Soil Resources

Key Points

- All alternatives and the Proposed RMP would increase the acreage of detrimental soil disturbance from timber harvest, road construction, and fuels treatments by 13–29 percent of current amounts during the first decade.
- The BLM would be able to reduce the acreage of detrimental soil disturbance from timber harvest, road construction, and fuels treatments through management practices that would limit initial compaction levels, remove existing or created compacted surfaces, and improve soil water and organic matter levels.
- Detrimental soil disturbance from public motorized travel activities would be highest under the No Action alternative because the action alternatives and the Proposed RMP would not designate any areas as *open* for public motorized access.

Summary of Notable Changes from the Draft RMP/EIS

- The analysis includes corrections to data for Alternative A under Issue 1. Additional acres of detrimental soil disturbance were not totaled correctly in the Draft RMP/EIS analysis.
- The analysis also includes updated data for Issue 2. The BLM revised road mileage calculations for all alternatives and the Proposed RMP based on reduced road miles when thinning forest stands.

Summary of Analytical Methods

Soil quality is the innate capacity of any soil to function within natural or managed ecosystem boundaries, to sustain plant and animal productivity, to maintain or enhance water and air quality, and to support ecosystem health. Land management practices most often reduce soil quality through declines in two ecosystem properties: site organic matter and soil porosity (Powers *et al.* 1990).

In this analysis, the BLM evaluated reductions in soil quality based on acres of detrimental soil disturbance. Detrimental soil disturbance is created when the innate soil properties change and the inherent capacity to sustain growth of vegetation is reduced (Powers *et al.* 1998). Detrimental soil disturbance generally represents unacceptable erosion levels, organic matter loss, soil compaction, soil displacement, severe heating to seeds or microbes, or a combination of these due to the implementation of management actions. The BLM evaluated the acres of detrimental soil disturbance created as a result of several sources of management-directed changes (e.g., ground-based and cable yarding, heating of soil during burning, and compaction during fuel reduction operations) and the cumulative total of all sources as a decrease in the innate ability of a soil to function and provide ecosystem services.

Evaluating soil quality is complicated by the diversity of soil properties that drive the functional processes, appraisal techniques, and soil uses (Page-Dumroese *et al.* 2000). This analysis evaluated a departure from soil quality using acres of detrimental soil disturbance rather than other measures such as changes to soil quality index or site index as discussed below.

Amacher *et al.* (2007) introduced the Forest Inventory and Analysis program that measured a number of chemical and physical properties of soils in order to address specific questions about forest soil quality or health. This soil quality index integrated 19 measured physical and chemical properties of forest soils into a single number that could serve as the soil's vital sign of overall soil quality. This effort monitors changes in forest soil properties with time, but this index requires specific data that is not available at this scale of analysis across the decision area.

Site index class characterizes soil productivity by tree height growth over a set time. Across the decision area, there is a distinct differentiation between the high productivity soils in the north (predominately Site Classes 2 and 3) and the lower productivity soils in the south (predominately Site Classes 4 and 5). However, this traditional measure of soil productivity does not encompass the full spectrum of the functions that define soil quality as the measurement requires a more holistic method that defines growth as it relates to functional processes in the soil.

For several aspects of this analysis, the BLM categorized the decision area into the coastal/north (the Salem, Coos Bay, and Eugene Districts, and the northern portion of the Roseburg District) and the interior/south (southern portion of the Roseburg District, the Medford District, and the Klamath Falls Field Office). This division represents a general divide in geology, soil conditions, and forest productivity within the planning area.

Issue 1

How would timber harvest under the alternatives affect soil quality?

Summary of Analytical Methods

Timber harvest causes detrimental soil disturbance most often from displacement of surface material and soil compaction during yarding activities. The extent of detrimental soil disturbance varies with the type of yarding method and the mitigation measures employed.

The intensity, location, and extent of compaction differ under a variety of yarding systems. In this analysis, the BLM assumed that determining the proper design measures to reduce or eliminate adverse effects could not be applied at this level of analysis but can be determined at the project scale as specific site conditions would be known. Therefore, the different yarding methods in this analysis assumed to create detrimental soil disturbance were applied under the alternatives and the Proposed RMP according to the following surface area percentage within each harvest unit:

- Ground-based – 35 percent
- Cable – 12 percent
- Aerial – 6 percent
  (Heilman *et al.* 1981, Fleming *et al.* 2006, Froehlich 1976, Han *et al.* 2009, Miller *et al.* 1989)

Ground-based cutting and yarding systems have the greatest detrimental effects to soil. Ground-based equipment includes previous models of rubber-tired skidders and tracked dozer equipment in addition to the current type of cut-to-length harvesters, feller bunchers, multi-wheeled forwarders, and excavators or de-limbers. When soil moisture contents result in maximum compaction effects, cut-to-length and whole-tree harvesting methods could cause a greater degree of soil compaction by needing an increased amount of designated skid trails across a harvest unit. Cut-to-length systems can cause less compaction in the center of the skid trail than whole tree harvesting especially when operators minimize compaction by placing heavy slash loads on skid trails before traversing a harvest unit. Whole-tree harvesting disturbs a larger area, sweeps slash from trails, and causes a high degree of compaction in the center of the track (Han *et al.* 2009). The extent of the equipment's coverage across a harvest unit can vary from several well-spaced designated skid trails to, coverage over a moderate amount of a harvest unit with unlimited skid trails. Typically, compaction on steeper slopes does not occur where slope conditions exceed ground-based machine capabilities because this equipment cannot operate on steeper slopes. In contrast, on accessible slopes, repetitive tracking across the same skid trail causes the extent of compaction to go deeper into the soil until equilibrium between site conditions and loads exists. More mechanized ground-based yarding equipment in use today is capable of traversing more of each harvest unit, both in area and on steeper slopes. These changes have resulted in equipment operating on terrain in new ways with heavy and large mechanical systems, and operating in harvest units where previous equipment had been unable to travel.

Cable yarding systems typically cause compaction at the landing area as well as within a harvest unit under cable corridors. Compacted areas stretch out like spokes from the landing or a road but are only as wide as the area of the sweeping tail end of a yarded log. Since there are many logs pulled to the landing along one yarding corridor, they create a compacted trail that ranges from 3 to 8 feet wide.

For aerial yarding, most compaction is within the work areas adjacent to a harvest unit. These areas generally undergo rehabilitation after harvest or are incorporated into the road system. Compaction from yarding activities inside such harvest units is typically negligible.

The BLM used available GIS data from the BLM Timber Sale Information System to determine the type of yarding system employed during timber harvest; this information provided an estimate of the levels of detrimental soil disturbance based on the assumed percentages listed above. The BLM used the final harvested acres from timber sale contracts from 1990 to 2012[118] to characterize current levels of detrimental soil disturbance. Using these 22 years of timber harvest data provides a partial indication of the current amount of detrimental soil disturbance. Past management of timber stands also have evidence of compacted trails within them. Depending on the soil type, root interactions, water and temperature conditions, and wildlife effects (e.g., burrowing and tunneling), the length of time soils remain compacted would be decades (Froehlich and McNabb 1984). However, the BLM does not have sufficient information to quantify detrimental soil disturbance from these older timber harvests at this scale of analysis. That level of detail should occur at the project level analysis.

The Woodstock model provided outputs on acres of each silvicultural system by alternative and the Proposed RMP for the first decade (see also **Appendix C** for more information). Districts provided estimates for projecting yarding methods based on past practices and projecting silvicultural systems under the alternatives and the Proposed RMP to estimate expected use of ground-based, cable, or aerial methods. The BLM only quantified the first decade of expected harvest for this analysis because yarding methods and equipment are subject to change and application of assumptions beyond the first decade would be speculative.

In this analysis, the BLM calculated the amount of detrimental soil disturbance generated from each timber harvest method by multiplying the areal extent (acres) of that yarding method by the percentages listed above.

Background

Soil compaction occurs when soil particles are pressed together reducing the pore space between them and increasing the weight of solids per unit volume of soil (bulk density). Soil compaction occurs in response to pressure from above (e.g., from animals or equipment). Heavy equipment operates directly on forest soils with a high potential to affect soil quality negatively, especially soil bulk density, which would affect plant and tree growth (Labelle and Jaeger 2011). Soil compaction during harvesting generally occurs in the first few passes of the equipment, but compaction reaches a maximum within the

[118] 2012 represents the most current year for which completed timber sale activity was available for analysis across the decision area.

first ten passes (Han *et al.* 2006). Bustos and Egan (2011) noted that compaction is a function of mass, number of passes, and total mass transported per pass. Using existing skid trails and having a designated skid trail system are effective methods for reducing impacts to soils with high initial bulk densities as this can result in less change to soil structure (i.e., compaction) than soils with a low initial bulk density (Han *et al.* 2009). The risk for compaction is greatest when soils are wet (USDA NRCS 1996). Compaction is usually described as an increase in bulk density and results in plants having to increase their root strength in order to penetrate the soil for growth.

Studies show that an increase of bulk density greater than 15 percent can have varied impacts to plant growth depending on soil texture, plant species, and competing vegetation (Tan *et al.* 2009). Powers *et al.* (2005) found that soil compaction effects depended upon initial bulk density and type; vegetation growth declined on compacted clay soils but increased on sands. Page-Dumroese *et al*. (2006) determined that overall, initial soil bulk density determined the degree of severe compaction. As initial bulk density increased, the level of change decreased. Fine-textured soils often had the lowest initial bulk density but the largest increase after treatment with a majority of compaction occurring after a single pass by the equipment. Long-term soil productivity studies in North America measured similar patterns of a larger percent increase in bulk density on fine-textured soils (Williamson and Neilsen 2000). Landsberg *et al*. (2003) measured resistance to penetration in 4 steep units with residual skid trails from salvage logging about 70 years earlier and the skid trails averaged more than elsewhere in the units. Page-Dumroese *et al.* (2006) noted some bulk density recovery after 5 years on coarse-textured soils in the surface soil (0–10 cm), but recovery was less in the subsoil (10–30 cm depth). Fine-textured soils such as silts and clays exhibited little recovery.

