind erosion is prevalent once soil cover is removed. Cold soils are common and less resilient to compaction. This unit has been entered previously and mechanical-equipment tracks are evident. Ecomap Section M242C - Eastern Cascades, Okanogan National Forest, Pacific Northwest Region.

Figure 4-29—Shallow ruts and increased compaction are visual attributes of previous mechanical activity.

Figure 4-30—Vegetation: Mixed conifer. The soils are influenced by a mantle of volcanic ash from Mount Mazama. The surface soil texture is silty clay loam. The treatment was a commercial thinning with a tracked harvester and processor. The photo illustrates a single pass with equipment and minimal forest floor impacts. Ecomap Section M332G - Blue Mountains, Umatilla National Forest, Pacific Northwest Region.

Figure 4-31—When conducting an assessment, compare the soil within the track and undisturbed area to assess the soil compaction.

Figure 4-32—Vegetation: Mixed conifer forest. Soils in this area are influenced by a mantle of volcanic ash from Mount Mazama. The surface soil texture is silt loam. The photograph illustrates legacy disturbance from a timber harvest approximately 20 years ago. Visual indicators of class-1 disturbance in previously harvested units include vegetation composition and vigor, depth of forest floor, presence of stumps or cull decks, increased resistance to penetration with tile spade, and or platy soils. Ecomap Section M332G - Blue Mountains, Umatilla National Forest, Pacific Northwest Region.

Figure 4-33—A closer inspection of the soil structure helps to observe the recovery of the soil. Areas with legacy disturbance can often be validated by reviewing older aerial photographs or stand records to pinpoint when an activity occurred.

Figure 4-34—Vegetation: Mixed conifer forest. Soils in this area are influenced by a mantle of volcanic ash from Mount Mazama. The surface soil texture is silt loam. Legacy disturbance is identified in the field from previous timber harvest approximately 20 years ago. Visual indicators of class-1 disturbance include vegetation composition and vigor, depth of forest floor, presence of stumps or cull decks, increased resistance to penetration with tile spade, and or platy soils. Ecomap Section M332G - Blue Mountains, Umatilla National Forest, Pacific Northwest Region.

Legacy disturbance

Legacy disturbance is identified in the field thru visual indicators including:

- Vegetation composition and vigor.
- Depth of forest floor.
- Presence of stumps.
- Cull decks.
- Platy soils.
- Increased resistance.to penetration with tile spade.

Figure 4-35—Old stumps and logs indicate legacy disturbance.

Figure 4-36—Vegetation: Sitka spruce. The surface soil texture is a gravelly silt loam. Slight depressions are evident from yarding the trees across to the landing. Ecomap Section M 245C - Southern Alexander Archipelago, Tongass National Forest, Alaska Region.

Indicators of forest floor disturbance

Indicators of forest floor disturbance:

- Ruts from yarding.
- Displaced soil.
- Vegetation type.
- Bare ground.

Figure 4-37—An older unit where logs were fully suspended as they were cable yarded across the narrow drainage to the landing area. Tongass National Forest, Alaska Region.

Figure 4-38—Vegetation: Sitka spruce and western hemlock. Surface soil texture is a gravelly silt loam. A shovel-yarding technique is used on slopes less than 20 percent. Slash mats are constructed to prevent rutting and support the weight of the shovel yarder (excavator). The soils have low bearing strength and adverse soil effects are avoided by combining a slash mat and equipment with a low (7 to 10 pounds per square inch) static load. Ecomap Section M245C - Southern Alexander Archipelago, Tongass National Forest, Alaska Region.

Figure 4-39—Areas with heavy slash mats are reviewed by the soil scientist to assess impacts to the forest-recovery response time. Ecomap Section M245C - Southern Alexander Archipelago, Tongass National Forest, Alaska Region.

CHAPTER 5
Defining Soil-Disturbance Class 2

The soil-disturbance class 2 is defined by the following characteristics:

Soil surface:

- Wheel tracks or depressions are evident in the mineral soil.
- Forest-floor layers partially intact or missing.
- Surface soil partially intact and may be mixed with subsoil.
- Moderate soil burn severity.
  - Surface soil-water repellency increased compared to the preburn conditions.
  - Black ash with the majority of the fuel consumed.
- Soil compaction is present in the mineral soil (down to about 12 inches).

Observations of soil physical condition:

- Change in soil structure from granular to platy.
- Platy structure is generally continuous.
  - Large roots may penetrate the platy structure; but fine and medium roots may not.

Soil-disturbance class 2 can be found throughout the landscape in both recent and older treatment units. Locations where one might expect to find class-2 disturbance is on main skid trails, flat terrain where there was more mechanized-equipment movement over the area, equipment turn locations, jackpot-burn piles with mixed fuels and soil, units with multiple operations occurring (e.g., thinning, mechanical-site preparation, prescribed burning), or units with large amounts of tree-volume removed.

