United States
Department of
Agriculture

Forest Service

Pacific Northwest
Research Station

Research Note
PNW-RN-535
December 2002

Assessing Visual Soil Disturbance on Eight Commercially Thinned Sites in Northeastern Washington

Jeffrey S. Tepp[1]

Abstract

Randomly located transects were used to assess visual soil disturbance on eight units in the Fritz Timber Sale, Colville National Forest. Equipment trails, mostly designated, accounted for about 25 percent of the total area. The cut-to-length harvester and forwarder combination with 130-foot trail spacing produced the least visual disturbance. Leaving slash on trails appeared to reduce displacement and rutting. Rehabilitation of trails, landings, and temporary roads could move seven of the eight units toward compliance with regional standards for detrimental disturbance. Validation of these regional standards is needed to determine the effects of soil disturbance on soil productive capacity.

Keywords: Soil disturbance, soil monitoring, harvesting effects, thinning, skyline, Pacific Northwest, assessment.

Introduction

This report documents visual soil disturbance (trails, landings, spur roads, displacement, erosion, and rutting) by using a transect method on eight operationally thinned research units on the Colville National Forest (NF) in northeastern Washington. Topics of discussion include visual disturbance after various harvesting methods, designated trail spacing, slash on trails, regional soil standards, and needed research. Landsberg and others (in press) related soil compaction to these harvesting methods.

Methods

Unit Characteristics, Treatments, and Practices

This soil disturbance assessment was conducted in recently thinned units in northeastern Washington on the Kettle Falls Ranger District of the Colville NF. The units were part of the Fritz Timber Sale in T. 36 N, R. 35 E (sec. 32 and 33) and T. 35 N, R. 35 E (sec. 4). The 70-year-old, mixed-conifer stands were commercially thinned in

[1] **Jeffrey S. Tepp** was a soil scientist, Forestry Sciences Laboratory, 1133 Western Avenue, Wenatchee, WA 98802, at the time of this research. Tepp is currently a soil scientist on the Superior National Forest, 8901 Grand Avenue Place, Duluth, MN 55808

summer 1998 on slopes greater than 25 percent (steep units, fig. 1) and in late summer and early fall 1999 on slopes less than 25 percent (flat units, fig. 2). Steep units had southwest aspects, whereas flat unit aspects varied (table 1). Compared with steep units, flat units were in forests of subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) rather than interior Douglas-fir/lodgepole pine(*Pseudotsuga menziesii* (Mirb.) Franco/ *Pinus contorta* Dougl. ex Loud.) and had greater stand density and basal area, but trees of smaller quadratic mean diameter (table 2). The percentage of starting basal area removed in thinning was more variable in the flat units (34-56) compared with the steep units (54-56), and a smaller percentage of trees were removed in flat units (table 2).

Based on a detailed soil survey (Zulauf and Starr 1979), soils on the flat units (Neuske silt loam, Nevine loam, Gahee loam, and Scar sandy loam) had finer texture in the surface soil than those on the steep units (76 percent was Merkel sandy loam, and 20 percent was mapped as rock land).

Contractors used different equipment combinations on designated trails at specified spacings to thin these overstocked stands (table 3). Ground-based equipment included two types of tracked, cut-to-length (CTL) harvesters, a rubber-tired forwarder, a tracked feller-buncher, and a rubber-tired skidder with swinging grapples (table 3).[2] The equipment was to be restricted to designated trails that were 14 feet wide and spaced 40 or 130 feet (center-to-center distance). To reduce soil disturbance, the harvester operator delimbed trees and placed the slash on skid trails before traversing them.

On three of the steep units, a ground-based harvester or feller-buncher was used initially to fell trees before a skyline cable system yarded logs or whole trees to landing areas. Designated trails were spaced at 40-foot intervals. Skyline corridors reused trails made by ground-based equipment. The fourth steep unit (no. 9) was thinned with a tracked harvester, and logs were retrieved with a forwarder on trails designated at 40-foot, center-to-center spacing. The four flat units were yarded with ground-based equipment on either 130- or 40-foot trail spacing. Theoretically, such trails spaced at 40 feet would occupy about 35 percent of the harvested area, and those spaced at 130 feet would occupy about 11 percent of the area.