In general, soil compaction that reduces water infiltration rates and large pore space for gas and water movement constitutes detrimental soil disturbance and can last decades (Froehlich and McNabb 1984, Cafferata 1992, Page-Dumroese *et al*. 2007). Compaction restricts rooting depth, which reduces the uptake of water and nutrients by vegetation. Compaction decreases the soil pore size that can absorb water and decreases soil temperature. Soil organisms respond to compaction by decreasing their soil organic matter decomposition, which then decreases their release of nutrients back into the soil. Smaller pore spaces decrease the infiltration of both water and air into soil, which can lead to runoff with a corresponding increase of water erosion risk or hazard. The degree of soil compaction depends on the type of equipment used, number of equipment passes over the same location, and site conditions such as soil texture, water content, and temperature (Tan *et al.* 2009). Powers *et al.* (1990) hypothesized that the two most important site disturbances that reduce forest productivity are soil compaction and organic matter removal. Richardson and Wulfsohn (2004) found the most important characteristics related to the fertility of a site are the organic matter in the forest floor as well as the upper mineral layer and soil porous structure.

Soil compaction reduces tree growth, but the relationship between compaction and tree growth is complex and difficult to predict because it is dependent on many variables. For example, Miller *et al.* (1996) found a reduction in the early growth of seedlings planted on compacted skid trails compared to uncompacted locations; however, growth of most seedlings on compacted locations caught up to uncompacted locations after eight years. Tan *et al.* (2009) also found variable responses of three-year-old seedlings, depending on level of compaction, species, organic matter removal, and intensity of amelioration of compacted surfaces. Decreasing competition for site resources (e.g., water and nutrients) would offset severe compaction, and tree growth may not be affected (Sanchez *et al.* 2006).

As cited in Richardson and Wulfsohn (2004), organic matter serves an important role in site fertility. Organic matter includes needle cast and leaf litter, limbs and boles of trees, and underground roots. Soil fertility from organic materials is another element that contributes to overall soil productivity. Leaving the finer materials, such as the needles or twigs, has been determined to contribute to soil productivity when removing the bole portion for processing (Farve and Napper 2009). Whole tree removal has been demonstrated to have impacts to soil productivity where nutrients are limited. However, implementation of forest management actions, including timber removal, fuel reduction, and biomass removal, have been found to protect soil productivity through reserving residual amounts of fine and down woody material (Farve and Napper 2009). Leaving a residual amount of cut material or redistributing fine materials or limbs without burning allows the decomposition processes an opportunity to work on those materials and return nutrients to the soil. This action allows a variety of soil microbes to exist and process materials as well as to increase water retention and provide resilience to the ecological system.

A vast array of microbiotic organisms with potential to be affected by detrimental soil disturbance exists in the soil. Most of these organisms are the decomposers of organic matter, which return nutrients to the soil for use by plant roots or other organisms. However, little research exists on the effects of detrimental soil disturbance on microbiotic organisms other than the fungi and bacteria components. Most research on soil compaction in forests has focused on tree growth in skid trails or on tree growth response after amelioration treatment. Only recently did Shestak and Busse (2005) compare microbial composition, community size, activity, and diversity on compacted forest soils. They noted their results show tolerance or resilience by microbial communities. These authors suggest the reconfiguration of pores following compaction resulted in reduced total porosity and a near elimination of large pores, but an increase in habitable pore volume use by bacteria and fungi. Therefore, with the exception of poorly drained soils or for those regions receiving high annual precipitation where saturation is a concern, changes with compaction appear to be of little consequence to the microbial community. Previous studies have identified a variety of negative, neutral, and positive responses, yet there are few unifying concepts (Busse *et al.* 2006).

Affected Environment and Environmental Consequences

Current levels of detrimental soil disturbance from past timber harvests include 29,564 acres in the decision area: 12,688 acres are in the coastal/north and 16,876 acres are in the interior/south (**Figure 3-139**). The 29,564 acres of detrimental soil disturbance from past timber harvests constitute approximately 1 percent of the decision area.

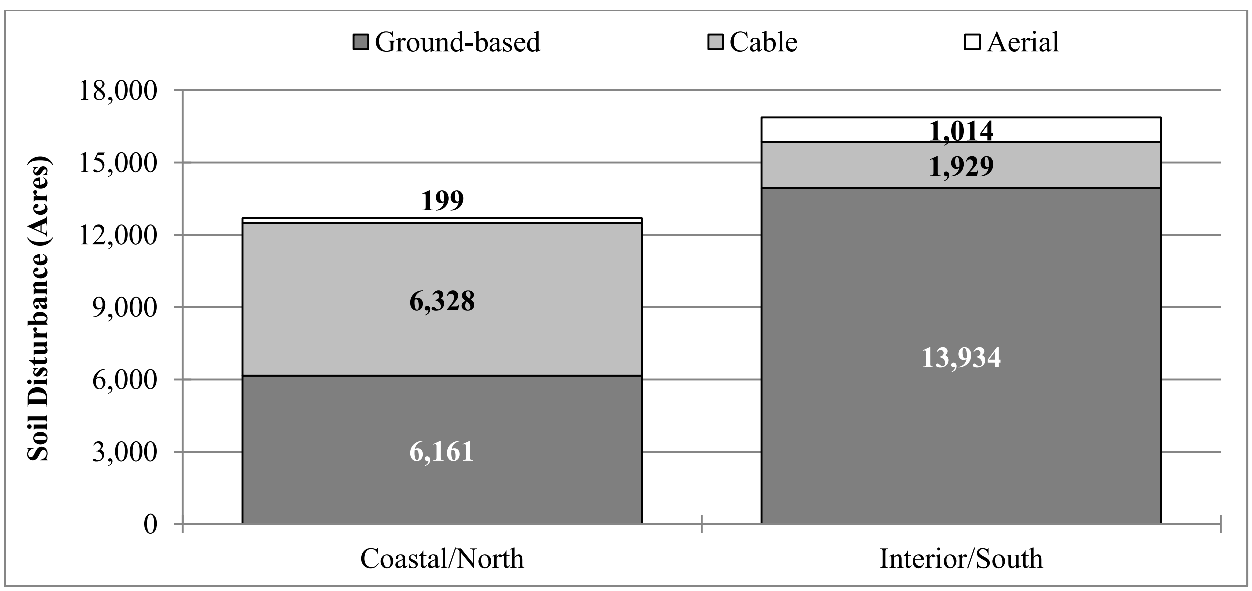

Figure 3-139. Detrimental soil disturbance from timber harvest by yarding system, 1990–2012

This acreage of detrimental soil disturbance constitutes 20 percent of the harvested acres in the decision area: 17 percent in the coastal/north and 23 percent in the interior/south. The interior/south has a higher percentage of detrimental soil disturbance on harvested acres because of the extensive use of ground-based yarding systems, which results in detrimental soil disturbance over a larger surface area within each harvest unit.

In the first ten years, the alternatives and the Proposed RMP would result in approximately 12,380–27,000 acres of detrimental soil disturbance from timber harvesting (**Figure 3-140** and **Table 3-207**). Alternative C would result in the most acreage of detrimental soil disturbance (27,000 acres) followed by Alternative B (25,217 acres), the No Action alternative (24,172 acres), the Proposed RMP (23,505 acres), and Alternative D (21,742 acres). In contrast, Alternative A would result in substantially smaller acreage of detrimental soil disturbance compared to the other alternatives and the Proposed RMP (12,380 acres) (**Table 3-207**). The amount of detrimental soil disturbance largely reflects the total acreage of timber harvested and the associated yarding system.

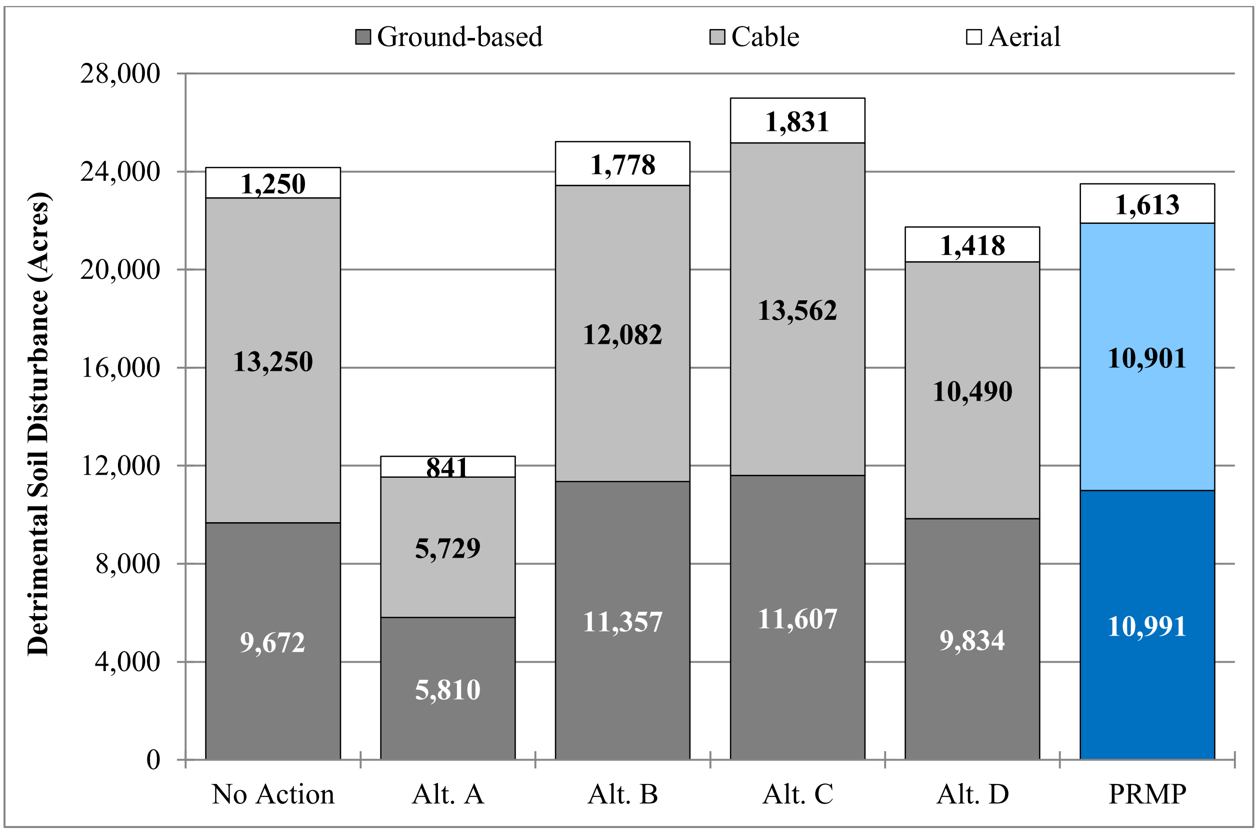

Figure 3-140. Detrimental soil disturbance from timber harvest by yarding system during the first decade