Soil-Disturbance Class 2

- Wheel tracks or depressions are evident and moderately deep.
- Forest-floor layers are partially missing.
- Surface soil partially intact and maybe mixed with subsoil.
- Soil burn severity from prescribed fires is moderate (black ash evident and water repellency may be increased compared to preburn condition).
- Soil compaction is moderately deep (up to 12 inches).
- Soil structure is changed from undisturbed conditions and may be platy or massive.

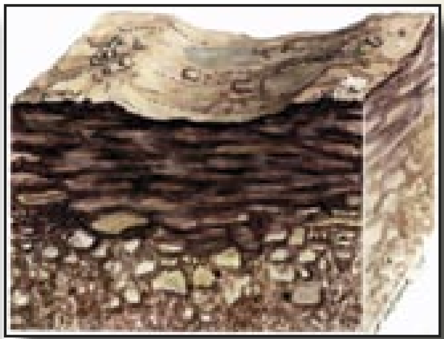

Figure 5-1—Soil disturbance class 2.

Figures 5-2 through 5-24 provide photographic examples of soil-disturbance class 2 from all Forest Service regions.

Figure 5-2—Vegetation: Lodgepole pine. The surface soil texture is sandy loam. The treatment prescription was to remove dead-and-dying lodgepole pine as a part of an insect salvage project. Extensive beetle infestation throughout the forest has resulted in a large volume of material being removed, leaving a clearcut appearance to the units. Potential adverse impacts to soils may occur from the number and density of skid trails, soil displacement, and amount of material left to maintain long-term soil productivity. Mechanized-equipment included a feller buncher and rubber-tired skidders. The unit was harvested in 2005-2006 (photo July 2007). Ecomap Section M331H - North-Central Highlands and Rocky Mountain, Arapaho-Roosevelt National Forest, Rocky Mountain Region.

Class 2

- Forest floor layers are missing.
- Soil compaction.
- Soil structure changed from undisturbed.

Figure 5-3—Vegetation: Lodgepole pine. The surface soil texture is sandy loam. This location was rated as class 2 after reviewing each soil attribute. The skid trail had increased soil compaction, and forest-floor layers were missing. Arapaho-Roosevelt National Forest, Rocky Mountain Region.

Figure 5-4—A closeup of soil conditions within the skid trail from figure 5-3.

Figure 5-5—Vegetation: Longleaf pine and slash pine. Generally, the soils are poorly drained and deep throughout the unit. The surface soil texture is sandy loam. The treatment prescription was to reduce basal area to 50- to 60-basal feet per acre. The skid trails were placed on 70-foot centers to disperse activity throughout the unit. The equipment used included a feller buncher and rubber-tired skidders. The harvesting was completed 2-weeks prior to this photograph being taken (photo February 2007). Ecomap Section 232D - Florida Coastal Lowlands, Apalachicola National Forest, Eastern Region.

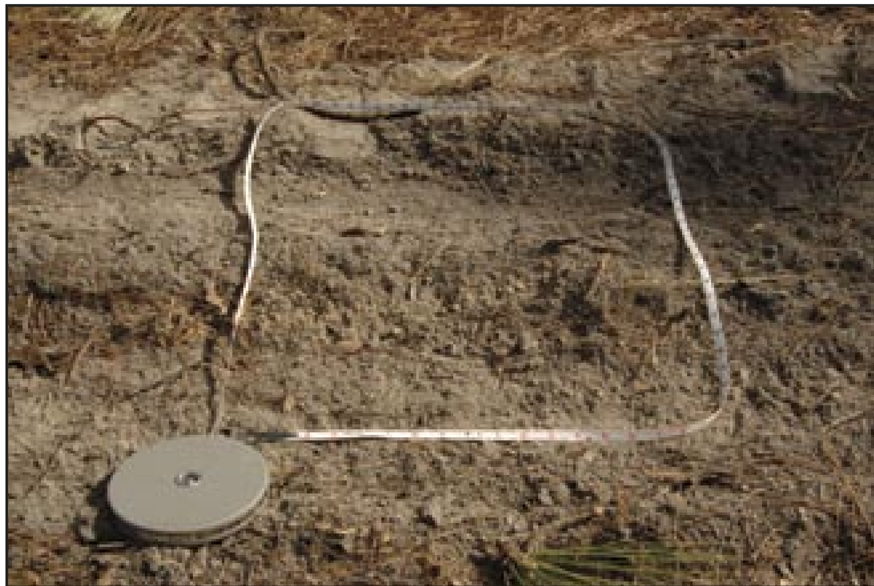

Figure 5-6—Bare soil and ruts are visual indicators of class-2 soil disturbance.

Class 2

- Bare soil.
- Ruts.

Figure 5-7—A closeup of the weak soil structure of the sandy loam soil that is prevalent in the treatment units.

Figure 5-8—Vegetation: Ponderosa pine. The surface soil textures include sandy loam and gravelly sandy loam. The treatment was implemented in 2004 to salvage dead trees from a 2004 wildfire and reforest the site. The main skid trail within the unit leads to the landing area (photo July 2007) and was subsoiled after it was used. Ecomap Section M242C - Eastern Cascades, Deschutes National Forest, Pacific Northwest Region.