---

[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

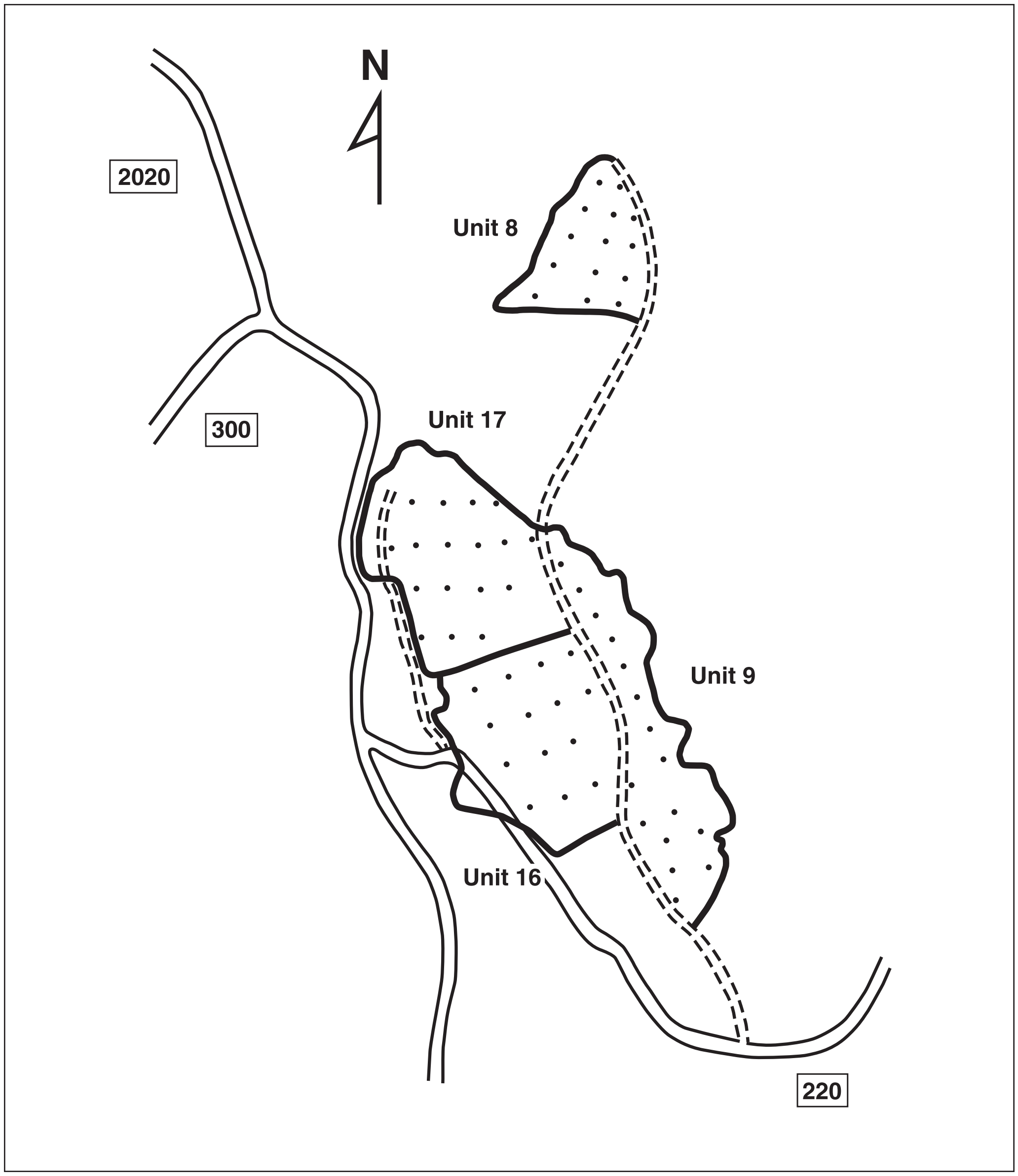

Figure 1—Location of steep units monitored for soil disturbance on the Colville National Forest, northeastern Washington. Solid double lines are permanent roads, and dashed doubled lines are temporary spur roads. Dots within each unit are the approximate starting locations of monitoring transects.