Table 3-207. Detrimental soil disturbance from timber harvest and by harvest method during the first decade for the coastal/north and interior/south

Detrimental Soil Disturbance	No Action		Alt. A		Alt. B		Alt. C		Alt. D		PRMP	
	Coastal/ North (Acres)	Interior/ South (Acres)	Coastal/ North (Acres)	Interior/ South (Acres)	Coastal/ North (Acres)	Interior/ South (Acres)	Coastal/ North (Acres)	Interior/ South (Acres)	Coastal/ North (Acres)	Interior/ South (Acres)	Coastal/ North (Acres)	Interior/ South (Acres)
Ground-based	5,496	4,176	2,364	3,446	4,847	6,510	5,633	5,975	4,411	5,423	4,560	6,431
Cable	9,320	3,930	3,421	2,308	7,368	4,715	8,812	4,750	6,760	3,730	6,360	4,541
Aerial	777	473	361	479	676	1,102	873	958	580	839	595	1,018
Sub Totals	15,594	8,578	6,147	6,233	12,890	12,327	15,318	11,682	11,750	9,992	11,515	11,990
Alternative/ Proposed RMP Totals	24,172		12,380		25,217		27,000		21,742		23,505	
Current Condition*	29,564		29,564		29,564		29,564		29,564		29,564	
Totals†	**53,736**		**41,944**		**54,781**		**56,564**		**51,306**		**53,069**	
Percentage of Current Condition	80%		42%		85%		91%		74%		80%	

* This acreage is derived from **Figure 3-139** that only described detrimental soil disturbance from the years 1990–2012.

† This number does not account for detrimental soil disturbance that is ameliorated over time.

The detrimental soil disturbance from timber harvest modeled during the first decade under the alternatives and the Proposed RMP would result in new disturbance levels ranging from 42–91 percent of the current levels of detrimental soil disturbance from past timber harvests (**Table 3-207**). As a result, the alternatives and the Proposed RMP, together with past timber harvest, would result in a cumulative total of detrimental soil disturbance ranging from 41,944 acres to 56,564 acres, which would account for about 2 percent of the decision area. Each alternative and the Proposed RMP would result in detrimental soil disturbance averaging 15–16 percent of the total area as harvested by the three different systems in the first 10 years. These acres of detrimental soil disturbance do not account for disturbance that has been or would be ameliorated over time.

The BLM would be able to ameliorate detrimental soil disturbance by reducing soil compaction after harvest in ground-based units, and the landing areas for other systems. However, the extent and effectiveness of such amelioration depends heavily on site-specific and project-specific factors. For example, past implementation of sub-soiling and placement of woody debris and organic matter in conjunction with planting or seeding of native soil surfaces has produced ecosystems that resemble the unaltered soil conditions; simple closure to traffic of a rocked surface does not. Because of the variability driven by site-specific conditions and amelioration systems employed, the BLM cannot quantify those reductions in detrimental soil disturbance in this analysis.

Detrimental soil disturbance could result in some reduction of future tree growth. The BLM incorporated an assumption of 10 percent growth loss in the vegetation modeling of future stand growth over the length of the next rotation in stands with 20 percent detrimental soil disturbance levels. Management direction limits the increase of detrimental soil disturbance to 20 percent of any given treatment unit and includes all types of disturbances, including those resulting from treatments as well as new road and landing areas. All alternatives and the Proposed RMP, as analyzed, would increase the current level of detrimental soil disturbance by various percentages. Thus for some alternatives including the Proposed RMP, some mitigation of these impacts through the application of best management practices would be required. Currently, detrimental soil disturbance covers approximately six percent of the decision area. Raising that level by 20 percent would increase the detrimental soil disturbance to approximately seven percent of the decision area. Even then, there is only an expected reduction of growth from those areas in the future of 10 percent. Therefore, the sustainability of all lands under the decision area remains at approximately 99 percent of their current potential. However, at this scale of analysis and with the data available, it is not possible to quantify specifically the reduction in future tree growth from detrimental soil disturbance because the influence of site-specific and project-specific factors on the extent and intensity of detrimental soil disturbance is unknown.

Issue 2

How would road construction under the alternatives affect soil quality?

Summary of Analytical Methods

In this analysis, the BLM assumed that both permanent and temporary road construction would result in detrimental soil disturbance. It is not possible to forecast in this analysis if a given road segment would be decommissioned and mitigate detrimental soil disturbance, or how long after decommissioning detrimental soil disturbance would continue. Therefore, this analysis assumed that all new road construction would result in detrimental soil disturbance even though eventual decommissioning might mitigate these soil effects for some roads.

The BLM assumed that road construction would result on average in detrimental soil disturbance across a 45-foot width from upper cutbank to the lower toe of fill. However, the BLM is typically able to construct forest roads to narrower widths, and the 45-foot width average represents an overstatement of these narrower road footprints. Because of modeling parameters, road construction modeled in Woodstock applied the 45-foot width assumption for all roads (Brian Thauland and Carolina Hooper, BLM, personal communication, July 2013).

The BLM described the calculation of the mileage of road construction under each alternative and the Proposed RMP in the Trails and Travel Management section in this chapter.

The BLM calculated the acreage of detrimental soil disturbance from road construction by multiplying the length of roads in feet by the 45-foot road width and converting the net square feet into acres.

The Planning Criteria identified that this analysis would also address landings (USDI BLM 2014, p. 156). However, most of the landing area would be included in the road construction assumptions and is therefore not included here as a separate analysis.

Background

Road construction—by its very nature—removes the organic layer, cuts deep into the soil horizon, and produces a compacted surface. This results in detrimental soil disturbance, which decommissioning can potentially ameliorate. However, the effectiveness of decommissioning in reducing detrimental soil disturbance is not clear. Tan *et al.* (2009) note better growth on compacted sites with coarse sandy soils. Most of the decision area does not have coarse sandy soil types with the exception of some areas in the Medford District.

As noted by Powers *et al.* (1990), soil compaction and organic matter removal are the two most important site disturbances caused by forest management practices. These have the largest potential to reduce forest productivity. Replenishing the organic matter and reducing the amount of compaction both within the depth of a road surface and across the surface are key factors to providing quality soils for future tree growth. Lloyd *et al.* (2013) describes the effectiveness of different road decommissioning techniques for rehabilitation of ecological and hydrological systems in densely roaded forest ecosystems. Their overarching hypothesis is that restoration designs that fail to address explicitly both aboveground and belowground ecosystem structure and function would result in recovery to an alternative state that has diminished ecological and hydrological functions relative to a forest where a road was never built.

Affected Environment and Environmental Consequences

There are currently 14,416 miles of roads in the decision area. This constitutes a detrimental soil disturbance on 79,311 acres which is approximately 3 percent of the decision area.

Over the first decade, Alternative C would have the largest acreage of detrimental soil disturbance from road construction (3,822 acres) while Alternative D would have the least (1,319 acres; **Figure 3-141)**.

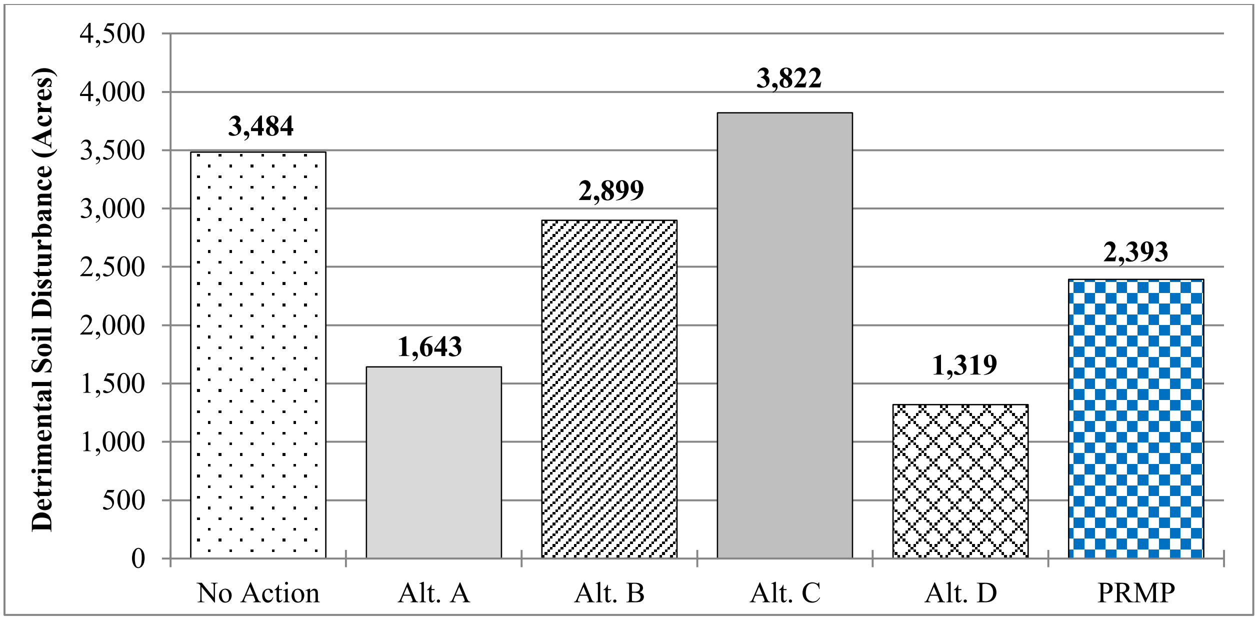

Figure 3-141. Detrimental soil disturbance from road construction during the first decade

The detrimental soil disturbance from road construction during the first decade under the alternatives and the Proposed RMP would constitute approximately 2–5 percent of the current detrimental soil disturbance from past road construction (**Table 3-208**). As a result, the alternatives and the Proposed RMP, together with past road construction, would result in a cumulative total of detrimental soil disturbance ranging from 80,630 to 83,133 acres.