Class 2

- Forest floor layers are missing.
- Soil compaction.
- Moderate soil burn severity.

Figure 5-9—Vegetation: Ponderosa pine. The surface soil texture is gravelly sandy loam. The treatment prescription included jackpot piling with an excavator to reduce fuel loading in the wildland-urban interface zone. Moderate soil-burn severity is evident with material consumed and black ash on surface. Piles burned during the winter of 2007 (photo July 2007). Ecomap Section M242C - Eastern Cascades, Deschutes National Forest, Pacific Northwest Region.

Figure 5-10—Vegetation: Ponderosa pine, white fir, Douglas-fir, and some pinyon pine and juniper. The area burned during the 2000 Rodeo Chedeski wildfire (photo March 2007) and the surface soil remains charred. Visual evidence of soil morphological indicators of increased soil compaction is present. Ecomap Section M313A - White Mountain-San Francisco Peaks- Mogollon Rim, Apache-Sitgreaves National Forest, Southwestern Region.

Visual indictors of Class 2

- Soil compaction.
- Ruts from equipment.
- Forest floor layers missing.
- Change in soil structure from undisturbed.

Figure 5-11—Vegetation: Mixed conifer. The soils are influenced by a mantle of volcanic ash from Mount Mazama. The surface soil texture is silty clay loam. Wheel tracks are evident in the mineral soil and forest-floor layers are missing. The treatment prescription is for a commercial thin to improve stand health using a tracked processor for cut-to-length logging. Soil has high clay content and holds moisture. After one to two passes with the equipment there was visual evidence of class-2 soil disturbance, and the operation was temporarily suspended. Ecomap Section M332G - Blue Mountains, Umatilla National Forest, Pacific Northwest Region.

Figure 5-12—Closeup of wheel tracks created from operating in suboptimal moisture conditions.

Figure 5-13—An example of the type and size of soil clod created from the equipment.

Figure 5-14—Vegetation: Ponderosa pine, white fir, Douglas-fir, with areas of pinyon pine and juniper. The treatment prescription was to reduce fuel risks in forests adjacent to the wildland-urban interface by thinning. This main skid trail has high use by rubber-tired skidders as trees are yarded into the landing. Ecomap Section M313A - White Mountain-San Francisco Peaks-Mogollon Rim, Apache-Sitegraves National Forest, Southwestern Region.

Figure 5-15—Vegetation: Northern hardwoods. The surface soil texture is fine sandy loam. Ecomap Section 212H - Northern Great Lakes, Hiawatha National Forest, Eastern Region.

Figure 5-16—Compaction-and-compression effects of equipment are observed in older skid trail. Loss of depth of A horizon is evident.

Skid trail differences due to:

- Age of impact and recovery.
- Degree of use: main skid versus single pass.

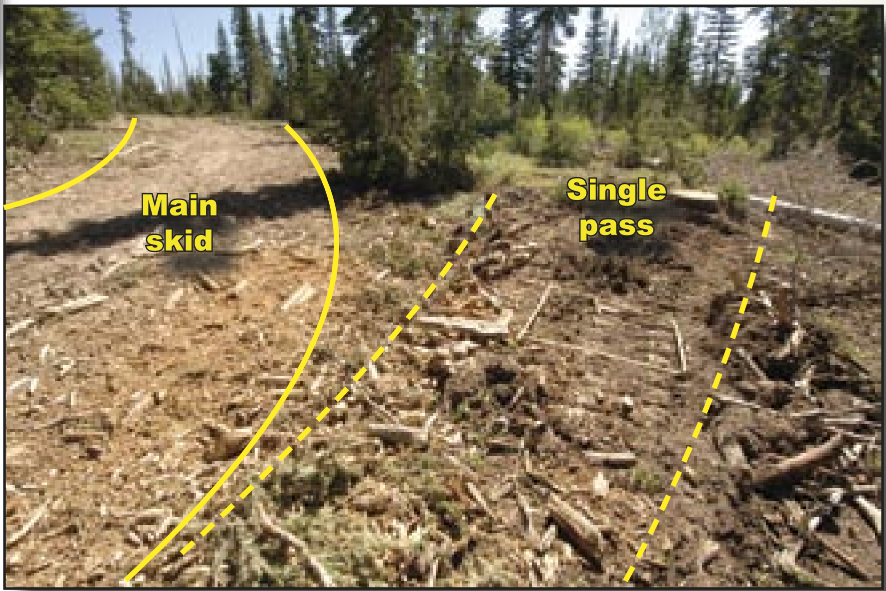

Figure 5-17—Vegetation: Western spruce-fir forest. The surface soil texture is gravelly clay loam. A field test revealed increased resistance to penetration when digging with a tile spade in the skid trail. Differences between an undisturbed, single-equipment pass, and multiple-equipment pass trail were observed. The photo shows the difference in soil disturbance from the main skid and a single-pass skid trail adjacent to each other. Ecomap Section M341C - Utah High Plateaus and Mountains, Dixie National Forest, Intermountain Region.