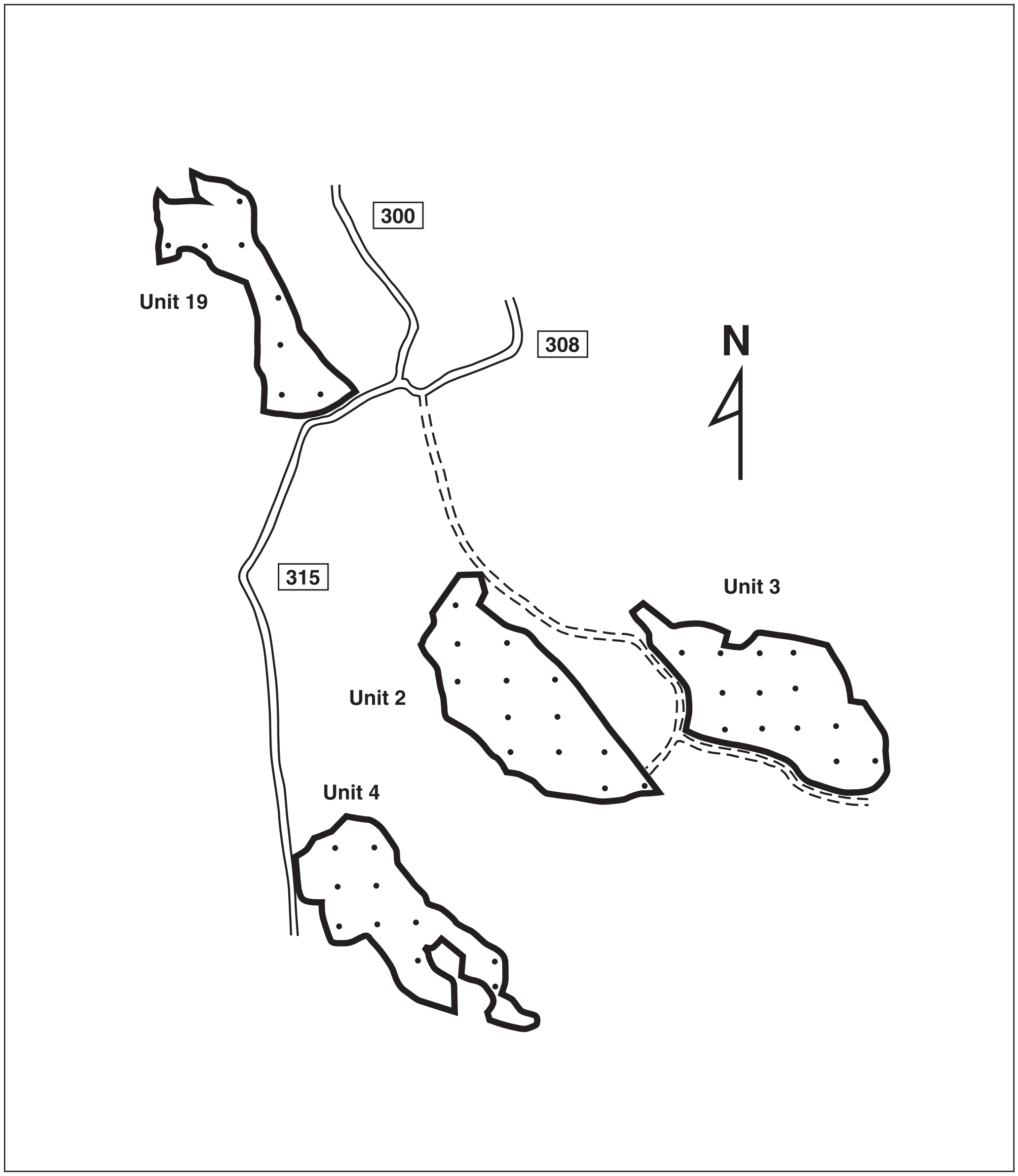

Figure 2—Location of flat units monitored for soil disturbance on the Colville National Forest, northeastern Washington. Solid double lines are permanent roads, and dashed doubled lines are temporary spur roads. Dots within each unit are the approximate starting locations of monitoring transects.

Table 1—Physical characteristics of 8 commercially thinned units

Topography and unit number	Area	Average Slope	Average Aspect	Average Elevation
	Acres	*Percent*		*Feet*
Steep:				
8	10	31	SW	4,700
9	20	36	SW	4,640
16	23	33	SW	4,450
17	23	25	SW	4,440
Flat:				
2	23	15	SE to SW	4,180
3	27	7	NE	4,070
4	18	13	SE	4,160
19	16	10	SE to S	4,460

Table 2—Most common plant association and stand characteristics for 8 units before commercial thinning, and percentage cut[a]

Topography and unit no.	Plant association[b]	Preharvest Basal area	Preharvest QMD[c]	Preharvest Stand density	Cut Trees	Cut Basal area
		Feet^2/acre	*Inches*	*Trees/acre*	*- - Percent*	*- -*
Steep:						
8	PSME/VAME	162.8	6.1	802	59	56
9	PSME/VAME	133.9	7.1	483	70	54
16	PICO/SHCA	155.8	6.4	701	64	56
17	PICO/SHCA	121.3	6.4	537	66	55
Flat:						
2	ABLA2/LIBOL	163.5	5.2	1,101	24	34
3	ABLA2/VAME	202.8	5.9	1,081	49	56
4	ABLA2/VAME	159.9	5.8	879	40	46
19	ABLA2/VAME/LIBOL	191.8	5.9	1,025	57	54

[a] Trees 1.0 inch and larger diameter at breast height (d.b.h.); Camp, A. 2000. Unpublished data. On file with: USDA Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 1133 N Western Ave., Wenatchee, WA 98801.