Table 3-208. Acres of cumulative detrimental soil disturbance from road construction during the first decade

Detrimental Soil Disturbance From Road Construction	No Action (Acres)	Alt. A (Acres)	Alt. B (Acres)	Alt. C (Acres)	Alt. D (Acres)	PRMP (Acres)
Current Condition	79,311	79,311	79,311	79,311	79,311	79,311
First Decade Construction	3,484	1,643	2,899	3,822	1,319	2,393
Totals	**82,795**	**80,954**	**82,210**	**83,133**	**80,630**	**81,704**
Construction Percentage of Current Condition	4.4%	2.1%	3.7%	4.8%	1.7%	3.0%

Under all alternatives and the Proposed RMP, given the analytical assumptions, approximately 51–61 percent of the new road construction would be permanent roads and 39–49 percent would be temporary roads (**Table 3-209**). Temporary roads include both native-surfaced and rock-surfaced roads. The BLM could potentially decommission these temporary roads to ameliorate detrimental soil disturbance. Lloyd *et al.* (2013) describes the effectiveness of different road decommissioning techniques, include removing rock, loosening the compacted sub-grade, replenishing some of the organic matter, and implementing erosion-control measures. By following those techniques found to be most successful, the BLM could potentially decommission temporary roads to ameliorate detrimental soil disturbance. In past project implementation, removing rock, loosening the compacted sub-grade, replenishing some of the organic matter, and implementing erosion-control measures have successfully established trees and protected the soil environment. On permanent roads, where roads are established using a hardened surface of gravel or pavement, the potential for decommissioning is lower, as the cost of decommissioning can be equal to or greater than the cost of construction. Under BLM terminology, permanent roads can be considered decommissioned when supporting infrastructure (e.g., remove culverts or cross-drains) is removed to close these roads from continued use. However, this level of decommissioning would retain the hard surface and compacted subsoil. As such, this level of decommissioning is not included in this soils analysis, as the roads would not be fully decommissioned to restore the soil environment. For the purposes of soil analysis in all alternatives and the Proposed RMP, the BLM only considers decommissioning of temporary roads to result in amelioration of detrimental soil disturbance to levels that successfully establish trees and protected the soil environment.

Table 3-209. Acres of detrimental soil disturbance from road construction by road type during the first decade

Detrimental Soil Disturbance by Road Construction Type	No Action (Acres)	Alt. A (Acres)	Alt. B (Acres)	Alt. C (Acres)	Alt. D (Acres)	PRMP (Acres)
Permanent Roads	1,763	990	1,586	2,233	799	1,275
Temporary Roads	1,721	653	1,313	1,589	520	1,118
Totals	**3,484**	**1,643**	**2,899**	**3,822**	**1,319**	**2,393**
Percentage of Permanent Roads	51%	60%	55%	58%	61%	53%
Percentage of Temporary Roads	49%	40%	45%	42%	39%	47%

Given the vast size of the planning area and the complexity of road construction, not all temporary roads would undergo decommissioning adequate to ameliorate detrimental soil disturbance. However, temporary roads disturb less of the subsoil and have lower traffic volumes and so would be the most likely to be decommissioned. Under all alternatives and the Proposed RMP, decommissioning of temporary roads would provide some reduction in the acres of detrimental soil disturbance, but it is not possible at this scale of analysis with the data available to quantify this potential reduction in this analysis.

Even if all newly constructed roads were permanent, the increased acreage of detrimental soil disturbance from new road construction in the first decade would range from 1.7–4.8 percent of the current total (**Table 3-208**). This would be an increase from the current condition of 3.2 percent of the decision area with detrimental soil disturbance from road construction, to 3.25–3.35 percent of the decision area after 10 years depending on the alternative and the Proposed RMP. Detrimental soil disturbance could result in some reduction of future tree growth as described in Issue 1. The BLM incorporated an assumption of one percent growth loss in future stand growth for every two percent of detrimental soil disturbance created. The increase of detrimental soil disturbance due to roads is included in the 10 percent growth loss over the length of the next rotation, as it comprises part of the 20 percent detrimental soil disturbance levels. This represents a negligible increase in the acreage of detrimental soil disturbance from road construction. It also represents an overestimation as these numbers represent overstatements of road widths (45 feet) for many BLM roads. This analysis is also an overestimate because the BLM does not quantitatively account for potential reductions from road decommissioning.

Issue 3

How would fuel reduction treatments under the alternatives affect soil quality?

Summary of Analytical Methods

Fuel reduction treatments can result in detrimental soil disturbance through soil compaction, soil displacement, bare soil erosion, excessive soil heating, or the production of a thick mulch of chopped or chipped vegetation. The portion of treated areas experiencing detrimental soil disturbance varies by fuel reduction methods.

In this analysis, the BLM grouped together fuel reduction treatments for activity fuels such as the slash remaining after timber harvest and for hazardous risk fuels not associated with timber harvest. This is a change from the discussion in the Planning Criteria, which presented separate issues for the effects of treatment of activity fuels and hazardous risk fuels (USDI BLM 2014, pp. 166–171). At this scale of analysis with the data available, treatments for activity fuels or hazardous risk fuels do not have a discernible difference in creating detrimental soil disturbance.

This analysis evaluated fuel reduction treatments over a 22-year period. Fuel reduction by any method is temporary in nature as vegetation resprouts and needs retreatment in 5–15 years. In some instances, the type of fuel treatment changes from the removal of larger diameter trees to the reduction of understory shrubs or small diameter trees which increases the fuels component after overstory removals.

The BLM derived the acreage of past fuel reduction treatments for activity fuels by querying the Mechpoly and Burnpoly corporate BLM data.[119] The BLM used the Woodstock model outputs to obtain acreages for each alternative and the Proposed RMP for the six different silvicultural treatments of broadcast burns, hand piles, machine piles, landing piles, lop and scatter, and mastication during the first decade.

The BLM derived the acreage of fuel reduction treatments for hazardous risk fuels by querying the district fuel specialists for the level of treatment in the past two decades. Then the BLM projected a decadal level of treatment. The BLM assumed in this analysis that the amount of fuel reduction treatments for hazardous risk fuels would be the same among the alternatives and the Proposed RMP. Based on management objectives and direction in the alternatives and the Proposed RMP, the BLM concluded that there is no basis for predicting a change in treatment of hazardous risk fuels from current and recent practices regardless of how other land management decisions would change.

The BLM assumed the following detrimental soil disturbance would occur: 25 percent of areas treated with excavator machine piling, 35 percent of areas treated with heavy machinery mastication methods, and 5 percent of areas treated with broadcast burning. These estimations incorporate the number of times equipment travels across the units, the length of the boom on the equipment, the size of the piles, the material size to burn, and conclusions from previous publications and studies describing negative effects to the soil.

In this scale of analysis, the BLM assumed that hand pile burning, landing pile burning, and lop and scatter methods of fuel reduction treatment would not result in measurable detrimental soil disturbance. Hand-piling material that is smaller in diameter and in smaller piles typically does not generate lethal soil temperatures. Landing piles can be large enough to generate lethal temperatures, but the area already has detrimental soil disturbance from road construction. The BLM has used two methods of lop and scatter: (1) manual labor to cut and disperse excess vegetation in the treated area and (2) mechanical grinders to cut and disperse excess material (Busse *et al*. 2014). Grinding equipment remains on existing roads limiting the potential for detrimental soil disturbance. Neither method would result in detrimental soil disturbance that would be measureable at this scale of analysis.

In this analysis, the BLM assumed that machine pile burning and broadcast burning have the potential to cause some detrimental soil disturbance, especially where concentration of slash would cause deep heating of the soil or where large wood would be allowed to smolder for long periods of time. However,

[119] These are two layers in the BLM's corporate GIS database. As fuel reduction treatments are completed, specialists input the activity into these layers. However, these layers are not complete.

these circumstances would constitute only a small portion of the broadcast burn area, and quick mop-up after burning would limit the scope and extent of any detrimental soil disturbance. For machine piling, the scattered nature of constructing piles is reliant on the level of fuel loading. Less fuel equals larger distances between piles and potentially less compaction and lethal temperatures during ignition of the piles. The burning of machine piles causes detrimental soil disturbance from both the soil compaction around the pile from the equipment and the heating of the soil beneath the center of the pile.

Generally, mastication involves using mechanical equipment to grind cut vegetation and distributing treated material by spreading or blowing it out on the ground (Busse *et al.*, 2014). For mastication of fuels, the BLM assumed that most machines would be mobile across the treatment area. The impact to the soil resources would come from compaction, displacement, and some concentration of chipped material deeper than three inches. The BLM has employed boom excavators and horizontal bar type machines that need to traverse most of the unit for mastication. Grinding of heavy fuel loads has previously built up chipped material that impedes plant growth.

The Planning Criteria provides more discussion of the analytical methods for detrimental soil disturbance from prescribed burning and is incorporated here by reference (USDI BLM 2014, pp. 157–161).