Figure 5-18—Signs of increased compaction in the main skid trail over the single-pass trail.

Single pass skid trail under sub-optimal conditions.

Figure 5-19—Vegetation: Western spruce-fir forest. The surface soil texture is gravelly clay loam. Increased resistance is apparent along with visual indicators of compaction deeper into the profile. Ecomap Section M341C - Utah High Plateaus and Mountains, Dixie National Forest, Intermountain Region.

Figure 5-20—Compacted soil found within skid trail.

Class 2 indicators

- Compressed soil.
- Change in vegetation.
- Platy soils.

Figure 5-21—Vegetation: Western spruce-fir forest with spruce dominating the overstory and subalpine fir in the understory. The surface soil texture is sandy loam. This unit was logged in 2004 to remove insect-damaged trees. Track-laying shears and rubber-tired skidders were used to yard logs. The soil prescription included avoiding slopes over 35 percent and subsoiling main skid trails and seeding with mountain brome after harvesting. The photo shows a remanent skid trail from the treatment conducted in 2004 (photo August 2007). Ecomap Section M331A - Yellowstone Highlands, Shoshone National Forest, Rocky Mountain Region.

Figure 5-22—A closeup of the skid trail illustrates weak platy soil structure.

Figure 5-23—Vegetation: Douglas-fir and western ponderosa forest. The surface soil texture is sandy loam. The treatment is a thinning operation conducted in 2006 (2007 photo) using a ground-based harvester and forwarder. Ecomap Province M333B - Flathead Valley, Flathead National Forest, Northern Region.

Figure 5-24—Closeup of forest-floor recovery in skid trail. Sample area is missing forest floor but small woody material and vegetation growth is apparent in surrounding area.

CHAPTER 6

Defining Soil-Disturbance Class 3

The soil-disturbance class 3 is defined by the following characteristics:

Soil surface:

- Wheel tracks and depressions highly evident.
- Forest-floor layers are missing.
- Evidence of surface soil removal, gouging, and piling.
- The majority of surface soil has been displaced. Surface soil may be mixed with subsoil. Subsoil partially or totally exposed.
- High soil burn severity has the duff and litter layer completely consumed. The surface soil color may be reddish or orange in places and the surface soil is water repellent.
- Soil compaction is deep in the soil profile (greater than 12 inches in depth).

Observations of soil physical conditions:

- Change in soil structure from granular structure to massive or platy structure greater than 12 inches in depth.
- Platy structure is continuous and roots do not penetrate the platy structure.

Landings, major skid trails, and temporary access roads often are classified as soil-disturbance class 3 due to equipment type and use. Soils with higher risk ratings due to high water tables, soil texture, slope steepness, or other conditions that increase the risk to the soil from equipment impacts should also be monitored.

Operations that occur during the “shoulder” period of a season or under suboptimal conditions may develop areas of class-3 soil disturbance. Often the sale administrator is the best source of information on areas of potential concern.

Soil-Disturbance Class 3

- Wheel tracks or depressions are evident and moderately deep.
- Forest-floor layers are partially missing.
- Surface soil partially intact and maybe mixed with subsoil.
- Soil burn severity from prescribed fires is moderate (black ash evident and water repellency may be increased compared to preburn condition).
- Soil compaction is moderately deep (up to 12 inches).
- Soil structure is changed from undisturbed conditions and may be platy or massive.

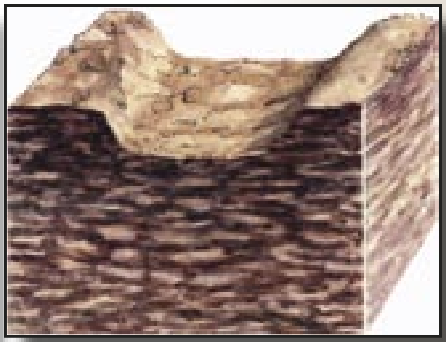

Figure 6-1 Soil-disturbance class 3.

Figures 6-2 through 6-24 provide photographic examples of class-3 soil disturbance from all Forest Service regions.

Figure 6-2—Vegetation: Ponderosa pine. The surface soil texture is sandy loam. The treatment prescription was to remove roadside hazard trees as a part of a fire-salvage sale. Ecomap Section M242C - Eastern Cascades, Deschutes National Forest, Pacific Northwest Region.

Figure 6-3—Closeup of soil structure from within the sample area on the skid trail.

Highlighted areas show extensive rutting due to soils with low load-bearing capacity.

Figure 6-4—Vegetation: Sitka spruce and western hemlock. The surface soil texture is gravelly silt loam. Private timber lands are at high risk to mechanical-equipment impacts due to low load-bearing capacity of the soil. In remote areas aerial reconnaissance may help identify areas of concern. Ecomap Section M245C - Southern Alexander Archipelago, Alaska Region.