[b] USDA FS codes: ABLA2 = *Abies lasiocarpa* (Hook.) Nutt. (subalpine fir), LIBOL = *Linnea borealis* var. *longiflora* (Torr.) Hulten (twinflower), VAME = *Vaccinium membranaceum* Dougl. ex Torr. (big huckleberry), PSME = *Pseudotsuga menziesii* (Mirb.) Franco (Douglas-fir), PICO = *Pinus contorta* Dougl. ex Loud. (lodgepole pine), SHCA = *Sheperdia canadensis* (L.) Nutt. (russet buffaloberry).

[c] QMD = quadratic mean diameter, the diameter of tree of average basal area.

Table 3—Harvesting methods and equipment used for commercial thinning

Unit number	Tree felling	Processing to logs	Trail spacing[a]	Slash left	Forwarding and yarding		
						Cable system	
					Ground-based equipment	Skyline	Corridor spacing[a]
			Feet				*Feet*
Steep:							
8	Harvester[b]	Harvester[b]	40	Yes	—	Uphill	130
9	Harvester[b]	Harvester[b]	40	Yes	Forwarder[c]	—	—
16	Feller-buncher[d]	Whole tree	40	No	—	Downhill	40
17	Harvester[b]	Harvester[b]	40	Yes	—	Downhill	130
Flat:							
2	Chain saw	Harvester[e]	130	Yes	Forwarder	—	—
3	Harvester[e]	Harvester[e]	40	Yes	Forwarder	—	—
4	Feller-buncher	Whole tree	130	No	Skidder[f]	—	—
19	Feller-buncher	Harvester[e]	130	Yes	Forwarder	—	—

[a] Spacing from center to center of adjacent trails or corridors applies to both harvesting and ground forwarding.

[b] Tracked Valmet 500T with tilting cab.

[c] Rubber-tired Valmet 892 forwarder (14-ton capacity).

[d] Tracked Timbco 445 feller-buncher with Quadco Hot-Saw felling head of 20-inch capacity.

[e] Tracked Kabelco 200 single-grip, cut-to-length harvester with Kato 500 saw head.

[f] Rubber-tired Cat 518 skidder with swinging grapples.

Assessment Procedures

Soil disturbance was assessed from July 20 to August 9, 2000, by using procedures adapted from Howes and others (1983). Soil compaction was not evaluated at this time, so this study reports **visual soil disturbance only**. A systematic grid orientated randomly on steep units (fig. 1) or in cardinal directions on flat units (fig. 2) provided starting points for randomly oriented soil-disturbance transects. Sampling intensity was about one transect per acre on steep units and one transect per two acres on flat units. At each starting point, a measuring tape was laid along a random bearing to a distance of 100 feet (no slope correction). Soil disturbance intercepted by this transect was classified and measured to the nearest foot. The length of each disturbance class was summed in each transect and for all transects within a unit to estimate mean percentage of visual disturbance. Each transect mean is an observation, and the difference among these transect means is a measure of variation.

The potential sampling area in each unit included permanent and temporary roads. The following categories were used to classify soil disturbance along each 100-foot transect:

- Trail—Area between the inside edges of lateral berms made by ground-based equipment used to harvest, process, and transport material to landing areas. Designated trails and supplemental, operator-selected trails were classified as trails.
- Landing—Area used to process and store harvested material before transport to mills.
- Spur road—Permanent or temporary road system around and within the units used by trucks to haul harvested material from landing areas to mills.
- Displacement—Area of at least 100 square feet and at least 5 feet in width in which greater than 50 percent of the A horizon has been removed (USDA FS 1998). This is considered "detrimental" displacement.
- Erosion—Visual evidence of surface loss in an area greater than 100 square feet, owing to rills, gullies, or sheet erosion (USDA FS 1998). This is considered detrimental erosion.
- Rutting—Depths of ruts or imprints is 6 inches or more. Soil deformation and loss of structure are observable, and usually bulk density is increased (USDA FS 1998). Also known as puddling and considered detrimental rutting.

If more than one disturbance occurred in the same place, then the disturbance with the largest area was recorded, and the other disturbance was noted. This situation occurred on trails where displacement or rutting was also present. Data were summarized by calculating the arithmetic mean, standard error, and 90 percent confidence intervals for each disturbance category among all transects within a unit. Statistical tests for differences among the units were not performed because units had different combinations of harvesting equipment and trail spacing; therefore, no replications existed for computing experimental error.