Background

Prescribed fire can heat the soil to a lethal temperature that kills the microbes, which process organic matter in the soil to provide nutrients to growing vegetation. These same organisms connect roots and soil, which provide additional water and increase water uptake for plants. Inadequately populated soils that lack diverse bacterial and fungi communities demonstrate reduced growing capacity and function which would result in less vegetative growth.

The effects of prescribed burning on soil physical, chemical, and biological properties depend on specific properties or species. Threshold temperatures classed by Busse *et al.* (2014) for soil physical, chemical, and biological properties fall into low, moderate, or high classes. Mortality of bacteria or fungi components, as well as seeds and fine roots of plants within the soil, occurs in the low class between 100 °F and 300 °F. Most soil structure and organic matter changes occur in the moderate class, between 390 °F and 930 °F. The high class is where nutrient volatilization proceeds and occurs between 700 °F and 2,700 °F. The lethal threshold for roots is approximately 140 °F, while that of many soil organisms is between 122 °F and 392 °F.

Chemical and biological effects to soils from prescribed burning include oxidation of surface and soil organic material, changes in nutrient availability and pool size, changes in pH, and lethal heating to biota and fine roots. Soil properties most indicative of detrimental changes differ between fuel reduction practices, making comparisons among treatment types problematic.

Soil heating is a particular concern given anticipated changes to soil nutrient content and availability, microbial composition and function, soil carbon content, soil mineralogy, water repellency, and infiltration following severe burning (Neary *et al.* 2005). Busse *et al.* (2013) determined that, regardless of pile size or fuel composition, the soil heat pulse during burning was quenched rapidly with soil depth. The greatest soil heating occurred in the surface 4 inches, whereas benign temperatures registered at the 12-inch depth; mean maximum values were 104 °F for slash piles and 167 °F for woodpiles. Soil moisture plays a key role in heating dynamics, particularly when burning natural fuels or scattering slash. Heat penetration is substantially lower in moist soil than in dry soil due to the additional energy required to heat water (Busse *et al.* 2010).

Soils in the interior/south are generally lower in organic matter and nutrients and are more susceptible to degradation by prescribed burning than soils in the coastal/north. Detrimental soil disturbance from prescribed burning is particularly severe with machine piling because piled fuel concentrates heat in the center of the pile and equipment use compacts the soil around the pile. Smaller hand piles or the use of broadcast burning generally results in less detrimental soil disturbance than machine piling.

Mastication occurs with various types of equipment, including wheeled or tracked equipment, equipment with a rotary head attached to a boom, and equipment with the rotary mechanism attached directly to the front of the equipment. Boom-mounted masticators can reach areas such as deep ditches and steep embankments and can treat more area with less compaction than machines with the rotary mechanism on the front of the machine (Ryans and Cormier 1994). Tracked equipment can work on steeper slopes and softer soils than wheeled equipment. Mastication would cause some soil compaction and displacement depending on the type of equipment, soil conditions and type, operator experience, and stand conditions. Limiting masticators to designated skid trails or using low-ground-pressure equipment can reduce the extent and intensity of physical soil disturbance (Busse *et al.* 2014). Most mastication fuels treatments are fundamentally different from ground-based harvest yarding systems in which yarding concentrates traffic to skid trails that receive multiple passes. Most masticators track over broad areas to treat fuels, especially if using a horizontal fixed bar design. Boom-mounted masticators are more similar to ground-based yarding; for this type of mastication treatment, confining the equipment to skid trails, operating on a deep slash mat, and using low ground pressure equipment reduces or avoids detrimental soil disturbance.

Mastication produces a coating of cut vegetation debris across the forest floor. Because the resulting debris is unlike the natural forest floor in terms of particle size, composition, bulk density, and moisture regime, there are few direct comparisons to natural wildland systems or processes. Due to the limited number of studies of mastication impacts on soil resources within the planning area, it is difficult to interpret long-term ecological consequences. Short-term studies published in the last 5 years have found few detrimental effects, but the majority of these studies are conducted on sandy soils in California and juniper woodland vegetation types in Colorado. Those soils do not compact in the same manner as clay-textured soils in the planning area. Most short-term impacts center on compaction, mycorrhizal reductions, and nutrient loss or tie up, but long-term consequences or indirect effects from mastication remain largely unstudied (Busse *et al.* 2014). These same studies caution that results are very site-specific and taking the results to other treatment areas needs to be conducted with caution. More research is needed to understand the variability across landscapes. Thus, the BLM has cautiously assumed that mastication will affect soil resources in a manner similar to timber harvesting with mechanical type systems.

Mastication can substantially modify soil temperature and moisture regimes by creating mulch that insulates the soil and traps moisture at the soil surface. This mulch would keep soils cooler in the summer and warmer in the late fall and early winter. The extent that cut vegetation debris is incorporated into the soil during mastication determines the degree that soil temperature changes and water content increases. Masticated debris can act as a barrier against both water infiltration into the soil and evaporative losses from the soil.

Reducing fuels through mastication has limited short-term effects on soil microbial communities, largely because of the insulating and buffering effect of the cut vegetation debris. Mastication removes vegetation, which opens treated areas to the sun, but the resultant mulch reduces soil drying. Studies of mastication treatments in pinyon-juniper woodlands did not find differences in abundance, species richness, or community composition of arbuscular mycorrhizal fungi 2.5 years after treatment (Busse *et al.* 2014).

Mastication would reduce soil nitrogen availability. Mulch is generally low in nitrogen and high in carbon. After the addition of mulch to the soil, microbes will use inorganic nitrogen from the soil in order to decompose the added carbon-rich material. Under such circumstances, this nitrogen immobilization could temporarily reduce the amount of soil nitrogen available for plant growth. While such effects on soil nitrogen are possible, few studies have examined nitrogen transformations and dynamics following mastication. The depth of mulch influences the effect of these treatments on plant-available nitrogen. Ryan *et al.* (2011) found that patchy mulch 0.5–1.5” thick had no negative impact on soil nitrogen at the stand level, but uniform mulch 3–6” thick had substantial effects on soil nitrogen. While the depth of the mulch layer was not identified, in a comparison of fuel treatments in the Sierra Nevada Mountains, commercial thinning followed by mastication did not significantly alter available nitrogen or net nitrification rates 2 years after treatment as compared to untreated control stands (Moghaddas and Stephens 2007). The soil moisture content of the study area is drastically less than the coastal/north portion of the decision area, and the microbial processes would not come into equilibrium in the same manner of the studies.

A study conducted from 2003 to 2008 on the southeastern edge of the Klamath Mountains in northern California found that mastication and burning treatments did not significantly alter any overall community composition and species richness of mycorrhizal fungi (Southworth and Gibson 2010). In addition, mechanical mastication followed by burning did not significantly change soil nutrients at the depth of fine roots and mycorrhizal fungi, and soil nutrient composition did not vary among treatments. Reduction in the fruiting bodies of truffles did occur if the masticated fuels were burned. This study area comes closest to soil and weather conditions found in the interior/south portion of the decision area. Limited research in this area—particularly on clay-textured soils that are well-drained—makes it difficult to determine that similar results would occur in the decision area, particularly in the coastal/north area.

Fuel reduction through biomass removal can remove both carbon and nutrients. Long-term productivity can be reduced by removing these materials, particularly where soils are previously low in these nutrients (Poggiani *et al*. 1983, Swank and Reynolds 1986). The risk of reduction in soil quality due to nutrient loss is largest in the areas of lower productivity in the interior/south. Removal of material to meet hazard reduction goals may conflict with long-term site productivity.

Under the 1995 RMPs, the BLM placed greater emphasis on removing hazardous fuels in the interior/south than in the coastal/north (**Table 3-210**). Fuel reduction for hazard risk included removal of material along roadsides and pulling material into treated harvest units, which the BLM may not have recorded as fuel reduction treatments. Many areas recorded as burn treatments do not reflect in the totals as hazardous fuels reduced.

Table 3-210. Fuel treatments by method, 2003–2012

Fuels Treatment	Coastal/North			Interior/South			Totals (Acres)
	Activity Fuel (Acres)	Hazardous Risk Fuel (Acres)	Total Area Treated (Acres)	Activity Fuel (Acres)	Hazardous Risk Fuel (Acres)	Total Area Treated (Acres)	
Underburn/Broadcast Burn	81,142	2,725	83,867	57,095	33,053	90,148	**174,015**
Machine Pile and Burn	310	16,690	17,000	33,976	25,018	58,994	**75,994**
Mastication	-	2,773	2,773	-	5,359	5,359	**8,132**
Total Treatment Acres	**81,452**	**22,188**	**103,640**	**91,071**	**63,430**	**154,501**	**258,141**

Affected Environment and Environmental Consequences

Fuel treatments over the past 20 years have potentially resulted in detrimental soil disturbance on 30,424 acres in the decision area: 9,292 acres in the coastal/north, and 21,132 acres in the interior/south (**Table 3-211**).

Table 3-211. Detrimental soil disturbance from fuel treatments by method, 2003–2012

Fuels Treatment	Coastal/North (Acres)	Interior/South (Acres)	Totals (Acres)
Underburn/Broadcast Burn	4,071	4,507	**8,578**
Machine Pile and Burn	4,250	14,749	**18,999**
Mastication	971	1,876	**2,847**
Totals	**9,292**	**21,132**	**30,424**

For each alternative and the Proposed RMP, the total detrimental soil disturbance acres from treatment disturbance ranges from approximately 4,400–10,100 acres (**Figure 3-142**). This acreage ranges from 5 to 7 percent of the acres treated in each of the alternatives and the Proposed RMP. Alternative C would result in the largest amount of detrimental soil disturbance from fuel treatments (10,139 acres), and Alternative D would result in the least (4,346 acres). Alternative A (4,410 acres), the No Action alternative (5,330 acres), the Proposed RMP (5,665 acres), and Alternative B (6,055 acres) would result in only slightly more detrimental soil disturbance from fuel treatments than Alternative D and substantially less than Alternative C.