Figure 6-5—Extensive rutting can occur without slash mats to protect the soil.

Figure 6-6—Vegetation: Longleaf pine and slash pine with some areas of oak, gum, and cypress cover. The surface soil texture is sandy loam. Due to a high water table and poorly drained soils the soil prescription included installation of several water table monitoring wells and restricting the number of skid trails. This main skid trail was used to remove all the timber thereby concentrating the impacts to an area the forest could later restore. Ecomap Section 232D - Florida Coastal Lowlands, Apalachicola National Forest, Southern Region.

Monitor units to assess:

- Degree of soil impacts.
- Extent of soil impacts.
- Duration of soil impacts.
- Distribution of soil impacts.

Figure 6-7—The platy soil structure is deep and continuous throughout the upper portion of the profile.

Figure 6-8—Closeup of platy soil structure from the main skid trail. Notice that there are few roots within the soil.

Figure 6-9—The soil risk rating for this area would identify the low load-bearing capacity of these soils due to a high water table. Deep ruts were created with a single equipment pass. Ecomap Section 232C - Atlantic Coastal Flatlands, Francis Marion and Sumter National Forest, Southern Region.

Figure 6-10—Vegetation: Southern mixed forest and oak, hickory, and pine forest. Forest cover in this area is mainly longleaf pine and slash pine. The soils have a high water table with low load-bearing capacity. The surface soil texture is sandy loam. The treatment prescription for this active treatment area is a biomass removal of pine and hardwood to reduce fire risk (photo February 2007). Most of the treatment area had class-1 soil disturbance but higher risk areas (high water table) had deep ruts. Ecomap Section 232 C - Atlantic Coastal Flatlands, Francis Marion and Sumter National Forest, Southern Region.

Highlighted areas illustrate rut depth and soil displacement.

Figure 6-11—Vegetation: Mixed conifer. The surface soil texture is sandy loam. This November 2006 photo shows recent thinning (within 2 months of when photo was taken) to improve stand health. Turning equipment often displaces soil and removes forest-floor cover. Ecomap Section M261B - Northern California Coast Ranges, Shasta-Trinity National Forest, Pacific Southwest Region.

Figure 6-12—The photo is a clearcut with extensive skid trails and surface-soil displacement. Ecomap Section M261B - Northern California Coast Ranges, Shasta-Trinity National Forest, Pacific Southwest Region.

Figure 6-13—Vegetation: Jeffrey-pine forest. The surface soil texture is a gravelly sandy loam. The treatment prescription is biomass thinning to reduce the fuel hazard and create a defensible fuel break. The class-3 soil disturbance is in areas adjacent to the landing from heavy vehicle traffic during moist soil conditions, which causes compaction deep in the soil profile. Active timber sale (photo November 2006). Ecomap Section M261G - Modoc Plateau, Lassen National Forest, Pacific Southwest Region.

Figure 6-14—A main skid trail shows deep wheel tracks and depressions. The forest-floor layers are missing and soil compaction is deep.

Figure 6-15—Deep ruts and displaced soil from turning equipment is evident.

Figure 6-16—Vegetation: Western spruce-fir forest. The surface soil texture is loam. This unit is part of an insect-salvage harvest of Engelmann spruce. Deep ruts and surface soil displacement from turning equipment reflect a class-3 soil disturbance. The soil scientist reviewed the area to explore options for yarding the cut trees to reduce and ameliorate effects to soils. Steep slopes add to the challenge of removing insect-salvage trees from the site. Ecomap Section M341C - Utah High Plateaus and Mountains, Dixie National Forest, Intermountain Region.

Soil-distubance class 3 attributes:

- Soil structure is changed from undisturbed conditions to platy or massive.

Figure 6-17—Vegetation: Ponderosa pine, white fir, Douglas-fir, and some areas of pinyon pine and juniper. Rutted segment of skid trail has deep compaction and platy soil structure without roots (photo March 2007). Ecomap Section M313A - White Mountain-San Francisco Peaks-Mogollon Rim, Apache-Sitgreaves National Forest, Southwestern Region.

Figure 6-18—Deeply compacted soils can be difficult to sample.

Subsurface attributes:
- Compaction-deep.
- Platy structure.

Figure 6-19—Compacted soil from main skid trail that may have been used during suboptimal moisture conditions.

Figure 6-20—Vegetation: Sitka spruce and western hemlock. The surface soil texture is gravelly silt loam. On steep slopes, trees are downhill cable yarded to the landing. Proper deflection is necessary to avoid loss of soil cover. Soil prescriptions include partial suspension to minimize bare soil. Ecomap Section M245C - Southern Alexander Archipelago, Tongass National Forest, Alaska Region.

Soil-distubance class 3 attributes:

- Bare soil.
- Ruts.
- Topsoil displacement.
- Compaction-deep.
- Change in soil structure.