Results

Of the six disturbance categories, only those that were sampled on at least one unit are included in the results (table 4). Erosion was not observed, whereas displacement and rutting were found in conjunction with trails. The trail category represented the largest percentage sampled on each unit, ranging from 19 to 30 percent of the area on steep units and 13 to 38 percent on flat units (table 4). All trails showed visual evidence of recent use.

Small-sample confidence limits (p = 0.10) were calculated according to Freese (1962) and are given in table 4. These 90 percent confidence limits are important for data interpretation because they estimate the range in which the true mean percentage of disturbance area resides. For example, sampling on unit 8 showed trails had an average (mean) area of 19.4 percent. We can be 90-percent confident that the true skid trail percentage lies somewhere within the interval, 11.8 to 27.0.

Spur roads were only transected on steep units (table 4), ranging from 1 to 8 percent of a unit's total area. The large estimated percentage of spur roads on unit 9 (8 percent) probably was due to several randomly located transects that crossed the temporary spur road bordering this unit. Even though spur roads were present on flat units, they were not sampled by the random transects. Although landing areas were present in all units, a landing was sampled only on unit 8; transects on other units did not intersect landings.

Variation among transects was large for landings and spur roads (table 4). Large standard errors resulted either from (1) a disturbance type being present in a small proportion of transects or (2) a disturbance sampled at an unusually high or low rate on one or two transects compared to other transects on the unit.

Area not accounted for by trails, landings, or spur roads consisted of a combination of undisturbed ground and disturbances that did not meet the spatial criteria for the disturbance categories listed above.

Severe displacement occurred on trails of steep unit 9. To allow equipment to get from the road to the stand, the trails cut several feet into the subsoil on the cut-bank (about 6 feet high) adjoining the spur road. Severe displacement was not present on trails located on other portions of unit 9. One trail on unit 4 had severe rutting in an area that was probably wet at the time of operation. Rutting also was observed on steep units 16 and 17 consisting of bared strips of soil about 3 feet wide located in the track areas of trails. This rutting was much more common on unit 16 compared with unit 17 (15 percent versus 2 percent of total area, respectively).

Discussion

Harvesting Methods

Harvesting methods that resulted in both the most and least visual disturbance were found on flat terrain. Whole-tree harvesting with a combination of feller-buncher, CTL harvester, and forwarder on flat ground (unit 19) created the most area in trails (38 percent). This slightly exceeds the theoretical skid trail coverage of 35 percent with 40-foot spacing. Chainsaw-felling of trees in combination with a CTL harvester and forwarder with 130-foot spacing on flat ground (unit 2) had the least area in trails (13 percent vs. theoretical 11 percent). The low percentage of trail coverage in flat unit 2 has two explanations: lowest percentage of trees and basal area cut (table 2) and designated trail spacing of 130 feet (table 3).

Table 4—Percentage of harvested area in specified categories of visual soil disturbance after commercial thinning, by harvest unit

Item	Steep units (and number of transects)				Flat units (and number of transects)			
	Unit 8 (14)	Unit 9 (16)	Unit 16 (14)	Unit 17 (17)	Unit 2 (13)	Unit 3 (14)	Unit 4 (10)	Unit 19 (8)
Method[a]	HSu	HFw	FbSd	HSd	HFw	HFw	FbSk	FbHFw
Trail spacing (feet)	40	40	40	40	130	40	130	130
				Percent				
Trails:								
Mean	19.4	27.5	25.4	29.8	12.5	28.9	27.8	37.5
SE[b]	4.3	2.8	3.1	4.5	13.9	8.2	14.3	23.2
CI lower[c]	11.8	22.6	19.9	21.9	5.5	25.0	19.6	22.0
CI upper[c]	27.0	32.4	30.9	37.7	19.5	32.8	36.0	53.0
Landings:								
Mean	.7	—	—	—	—	—	—	—
SE	.7	—	—	—	—	—	—	—
CI lower	-.5	—	—	—	—	—	—	—
CI upper	1.9	—	—	—	—	—	—	—
Spur roads:								
Mean	2.8	7.6	1.6	1.1	—	—	—	—
SE	2.8	3.6	1.6	1.1	—	—	—	—
CI lower	-2.2	1.3	-1.2	-.8	—	—	—	—
CI upper	7.8	13.9	4.4	3.0	—	—	—	—

— = no disturbances in this category were sampled.

[a] Harvesting methods used: H = harvester; Su = uphill Fw = forwarder; Fb = feller-buncher; Sd = downhill skyline; Sk = skidder.

[b] SE = standard error of the arithmetic mean for the sample.

[c] CI = lower and upper limits for 90 percent (p = 10) confidence interval (Freese 1962).