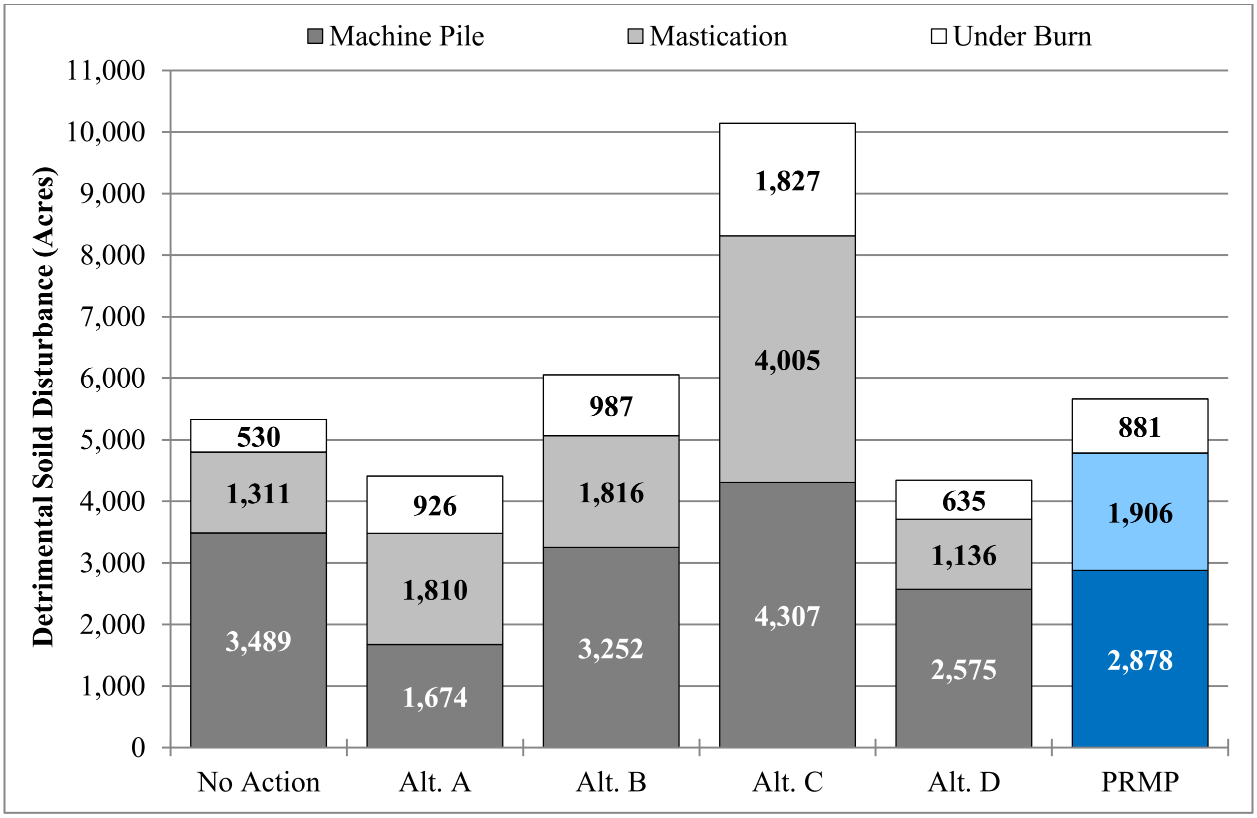

Figure 3-142. Detrimental soil disturbance from fuel treatments during the first decade

The detrimental soil disturbance from fuel treatments during the first decade under the alternatives and the Proposed RMP would be approximately 14–33 percent (**Table 3-212**) of the current detrimental soil disturbance from past fuel treatments. As a result, the alternatives and the Proposed RMP summed with past fuel treatments would result in a cumulative total of detrimental soil disturbance ranging from 34,770 acres to 40,563 acres.

Table 3-212. Detrimental soil disturbance from fuels treatments compared to the current condition

Detrimental Soil Disturbance From Fuel Reduction Treatments	No Action (Acres)	Alt. A (Acres)	Alt. B (Acres)	Alt. C (Acres)	Alt. D (Acres)	PRMP (Acres)
Current Condition	30,424	30,424	30,424	30,424	30,424	30,424
Fuels Reduction Treatments	5,330	4,410	6,055	10,139	4,346	5,665
Totals	**35,754**	**34,834**	**36,479**	**40,563**	**34,770**	**36,089**
Percentage of Current Condition	18%	14%	20%	33%	14%	19%

There are differences among the alternatives and the Proposed RMP based on the method of treatment that would produce different detrimental effects. Except Alternative A, machine piling would be the largest contributor to detrimental soil disturbance (**Figure 3-142**) in the alternatives and the Proposed RMP. Mastication is the largest contributor to detrimental soil disturbance in Alternative A. Where machine piling occurs, there would be compaction that would reduce seedling growth or impede vegetative cover of native plants. Where soil temperature is elevated above lethal temperatures, there would be loss of microbial activity and reduced soil attachment to roots that improve growth. If masticated materials accumulate in layers greater than 3 inches, the mulch layer would impede evaporation, water infiltration, and solar heating. The effect on seedling growth could be negative or positive depending on site and soil particulars. Across the 2.5 million acre decision area, the total number of treated acres would range from 5,330 to 10,139 acres. This increased level of detrimental soil disturbance would reflect a 10 percent reduction of growth on less than half of one percent of the decision area, which constitutes an insignificant loss under any alternative.

Issue 4

How would public motorized travel activity under the alternatives affect soil quality?

Summary of Analytical Methods

In this analysis, the BLM assumed that areas designated as *open* for public motorized access would experience detrimental soil disturbance. Areas designated as *closed* would not experience detrimental soil disturbance because the BLM would not permit public motorized travel activities. Areas designated as *limited* would not experience measurable additional detrimental soil disturbance because the BLM would limit public motorized travel activities to existing or designated roads and trails, which have already experienced detrimental soil disturbance through the construction of the roads or trails. Until the BLM completes route designations through implementation-level travel management planning (TMP), the BLM cannot identify which routes would be designated in any alternative and the Proposed RMP. Therefore, the BLM cannot quantify these more site-specific effects in this analysis, and the BLM would address these effects as part of the analysis supporting implementation-level TMP decisions.

Although the BLM has some site-specific and anecdotal information about illegal public motorized travel activities, the BLM does not have a basis for predicting the location or effects of any widespread or systematic illegal public motorized travel activities. In addition, much of the decision area has physical limitations to potential illegal public motorized travel activities, including dense vegetation, steep slopes, and locked gates. Terrain, vegetation, and a greater amount of open spaces in most of the interior/south can lead to degradation and erosion in a greater proportion than the coastal/north where vegetation is denser and terrain is steeper. However, the BLM lacks a basis for characterizing current illegal public motorized travel activities or forecasting potential illegal public motorized travel activities in the future under any of the alternatives and the Proposed RMP at this scale of analysis. In this analysis, the BLM assumed that members of the public participating in motorized travel recreation would operate vehicles consistent with BLM decisions about public motorized travel opportunities (see the Trails and Travel Management section of this chapter).

Background

Public motorized travel activities can cause detrimental soil disturbance as vehicle traffic compacts or displaces soil (Ouren *et al*. 2007). The effects can vary based on the type of vehicle. Vehicles include two-wheel and four-wheel all-terrain vehicles, large four-wheel-drive trucks, sport utility vehicles, and any other vehicle capable of off-road travel. Depending on the type of soil, there will be different effects. Relatively uniform sandy or clay soils are less vulnerable to compaction than loamy sands or coarse-textured, gravelly soils characterized by variability in particle size (Lovich and Bainbridge 1999). In addition, soils capable of holding greater water content are more susceptible to compaction than soils containing less moisture (Webb 1982). However, even soils in semi-arid and arid lands experience compaction because the texture of these soils is slow to recover through natural soil-loosening processes, including shrinking, swelling, drying, wetting, freezing, and thawing (Webb 1982).

Public motorized travel activities can cause soil erosion, which occurs when fine-grained particles blow off in the wind or wash off due to precipitation on an unprotected surface. The removal of the top layers of soil, particularly the organic matter, degrades the potential for soil function. The result can range from barren surfaces or very deep gullies depending on soil type, slope gradient, and amount of exposure to precipitation.

Affected Environment and Environmental Consequences

Under the No Action alternative, approximately 63,500 acres of the decision area would remain designated as *closed* for public motorized access, and approximately 319,600 acres would remain designated as *open* for public motorized access (see Trails and Travel Management **Table 3-218** in this chapter). The BLM would designate the remaining 84.4 percent as *limited* for public motorized access. Detrimental soil disturbance has occurred, and would continue to occur, on some portion of the 319,600 acres designated as *open* for public motorized access. It is not possible for the BLM to determine at this scale of analysis with current data the extent of the 319,600 acres of *open* for public motorized access that are actually experiencing detrimental soil disturbance or would experience detrimental soil disturbance in the future. However, within areas designated as *open* for public motorized access, such effects would occur throughout the *open* area without future analysis or decision-making by the BLM.

Under all action alternatives and the Proposed RMP, there would be no areas designated as *open* for public motorized access. Compared to the No Action alternative, this would curtail potential detrimental soil disturbance on over 319,400 acres or 13 percent of the decision area currently designated as *open*. The BLM would designate the entirety of the decision area as *closed* for public motorized access or *limited* for public motorized access. While public motorized vehicle use for recreational purposes is expected to increase as opportunities and demand increase (see Recreation and Visitor Services in this chapter), additional detrimental soil disturbance from public motorized travel on roads and trails would not be expected under the action alternatives or Proposed RMP from increased use. The BLM assumes that *limited* designations would confine continued public motorized travel activities to proposed, existing, or designated roads and trails, which would have already experienced detrimental soil disturbance through the construction of the roads or trails. As such, there would be no additional detrimental soil disturbance from public motorized travel activities measurable at this scale of analysis with the data available under any of the action alternatives or the Proposed RMP.

Until the BLM completes route designations through implementation-level TMPs, the BLM cannot identify specific routes designated in any alternative or the Proposed RMP. Therefore, the BLM cannot quantify these more site-specific effects in this analysis, and the BLM would address these effects as part of the analysis supporting implementation-level TMP decisions.