Figure 6-21—Vegetation: Lodgepole pine is dominate. The surface soil texture is sandy loam. This large unit was treated to remove insect-killed trees. The main skid trail has no soil cover, increased soil compaction, soil displacement, and some areas of soil rutting. The soil scientist reviewed the area after treatment and included mitigation measures to reduce compaction and the areal extent of skid trails, landings, and temporary roads in subsequent insect-salvage units. The treatment was implemented in 2005 (photo August 2007). Ecomap Section M331H - North-central Highlands and Rocky Mountain, Arapaho-Roosevelt National Forest, Rocky Mountain Region.

Figure 6-22—Closeup of soil compaction within the skid trail.

Figure 6-23—Vegetation: Jack pine. The surface soil texture is sandy loam. After timber harvest in this 40-year-old jack pine unit with heavy mortality from insects, the unit was prepared for planting using a roller chopper that breaks up the remaining slash. Prior to planting, the area is scalped to create openings for reforestation. Areas of bare and gouged soil indicate class-3 soil disturbance. Ecomap Section 212H - Northern Great Lakes, Hiawatha National Forest, Eastern Region.

Figure 6-24—Closeup of soil found within the treatment unit shown in figure 6-23.

CHAPTER 7
Mechanical Equipment Used in Harvest and Post-Harvest Operations and Their Potential Soil Impacts

Felling and yarding trees to a landing is often accomplished with mechanized equipment. It is during these operations that the risk of soil disturbance is greatest. Because of the design, some mechanized felling and yarding equipment is more prone to cause soil disturbance (in terms of extent and degree). However, all equipment can cause unwanted soil disturbance if it is operated improperly or beyond its capability.

Volume of timber removed from a given stand, log size, residual slash, and soil conditions at time of operation, also play important roles in determining the amounts and effects of soil disturbance.

Post-harvest operations, such as mechanical-slash treatment and site preparation, also have the potential to generate varying degrees of soil disturbance. In some instances, these operations can create more soil disturbance than the original felling and yarding operations. Creation of soil disturbance also may be a management objective in some site-preparation operations.

When planning timber-harvest and post-harvest operations, land managers must not only consider the capabilities and limitations of specific equipment, but also the kinds of soils on which operations will occur. On low-risk soils, for example, managers may have a wider range of equipment choices and timing of operations than they do on high-risk soils.

Harvest Equipment

Mechanized timber-harvesting technology has evolved over the years, and new machinery is available that provides cost-effective operations and limits soil disturbance. A prudent manager will select the best equipment for a particular job based on analysis of vegetation, topography, and soil characteristics as well as project objectives and economics. Figures 7-1 through 7-30 show the mechanized timber-harvesting equipment at work.

Common equipment and machinery used for felling include:

- Wheeled feller-buncher.
- Tracked feller-buncher.
- Excavator with harvesting head.
- Harvester.

A wheeled feller-buncher can have a boom-mounted head or—more commonly—a drive-to-tree configuration. Considerations for the soil prescription for the unit include the amount of ground surface covered by the equipment, the soil type and its risk rating within a proposed harvest unit, its inherent risk of damage by equipment, static and dynamic load effects, and slope limitations. Log size and volume to be removed also are important considerations.

Figure 7-1—A rubber-tired feller-buncher harvesting trees.

Tracked Feller-Buncher

A tracked feller-buncher is similar to an excavator with a cutting head attached to the end of the boom, which provides lateral reach capabilities that enable the operator to fell and stack trees in bunches without having to drive to each one. Track-laying equipment generally has a lower static and dynamic load than wheel-based equipment. Depending on equipment size and reach capability, there is less soil disturbance.

Tracked feller-bunchers come in many sizes. Choose the size of the equipment based on volume and size of timber to be removed, soil risk factors, and topographic characteristics.

Figure 7-2—A tracked feller-buncher working at a single location. Once all trees are felled and bunched at this location, the machine will move to the next setting.

Harvester

Harvesters generally are mounted on high-flotation, low-ground-pressure tires. The number of wheels can vary. Harvesters have long booms with an attached cutting and processing head. As each stem is cut, it is delimbed and bucked into desired lengths. Logs are bunched for later retrieval and yarding to a landing by a forwarder.

Figure 7-3—A rubber-tired harvester operating over rocky soils.

Figure 7-4—A harvester equipped with a processing head felling a tree.

Figure 7-5—A processing head is delimbing the tree prior to its being cut into lengths and picked up by a forwarder.

Forwarder

The forwarder is a self-propelled machine that is self-loading and designed to transport trees by carrying them completely off the ground. When combined with a harvester it is known as a cut-to-length system.

Forwarders often can be used to redistribute slash created by harvester operations onto trails to reduce soil impacts.

Figure 7-6—A forwarder loading processed logs into the bunk. Note use of the slash mat that was created to reduce soil disturbance.

Three-Wheeled Feller-Buncher

A three-wheeled feller-buncher commonly is used throughout the country. It is fast and maneuverable and can operate easily in densely stocked stands, but it has limitations on tree diameter. The machine must travel to each tree, and it can impact a large portion of a harvest unit. Soil concerns are related to the extent of ground surface impacted and forest-floor removal.