The combination of harvester and uphill skyline (unit 8) had the least visual disturbance of the steep units (23 percent total, 19 percent skid trails). A harvester with downhill skyline on 130-foot spacing (unit 17) produced more skid trails than did a feller-buncher with downhill skyline on 40-foot spacing (unit 16). Unit 16 had much more rutting in the skid trails compared with unit 17, probably owing to the whole-tree processing used on unit 16 that did not leave slash on the skid trails. The resulting bare ground was subjected to feller-buncher traffic and the potential for partially suspended logs to create additional disturbance.

It cannot be determined directly from this study what proportion of disturbance was caused by ground-based equipment versus skyline yarding on steep units because the study was conducted 2 years after operations were completed. Separate sampling would be required for ground-based and skyline operations to attribute disturbances to specific operations. This may not be realistic from an operational standpoint because all ground-based operations would need to be completed, and then harvesting temporarily stopped to allow sampling before skyline operations resumed to yard material to landing areas.

When combined with chainsaw felling, skyline yarding usually causes less overall soil disturbance than ground-based yarding (Allen and others 1999, Cromack and others 1978, Dyrness 1965, Miller and Sirois 1986). Youngblood (2000), however, concluded that partial suspension of logs on skyline units on ash-derived soil exposed more mineral soil than did forwarders. Youngblood examined both the area of exposed mineral soil and rutting (depressions in mineral soil 1 inch deep) on six units of the Limber Jim Fuel Reduction Project on the Wallowa-Whitman NF. Treatments on Limber Jim were similar to those of steep units in this study: trees felled with a CTL harvester, processed logs piled next to the trails, and a forwarder or skyline used to transport logs to landings. Exposed soil percentages ranged from 0.6 to 3.7 percent from the forwarder and 5.7 to 10.2 percent from skyline. Although rutting ranged from 4.7 to 14.6 percent for the forwarder and 7.3 to 9.8 percent for the skyline, no consistent differences were found between the yarding methods (Youngblood 2000).

Trail Spacing

Designated-trail spacing appears to have little influence on percentage of area in trails. For all units, trails designated at 130-foot spacing averaged 25.9 percent (range: 12.5 to 37.5 percent) compared to 26.2 percent (range: 19.4 to 29.8 percent) for trails designated at 40-foot spacing (table 4). Theoretically, 130-foot spacing should result in about 11 percent skid trails, and 40-foot spacing should have about 35 percent skid trails, when trails are 14 feet wide.

To determine if each unit was within theoretical limits, the theoretical trail percentages can be compared to the 90 percent confidence intervals for sampled trails (table 4). With 40-foot trail spacing, four of the five units had an upper confidence limit that was less than the theoretical 35-percent coverage, and the confidence interval for unit 17 contained the theoretical 35 percent. These results indicate that compliance to the 40-foot spacing criteria was good, and supplemental trails were not created.

With 130-foot trail spacing, compliance does not appear as good. Only the confidence interval for unit 2 contained the theoretical 11-percent trail area (table 4). Confidence intervals for units 4 and 19 were above the 11-percent theoretical area for 130-foot spacing. These results indicate that unit 2 had good compliance with 130-foot spacing criteria, whereas units 4 and 19 had trail coverage that exceeded the theoretical 11 percent. Deviation from the designated 130-foot center-to-center trail spacing is not surprising given the distance between trails. If one assumes a 30-foot reach by the harvesting equipment on a 14-foot-wide trail, then there would be an area 56 feet wide between the trails that equipment could not reach. A supplemental trail made between the designated trails to harvest material originally missed would have been counted as a trail in my assessment. This explanation likely is supported by differences in number of trees removed (table 2). The removal of 24 percent of the initial trees in unit 2 was probably accomplished by the harvester remaining on the designated trail; fewer trees beyond the 30-foot reach of this equipment were cut. To remove 40 or 57 percent (units 4 and 19, respectively), supplemental trails were used.

Another explanation for the differences between observed and theorized trail-spacing percentages include the random location of transects (sampling error). An example of sampling error is unit 19, where two transects fell within trails, resulting in much higher trail percentage (37.5) compared with other transects on the unit. These two transects had a strong influence on the final statistics because they were one-quarter of the total transects for the unit.

Using similar monitoring methods, Sullivan (1988) reported only 8 percent in skid trail area for a commercial thinning on the Malheur NF that used a tracked D6 or smaller and a rubber-tired Cat 518 skidder (as used at Fritz unit 4). The area of all trails (primary, secondary, tertiary) was estimated: skid trails were not designated but selected by the equipment operators.[3] The Malheur site was characterized as a light to medium thinning.[4] At the Fritz sale, percentage of trees removed on the Colville NF ranged from 24 to 70 percent (table 2), and trail area (designated and supplemental) was about fourfold greater, in part, because designated trails were 14 feet wide. I have no further explanation for this discrepancy.