Issue 5

How would the combination of timber harvest, road construction, and fuel reduction treatments[120] *under the alternatives affect soil quality?*

Summary of Analytical Methods

In this analysis, the BLM combined the individual levels of detrimental soil disturbance from timber harvest, road construction, and fuel reduction treatments. For the purposes of this analysis, the BLM considered all acres of detrimental soil disturbance to be equal: acres of detrimental soil disturbance from timber harvest are equivalent to those from road construction or fuel reduction treatments. There are

[120] The BLM is unable to measure detrimental soil disturbance from public motorized travel activities with the data currently available at this scale of analysis (see Issue 4). Therefore, the BLM did not combine detrimental soil disturbance from public motorized travel activities with these other sources because no quantifiable metric is presently available.

differences in how detrimental soil disturbance from different management actions would affect soil quality. However, it is not possible to distinguish quantitatively these differences in detrimental soil disturbance at this scale of analysis with the data currently available. In addition, there would likely be some overlap in the acres of detrimental soil disturbance from these three sources (i.e., the same location within a harvest unit would experience detrimental soil disturbance from the ground-based yarding equipment during harvesting and from machine piling and burning during fuels treatment). However, it is not possible at this scale of analysis to separate the acres of detrimental soil disturbance from each source and identify overlapping acres. Therefore, these estimates overestimate the acres of detrimental soil disturbance in part because of the overlapping acres.

The BLM compared the combined amount of detrimental soil disturbance to a threshold of 20 percent of areas treated. The BLM derived this analytical threshold in part from a U.S. Forest Service Pacific Northwest Region standard in which overall soil quality is considered negatively impacted and amelioration must ensue when detrimental soil disturbance exceeds 15 percent of an area treated (USDA FS 2010). However, this 15 percent standard does not account for road construction. The BLM increased this analytical threshold from 15 percent to 20 percent to account for detrimental soil disturbance from road construction. This 20 percent threshold only provides an approximate analytical threshold at this scale of analysis. Comparing the amount of detrimental soil disturbance as a percentage of total area treated across the decision area over 10 years to this 20 percent analytical threshold provides only limited and approximate information. This estimated percentage does not reveal whether or not any particular site or treatment area would exceed this 20 percent threshold. The relevant scale for evaluating detrimental soil disturbance and determining the need for mitigation or amelioration is at the site scale such as an individual timber harvest unit or individual treatment area.

Affected Environment and Environmental Consequences

Currently, 139,299 acres in the decision area have experienced detrimental soil disturbance from past timber harvest, road construction, and fuel reduction treatments (**Table 3-213**).

Table 3-213. Detrimental soil disturbance from all sources, by the current condition and during the first decade

Management Action	Current Condition (Acres)	No Action (Acres)	Alt. A (Acres)	Alt. B (Acres)	Alt. C (Acres)	Alt. D (Acres)	PRMP (Acres)
Fuels Treatments	30,424	5,330	4,410	6,055	10,139	4,346	5,665
Road Construction	79,311	3,484	1,643	2,899	3,822	1,319	2,393
Timber Harvest	29,564	24,172	12,380	25,217	27,000	21,742	23,505
Totals	139,299	32,986	18,433	34,171	40,961	27,407	31,563
Total Combined with Current Condition	-	**172,285**	**157,732**	**173,470**	**180,260**	**166,706**	**170,862**
Percentage of Current Condition		24%	13%	25%	29%	20%	23%

Through the first decade, the alternatives and the Proposed RMP would increase detrimental soil disturbance amounts by 13–29 percent of current amounts. Alternative C would result in the largest combined increase in detrimental soil disturbance (40,961 acres), with decreasing acreages in Alternative B (34,171 acres), No Action (32,986 acres), the Proposed RMP (31,563 acres), and Alternative D (27,407 acres). Alternative A would result in the smallest combined increase in detrimental soil disturbance (18,433 acres).

Timber harvest activities are the largest source of detrimental soil disturbance under the alternatives and the Proposed RMP. New road construction based on silvicultural management would be low under all alternatives and the Proposed RMP as most of the required transportation system is currently in place. Fuels treatments for both the disposal of harvest waste and fire risk reduction activities under the alternatives and the Proposed RMP would use less of the treatment methods likely to result in detrimental soil disturbance than in the past. The expected treatments employ more hand piling or scattering, more landing burning, and less mastication or machine piling acres.

As noted in the issues above, the BLM would be able to reduce the acreage of detrimental soil disturbance from timber harvest, road construction, and fuel reduction treatments through management practices that would limit initial compaction levels, remove existing or created compacted surfaces, and improve soil water and organic matter levels. The BLM would apply the best management practices listed and described in **Appendix J** as necessary to limit the overall detrimental soil disturbance to 20 percent or less. However, because the extent and effectiveness of such mitigation or amelioration depends heavily on site-specific and project-specific factors, the BLM cannot quantify those reductions in detrimental soil disturbance in this analysis. Management direction limits the increase of detrimental soil disturbance to 20 percent of any given treatment unit and includes all types of disturbances, including those resulting from treatments as well as new road and landing areas. All alternatives and the Proposed RMP, as analyzed, would increase the current level of detrimental soil disturbance by various percentages. Thus for some alternatives including the Proposed RMP, some mitigation of these impacts through the application of best management practices would be required. Currently the detrimental soil disturbance covers approximately six percent of the decision area. Raising that level by 20 percent would increase the detrimental soil disturbance to approximately seven percent of the decision area. Even then, there is only an expected reduction of growth from those areas in the future of 10 percent. Therefore, the sustainability of all lands under the decision area remains at approximately 99 percent of their current potential.

References

Amacher, M. C., K. P. O'Neil, and C. H. Perry. 2007. Soil vital signs: A new Soil Quality Index (SQI) for assessing forest soil health. Research Paper RMRS-RP-65WWW. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 12 pp. http://www.fs.fed.us/rm/pubs/rmrs_rp065.pdf.

Busse, M. D., S. E. Beattie, R. F. Powers, F. G. Sanchez, and A. E. Tiarks. 2006. Microbial community responses in forest mineral soil to competition, organic matter removal and vegetation control. Can. J. For. Res. **36**(3): 577–588. http://www.srs.fs.usda.gov/pubs/ja/ja_busse001.pdf.

Busse, M. D., C. J. Shestak, K. R. Hubbert, and E. E. Knapp. 2010. Soil physical properties regulate lethal heating during burning of woody residues. Soil Science Society of America Journal **74**(3): 947–955. http://dx.doi.org/10.2136/SSSAJ2009.0322.

Busse, M. D., C. J. Shestak, and K. R. Hubbert. 2013. Soil heating during burning of forest slash piles and wood piles. International Journal of Wildland Fire **22**(6): 786–796. http://dx.doi.org/10.1071/WF12179.

Busse, M. D., K. R. Hubbert, and E. E. Y. Moghaddas. 2014. Fuel reduction practices and their effects on soil quality. General Technical Report PSW-GTR-241.USDA Forest Service, Pacific Southwest Research Station. Albany, CA. 156 pp. https://www.firescience.gov/projects/08-2-1-14/project/08-2-1-14_Soils_Synthesis.pdf.

Bustos, O., and A. Egan. 2011. A comparison of soil compaction associated with four ground-based harvesting systems. ProQuest Earth Science Collection, Northern Journal of Applied Forestry **28**(4): 194–198.

Cafferata, P. 1992. Soil compaction research. In: Skaugset, A., editor, Forest soils and riparian zone management–the contributions of Dr. Henry A. Froehlich to forestry. Oregon State University, Corvallis, OR. pp. 8–22.

Coulter, E. D., K. Coulter, and T. Mason. 2002. Dry forest mechanized fuels treatment trials project. Final Report to the USDA Forest Service, Pacific Northwest and Intermountain Regions. https://secure.hosting.vt.edu/www.cofe.frec.vt.edu/documents/2002/COFE_2002_DodsonCoulter_et_al.pdf.

Farve, R., and C. Napper. 2009. Biomass fuels and whole tree harvesting impacts on soil productivity–Review of literature. USDA Forest Service, National Technology & Development Program, San Dimas, CA. 66 pp. http://www.fs.fed.us/t-d/pubs/pdf/hi_res/09201803hi.pdf.

Fleming, R. L., R. F. Powers, N. W. Foster, J. M. Kranabetter, D. A. Scott, F. Ponder, Jr., S. Berch, W. K. Chapman, R. D. Kabzems, K. H. Ludovici, D. M. Morris, D. S. Page-Dumroese, P. T. Sanborn, F. G. Sanchez, D. M. Stone, and A. E. Tiarks. 2006. Effects of organic matter removal, soil compaction, and vegetation control on a 5-year seedling performance: a regional comparison of long-term soil productivity sites. Canadian Journal of Forest Research **36**(3): 529–550. http://dx.doi.org/10.1139/x05-271.

Froehlich, H. A. 1976. The influence of different thinning systems on damage to soil and trees. Proceedings, XVIIIUFRO World Congress Division IV. pp. 333–334.

Froehlich, H. A., and D. S. McNabb. 1984. Minimizing soil compaction in Pacific Northwest forests. pp. 159–192. In E. L. Stone (ed.) Forest soils and treatment impacts. Proceedings of the 6th North American Forest Soils Conference. Knoxville, TN. http://forest.moscowfsl.wsu.edu/smp/solo/documents/RPs/Froehlich_McNabb_1983.pdf.

Han, H.-S., D. Page-Dumroese, S.-K. Han, and J. Tirocke. 2006. Effect of slash, machine passes, and soil moisture on penetration resistance in a cut-to-length harvesting. International Journal of Forest Engineering **17**(2):11–24. http://www.fs.fed.us/rm/pubs_other/rmrs_2006_han_h001.pdf.

Han, S.-K., H.-S. Han, D. Page-Dumroese, and L. R. Johnson. 2009. Soil compaction associated with cut-to length and whole tree harvesting of a coniferous forest. Canadian Journal of Forest Research **39**: 976–989. http://www.fs.fed.us/rm/pubs_other/rmrs_2009_han_s001.pdf.