After a tree is felled, the whole tree is yarded into the landing area by a skidder. Limbs are removed at the landing where additional processing may occur. Soil-nutrient cycling must be considered when developing project design features.

Figure 7-7—Front view of a three-wheeled feller-buncher.

Figure 7-8—Fast and maneuverable, the three-wheeled feller-buncher can fell small-diameter trees quickly.

Figure 7-9—Often a larger feller-buncher will work with the smaller, three-wheeled feller-buncher to fell the large-diameter trees in a treatment unit.

Skidders

Skidders transport the cut trees to the landing area. There are several types of skidders, including:

- Grapple-skidder. This machine is used extensively to assemble and hold a load. It uses a hydraulic grapple or “pincher” to hold a turn of logs. One advantage of the grapple-skidder is that one end of a turn of logs can be lifted free of the ground in order to avoid gouging and displacing surface soil.
- Cable-skidder. This machine uses a main winch-cable and choker-set to assemble and hold a load. A cable-skidder is more versatile than a grapple-skidder, and the operator can “pull rope” to reach logs that cannot be driven to or that have unfavorable soil considerations.
- Tracked-skidder/bulldozer. This machine is mounted on tracks rather than on rubber tires. Most of these machines use a cable winch, and some have fair-leads to partially lift one end of the logs free of the ground.

Grapple-skidders vary in size. Notice the size difference between these two grapple-skidders.

Figure 7-10—A small grapple-skidder can maneuver easily in tight areas.

Figure 7-11—This large grapple-skidder can bring a large load of trees into a landing area. Identify compaction or rutting concerns in areas with high risk-rated soils.

Figure 7-12—A grapple-skidder with chains used for winter logging operations.

Skidding Sequence

Trees are bundled by the feller-buncher and they are often stacked one behind another, similar to cars of a train.

Figure 7-13—Bundles of trees are ready to be moved into the landing area for sorting and processing.

Figure 7-14—The grapple-skidder moves into position and grabs an entire bundle of trees.

Figure 7-15—The bundle of trees is pulled into the landing area for further processing.

Figure 7-16—Logs are delimbed, cut, and sorted prior to being trucked to the sawmill or cogeneration power plant. The landing size is an important consideration from both a safety and a soil-impact perspective.

Figure 7-17—At the landing site some of the logs and residues may be processed further. A chipper is often brought into the landing once all the saw-logs are removed. Small-diameter logs may be chipped. Limbs and branches may be redistributed on skid trails or placed in a pile for burning.

Figure 7-18—Chip-van access into a unit was accomplished by removing the saw logs and then chipping the smaller logs. Once this process is completed, the landing access can be closed and the area subsoiled to improve infiltration.

Cable Yarding

Cable-yarding systems generally are used in areas with steep topography (slopes over 35 percent), or where other significant resource concerns may exist. Most cable systems used today are designed to either partially or totally suspend logs above the ground. Logs are attached to the cable using “chokers.”

There are many cable-logging systems (yarders, towers, carriages) in use today. Each system is designed to operate within certain topographic conditions and log-size parameters. These systems are not discussed in this guide.

While cable systems create little soil disturbance (approximately 3 to 5 percent) within timber-harvest units, they do have the potential to create significant amounts of soil disturbance just below the landings. Often, such disturbance can concentrate water draining from the landing, which can cause unacceptable amounts of surface soil erosion and also trigger mass movement. In blind-lead situations, cable logging can generate large amounts of soil displacement where turns of logs (the number of logs hauled in one trip) create long, linear gouges. Depending on the particular system used, cable operations may require more roads and larger landings than some ground-based systems.

Cable Yarding (cont)

Figure 7-19—A cable-yarding operation is set up on a spur road harvesting trees on this steep slope.

Figure 7-20—Logs are brought up to the landing area with the small swing-yarder and then sorted and loaded onto log trucks.

Shovel Yarding

Shovel yarding uses an excavator body with a grapple-head attachment. This equipment generally is used on more gentle slopes. Often the shovel-yarder will lay down a slash mat to walk on as it yards the cut trees towards the landing.

Figure 7-21—Working on the sideslope, the shovel-yarder is moving the logs towards the landing.

Figure 7-22—Shovel-yarding the felled trees towards the landing in Alaska.

Post-Harvest Mechanical-Treatment Equipment

The next step, after an area is harvested, is to ensure that the treatment objectives are met. Many forest-health and fuel-reduction prescriptions require follow-up treatments to reduce ladder fuel. Options available to eliminate ladder fuels depend on resource objectives not limited to soil and fuel prescriptions, air-quality constraints, slope, and cost. The fuel type and amount also factor into the eventual treatment design. Mechanical equipment (mowers and masticators) eliminate the fuel ladder and leave the residue onsite. Other treatments that remove the fuel from the treatment area include jackpot piling and burning of fuels, or broadcast burning.