Trail Slash

Slash placed by the tracked harvesters appeared to reduce soil rutting on skid trails in steep units. Based on visual appearance, units in decreasing order of amount of slash left on trails were unit 8, unit 17, unit 9, and unit 16. Slash was not left intentionally on trails of unit 16 (table 3) because whole trees were yarded rather than being processed into logs before yarding. Original low stand density (table 2) appeared to minimize the amount of slash left on unit 9.

Slash left on trails of flat units also appeared to reduce rutting. Severe rutting was observed only in unit 4 where little woody debris remained on trails because a rubber-tired skidder was used to pull whole trees to landing areas. The amount of slash appeared to vary along individual trails within a unit, possibly a result of the number of trees processed in any one location.

Seixas and others (1995) suggest leaving slash on the skid trails if multiple passes will be made over the same trails. They left three experimental amounts of slash on skid trails (0, 2, and 4 pounds per square foot) and measured compaction (soil bulk density) after one and five passes of a forwarder. After one pass, no difference in compaction was measured among the three slash amounts. After five passes, compaction increased where no slash was present but did not increase with slash present (either amount).

Regional Standards and Needed Future Research

National forests of the Pacific Northwest Region have the regional standards that no more than 20 percent of the soil in an activity area may be in a “detrimentally damaged” state (USDA FS 1998). This 20-percent area limit for detrimental soil damage was set to achieve the objectives of maintaining or improving soil and water quality, and to

---

[3] Sullivan, T. 2001. Personal communication. Soil scientist, USDA Forest Service, Rocky Mountain Region, P.O. Box 25127, Lakewood, CO 80225.

[4] Sullivan, T. 2001. Re: China thin—How much removed? tsullivan01@fs.fed.us (2 February).

avoid permanently impairing land productivity (USDA FS 1998). Allowances are made in the standards for areas subjected to prior activity. The standards define a threshold condition at which soil is considered detrimentally damaged: compacted, puddled, displaced, severely burned, or eroded.

McMahon (1995) cautions that disturbance assessment provides only an estimate of actual disturbance levels. After comparing the accuracy and repeatability of conventionally used point and line transect methods, he stated (p. 32):

> In operational situations, where single ground surveys are being used to assess site disturbance, it is necessary to recognize the inherent variability in estimated results. This is particularly important when using the assessment results to determine compliance with a quantitative standard. For instance, if statutory regulations stipulate specific limits on allowed disturbance, then a result which exceeds the limit by several percent may not truly reflect the level of disturbance but may actually reflect the extent of method consistency. The same also applies to estimates that are several percent less than the limit value. Thus, it is recommended that the accuracy and consistency of the method being used are known, and that interpretations and regulatory standards recognize method limitations.

The Fritz sale units come close to meeting regional standards. Although some steep units and flat units had had a prior salvage harvest, old skid trails were not counted in this assessment. Because trails were the major disturbance category sampled, the 90 percent confidence intervals about the unit means (table 4) could be used to judge whether a unit met the 20-percent area of disturbance standard. This assumes that designated trails were detrimentally compacted, which may or may not be accurate, especially where harvesters traveled over slash. If confidence intervals were below the 20-percent area limit, then the unit would be considered within the regional limits. If confidence intervals contain the 20-percent area, the unit may or may not be within regional limits. Three units (8, 16, and 4) may or may not be within regional limits, and four units (9, 17, 3, and 19) exceeded regional limits for area of disturbed soil. Only unit 2 had 90 percent confidence intervals below 20 percent (5.5, 19.5). The other units had lower limits 2 to 5 percent greater than the 20-percent limit, with upper limits ranging from 27 to 53 percent. Remediation is a possible solution. Plans can be implemented to rehabilitate skid trails, temporary roads, and landings that would reduce detrimental damage and reclassify the units toward compliance with the 20-percent area limit.

The objective of maintaining soil quality without permanent impairment of land productivity has both temporal and spatial considerations. The term “permanent impairment” causes difficulty because it implies the detrimentally damaged soil will not return to its original productive capacity. A disturbance category that would come closest to permanently impairing productivity is a road that is a part of the permanent road system. Other categories (skid trails used to extract trees, landings used to process the trees, and temporary roads used to transport material to permanent roads) can all be rehabilitated to reduce effects from the harvesting operation. Even without rehabilitation, these areas eventually would be able to support tree growth as the soil recovers naturally.