Heilman, P. E., H. W. Anderson, and D. M. Baungartner, eds. 1981. Forest soils of the Douglas-fir region. 298 pp.

Johnson, D. W. 2010. Soil quality: some basic considerations and case studies. In Page-Dumroese, D., D. Neary, C. Trettin, tech. eds. 2010. Scientific background for soil monitoring on National Forests and Rangelands: workshop proceedings; April 29–30, 2008; Denver, CO. Proc. RMRS-P-59. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. pp. 1–12. http://www.fs.fed.us/rm/pubs/rmrs_p059.pdf.

Labelle, E. R., and D. Jaeger. 2011. Soil compaction caused by cut-to-length forest operations and possible short-term natural rehabilitation of soil density. Soil Science Society of America Journal **75**(6): 2314–2329. http://dx.doi.org/10.2136/sssaj2011.0109.

Landsberg, J. D., R. E. Miller, H. W. Anderson, and J. S. Tepp. 2003. Bulk density and soil resistance to penetration as affected by commercial thinning in northeastern Washington. Research Paper PNW-RP-551.USDA Forest Service, Pacific Northwest Research Station, Portland, OR. 35 pp. http://www.fs.fed.us/pnw/pubs/rp551.pdf.

Lloyd, R. A., K. A. Lohse, and T. P.A. Ferré, 2013. Influence of road reclamation techniques on forest ecosystem recovery. Frontiers in Ecology and the Environment **11**(2): 75–81. http://dx.doi.org/10.1890/120116.

Lovich, J. E., and D. Bainbridge. 1999. Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration. Environmental Management **24**(3): 309–326. http://sbsc.wr.usgs.gov/products/pdfs/restore.pdf.

Miller, R. E., W. Scott, and J. W. Hazard. 1996. Soil compaction and conifer growth after tractor yarding at three coastal Washington locations. Canadian Journal of Forest Research **26**(2): 225–236. http://forest.moscowfsl.wsu.edu/smp/solo/InfoPath/documents/Miller.pdf.

Miller, R. E., W. I. Stein, R. L. Heninger, W. Scott, S. N. Little, and D. J. Goheen. 1989. Maintaining and improving site productivity in the Douglas-fir region. pp. 98–136 In: D. A. Perry and others, eds. Maintaining the long-term productivity of Pacific Northwest forest ecosystems. Proceedings of a symposium, March 31–April 2, 1987. http://www.fs.fed.us/pnw/olympia/silv/publications/opt/326_MillerEtal1989.pdf.

Moghaddas, E. Y., and S. L. Stephens. 2007. Thinning, burning, and thin-burn fuel treatment effects on soil properties in a Sierra Nevada mixed-conifer forest. Forest Ecology and Management **250**(3): 156–166. http://dx.doi.org/10.1016/j.foreco.2007.05.011.

Neary, D. G., K. C. Ryan, and L. F. DeBano. 2005. Wildland fire in ecosystems: effects of fire on soil and water. General Technical Report RMRS-GTR-42-vol. 4. USDA Forest Service, Rocky Mountain Research Station, Ogden, UT. 250 pp. http://www.fs.fed.us/rm/pubs/rmrs_gtr042_4.pdf.

Ouren, D. S., C. Haas, C. P. Melcher, S. C. Stewart, P. D. Ponds, N. R. Sexton, L. Burris, T. Fancher, and Z. H. Bowen. 2007. Environmental effects of off-highway vehicles on Bureau of Land Management lands: A literature synthesis, annotated bibliographies, extensive bibliographies, and internet resources: U.S. Geological Survey, Open-File Report 2007-1353, 225 pp. https://www.fort.usgs.gov/sites/default/files/products/publications/22021/22021.pdf.

Page-Dumroese, D., M. Jurgensen, W. Elliot, T. Rice, J. Nesser, T. Collins, and R. Meurisse. 2000. Soil quality standards and guidelines for forest sustainability in northwestern North America. Forest Ecology and Management **138**(1): 445–462. http://www.fs.fed.us/rm/pubs_other/rmrs_2000_page_dumroese_d001.pdf.

Page-Dumroese, D., M. Jurgensen, A. E. Tiarks, F. Ponder Jr., F. G. Shanchez, R. L. Fleming, J. M. Kranabetter, R. F. Powers, D. M. Stone, J. D. Elioff, and D. A. Scott. 2006. Soil physical property changes at North American long-term soil productivity study sites: 1 and 5 years after compactions. Canadian Journal of Forest Research **36**: 551–564. http://www.srs.fs.usda.gov/pubs/ja/ja_page-dumroese001.pdf.

Page-Dumroese, D., R. Miller, J. Mital, P. McDaniel, and D. Miller, tech. eds. 2007. Volcanic-ash-derived forest soils of the inland Northwest: Properties and implications for management and restoration. Proceedings RMRS-P-44, November 9–10, 2005, Coeur d'Alene, ID. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 220 pp. http://www.fs.fed.us/rm/pubs/rmrs_p044.pdf.

Poggiani, F., H. T. Z. Couto, and W. S. Filho. 1983. Biomass and nutrient estimates in short rotation intensively cultured plantation of *Eucalyptus grandis*. Revista IPEF **23**: 29–36, abr. 1983, Piracicaba, Sao Paulo, Brazil.

Powers, R. F., A .E. Tiarks, and J. R. Boyle. 1998. Assessing soil quality: practicable standards for sustainable forest productivity in the United States. In: Davidson, E. A., M. B. Adams, and K. Ramakrishna (eds.). The contribution of soil science to the development and implementation of criteria and indicators of sustainable forest management. Special Publication No. 53. Soil Science Society of America (SSSA), Madison, WI, 53±80 pp. https://dl.sciencesocieties.org/publications/books/abstracts/sssaspecialpubl/thecontribution/53.

Powers, R. F., D. H. M. Alban, R. E. Miller, A. E. Tiarks, C. G. Wells, P. E. Avers, R. G. Cline, R. O. Fitzgerald, and N. S. Loftus, Jr. 1990. Sustaining site productivity in North American forests: Problems and prospects. pp. 49–79 in Sustained Productivity of Forest Soils, University of British Columbia, Vancouver, BC, Canada.

Powers, R. F., D. A. Scott, F. G. Sanchez, R. A. Voldseth, D. Page-Dumroese, J. D. Elioff, and D. M. Stone. 2005. The North American long-term soil productivity experiment. Findings from the first decade of research. Forest Ecology and Management **220**(2005): 31–50. http://www.srs.fs.usda.gov/pubs/ja/ja_powers002.pdf.

Richardson, E., and D. Wulfsohn. 2004. Landscape-level comparison of soil impacts by two forest harvesting systems. AgEng2004, Leuven, Belgium, September 12–16, 2004. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.615.3889&rep=rep1&type=pdf.

Ryan, M., M. A. Battaglia, C. Rhoades, and M. E. Rocca. 2011. Reducing fuels through mulching treatment: What are the ecological effects? Fire Science Brief Issue 140. 6 pp. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1126&context=jfspbriefs.

Ryans, M., and D. Cormier. 1994. A review of mechanized brush-cutting equipment for forestry. Special Report No. SR-10. Forest Engineering Research Institute of Canada (FERIC). 36 pp.

Sanchez, F. G., A. D. Scott, and K. H. Ludovici. 2006. Negligible effects of severe organic matter removal and soil compactions on loblolly pine growth over 10 years. Forest Ecology and Management **227**: 145–154. http://www.srs.fs.usda.gov/pubs/ja/ja_sanchez010.pdf.

Shestak, C. J., and M. D. Busse. 2005. Compaction alters physical but not biological indices of soil health. Soil Science Society of America Journal **69**: 236–246. http://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=4078&content=PDF.

Southworth, D., and J. Gibson. 2010. Going underground: Studying fuel treatment effects on the mycorrhizal community of Northern California. Fire Science Brief, Issue 105. 6 pp. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1103&context=jfspbriefs.

Swank, W. T., and B. C. Reynolds. 1986. Within-tree distribution of woody biomass and nutrients for selected hardwood species. Paper presented at Eighth Annual Southern Forest Biomass Workshop, Knoxville, Tennessee, June 16–19, 1986. http://coweeta.uga.edu/publications/435.pdf.

Tan, X., M. P. Curran, S. X. Chang, and D. G. Maynard. 2009. Early growth responses of lodgepole pine and Douglas-fir to soil compaction, organic matter removal, and rehabilitation treatments in southeastern British Columbia. Forest Science ProQuest Earth Science Collection **55**(3): 210–220. http://nofc.cfs.nrcan.gc.ca/publications/?id=30076.

USDA FS. 2010. Forest Service Manual (FSM) 2500, Chapter 2550 Soil Management, Amendment No. 2550-2010-1, effective November 23, 2010. USDA Forest Service, Forest Service Manual National Headquarters (WO), Washington, D.C. http://www.fs.fed.us/biology/resources/pubs/soils/wo_fsm2550.pdf.

USDA Natural Resources Conservation Service (NRCS). 1996. Soil quality resource concerns: compaction. Soil Quality Information Sheet. April 1996. 2 pp. http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_019200.pdf.

USDI BLM. 2014. Resource Management Plans for Western Oregon Planning Criteria. Bureau of Land Management, Oregon/Washington State Office, Portland, OR. http://www.blm.gov/or/plans/rmpswesternoregon/files/rmp-criteria.pdf.

Webb, R. H. 1982. Off-road motorcycle effects on a desert soil. Environmental Conservation **9**(3): 197–208. http://dx.doi.org/10.1017/S0376892900020403.
Williamson, J. R., and W. A. Neilsen. 2000. The influence of forest site on rate and extent of soil compaction and profile disturbance of skid trails during ground-based harvesting. Canadian Journal of Forest Research **30**: 1196–1205. http://www.nrcresearchpress.com/doi/pdf/10.1139/x00-041.