One of the most common treatments has been the machine piling of slash using rubber-tired or tracked vehicles. These vehicles are often the same vehicles used in skidding operations. The slash piles are subsequently burned. If not done carefully, this operation has a high potential for creating undesirable amounts of soil disturbance, especially topsoil displacement. Pile burning can cause localized areas where the soil's physical and chemical properties have been irreversibly altered. Machine slash piling can be done successfully if equipment is outfitted with brush rakes and operators use extreme care not to incorporate the mineral soil into the piles.

Masticators and mowers commonly are used to reduce the size and vertical distribution of fuels. While the masticator and mower heads do not actually impact the ground, the excavator must travel to areas of fuel concentrations. This can create varying amounts of soil disturbance depending on how fuels are distributed within a treatment unit. The forest floor and topsoil easily can be displaced, especially where equipment makes turns. Hydro-ax and Tomahawk are examples of this equipment.

Figure 7-23—An excavator with a masticator attachment is shredding live vegetation.

Figure 7-24—The masticator-head grinds or flails woody vegetation into chips that provide soil cover.

Skidder-Mounted Roller-Chopper

The roller-chopper is a large drum pulled behind a skidder. The drum can be filled with water to add more weight, which helps to chop the woody material left onsite. The drum has several cutting blades that “chop” live vegetation and downed woody material. The residue is placed in contact with the ground surface, which helps facilitate decomposition and reduce the fire hazard. Most soil disturbance is generated by the vehicle towing the drum, although some severe compaction may occur directly under the cutting blades. The roller-chopper is used as a site-preparation technique in the Southern and Eastern Regions.

Figure 7-25—The front end of the skidder with a brush-rake attachment.

Figure 7-26—A roller-chopper drum with blades designed to "chop" downed material.

Figure 7-27—A roller-chopper is breaking up forest residues on the Hiawatha National Forest after a salvage harvest.

Figure 7-28—Chains have been attached to create openings and expose bare soil.

Soil Restoration Equipment

Many types of equipment have been developed and used over the years to restore soil disturbed by timber-harvest and post-harvest operations. While well intended, soil-restoration efforts can often produce unwanted soil disturbance if they are not designed to achieve specific objectives.

Early efforts consisted of brush rakes attached to blades on either rubber-tired or tracked vehicles. Rock rippers also were used frequently to ameliorate effects of soil compaction. Neither piece of equipment produced the desired results and often created soil conditions worse than the ones being restored (furrows, dragging large stones and boulders to the surface, additional compaction, etc.).

In the 1980s and 1990s, soil cultivators, winged-subsoilers, and self-drafting winged-subsoilers were developed to improve results of soil-restoration projects. Soil cultivators were designed to be towed by small tracked vehicles. They could be lifted from the soil when stumps and boulders were encountered and, because of their small size, could be maneuvered into areas that could not be reached by larger pieces of equipment. Soil cultivators also resulted in less damage to residual trees.

Winged-subsoilers were an improvement over soil cultivators. They were designed to lift and shatter compacted soils without “plowing” them or dragging large rocks and boulders to the surface. They attach to the toolbar behind medium-to-large tracked vehicles. On self-drafting subsoilers, each shank is attached to an individual hydraulic mount that independently lifts the wing when obstructions, such as roots, stumps, and rocks, are encountered. The wings seek their maximum depth without additional weight. Again, this equipment produces desired results only when used properly under the correct soil conditions.

Figure 7-29—A modified excavator head to decompact landings and skid trails.

Figure 7-30—Subsoiling skid trail with a ripper shank on an excavator.

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Appendix

National Soil Disturbance Monitoring Form

Project ID: 0 | Unit ID: 0 | Observer: 0 | **GPS** (Starting Point) | Latitude: | Longitude: | Datum: | UTM East | UTM North | UTM Zone

Date: | Monitoring Type: 0 | Point Spacing (m): | Confidence level? Enter 70, 75, 80, 85, 90, 95 | 70 | Minimum Required Sample Size | #DIV/0! | Interval Width (enter 10 or 20) | 10

Direction:

Sample point	1	2	**3**	4	5	**6**	7	8	**9**	10	11	**12**	13	14	**15**	16	17	**18**	19	20	**21**	22	23	**24**	25	26	**27**	28	29	**30**	31	32	**33**	34	35	**36**	37	38	**39**	40	41	**42**	43	44	**45**	46	47	**48**	49	50	**51**	52	53	54	**55**	56	57	**58**	59
f. floor depth (cm):																																																											
Forest floor Impacted?																																																											
Live Plant?																																																											
Invasive Plant?																																																											
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Coarse Woody? >7cm																																																											
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San Dimas Technology and Development Center (SDTDC) national publications are available on the Internet at: http://www.fs.fed.us/eng/pubs/

Forest Service and U.S. Department of the Interior, Bureau of Land Management employees also can view videos, CDs, and SDTDC individual project pages on their internal computer network at: http://fsweb.sdtdc.wo.fs.fed.us/

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