Compaction is an example of a disturbance in Northwest forests that provides different results over time. Miller and others (1996) compared growth of three conifer species planted on and off skid trails on three clearcut sites in western Washington. Despite growth reductions in year 2 and residual increases in bulk density of skid trails greater than 20 percent that remained 8 years after planting, no significant differences in tree height and volume existed between trees planted on and off skid trails, with the exception of small but statistically significant growth reductions at one site for western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). Wass and Smith (1997) report similar results for lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) 10 years after planting in British Columbia. In some coarse-textured soils, compacted soil may improve tree growth by providing physical soil conditions that favorably influence tree growth compared with undisturbed areas (Powers and Fiddler 1997).

More research is clearly needed to quantify the effects of soil disturbance on site productivity. Specifically, validating the assumptions of regional standards is needed: To what extent do detrimental soil conditions (compaction, displacement, severely burned, eroded, puddled) actually impair land productivity? For example, detrimental compaction for volcanic ash or pumice soils is defined as a 20-percent increase in bulk density over undisturbed conditions (USDA FS 1998). How much does a 20-percent increase in bulk density impair land productivity and for how long? Validation is needed in a variety of locations and vegetation types in the Pacific Northwest to determine the consequence of detrimental soil conditions in different areas, conditions, and timeframes. Finally, validation should be conducted after commercial harvests, so results accurately reflect operational conditions under which standards are applied.

Conclusions

On 10- to 15-percent slopes, commercial thinning with a feller-buncher, CTL harvester, and forwarder (40-foot trail spacing) resulted in the most visual disturbance of all units assessed. In contrast, a CTL harvester and forwarder with 130-foot spacing had the least visual disturbance of all units. On slopes exceeding about 30 percent, the combination of CTL harvester and uphill skyline had the least visual disturbance of those units that used the combination of ground-based equipment and skyline yarding. Although spur roads and landing areas existed, their area was poorly estimated by the randomly located transects.

Compliance to designated 40-foot trail spacing was good, but two of three units did not appear to comply with 130-foot spacing, based on estimated vs. theoretical trail percentages. With such wide spacing between designated trails, the machine operator had either to leave the trail to cut intervening trees or leave these trees uncut. Placing slash on trails in front of equipment appeared to reduce rutting and displacement. Four units may have exceeded the Pacific Northwest Region’s standard for leaving at least 80 percent of the activity area without detrimental damage; however, damaged areas can be rehabilitated.

Insufficient knowledge exists about the effects that different types of disturbance have on soil productive capacity; validation research is clearly needed. Validation should be conducted on operational timber sales to reflect conditions under which standards are applied.

Acknowledgments

I thank Joan Landsberg for the opportunity to conduct this project, Joanna Behrens for assisting with fieldwork, John Lehmkuhl and Roger Fight for providing the funding to summarize and publish the data, and Richard Miller and anonymous reviewers for reviewing earlier drafts of the manuscript. Thanks also to Dave Newton, Gary Nielsen, and Tom Pawley from the Colville National Forest for administering the commercial thinning and providing helpful information. Research was conducted as part of the Creating Opportunities (CROP) appropriations bill from the U.S. Congress.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches	2.45	Centimeters
Feet	.304	Meters
Acres	.405	Hectares
Pounds per square foot	4.9	Kilograms per square meter

Literature Cited

Allen, M.M.; Taratoot, M.; Adams, P.W. 1999. Soil compaction and disturbance from skyline and mechanized partial cuttings for multiple resource objectives in western and northeastern Oregon, U.S.A. In: Sessions, J.; Chung, W., eds. Proceedings of the international mountain logging and 10th Pacific Northwest skyline symposium. [Corvallis, OR]: [Oregon State University, Department of Forest Engineering]: 107-117.

Cromack, K., Jr.; Swanson, F.J.; Grier, C.C. 1978. A comparison of harvesting methods and their impact on soils and environment in the Pacific Northwest. In: Youngberg, C.T., ed. Forest soils and land use: proceedings of the fifth North American forest soils conference. Fort Collins, CO: Colorado State University, Department of Forest and Wood Sciences: 449-476.

Dyrness, C.T. 1965. Soil surface compaction following tractor and high-lead logging in the Oregon Cascades. Journal of Forestry. 63: 272-275.

Freese, F. 1962. Elementary forest sampling. Agric. Handb. 232. Washington, DC: U.S. Department of Agriculture, Forest Service. 91 p.

Howes, S.W.; Hazard, J.W.; Geist, J.M. 1983. Guidelines for sampling some physical conditions of surface soils. R6-RWM-146. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 34 p.

Landsberg, J.D.; Miller, R.E.; Anderson, H.W.; Tepp, J.S. [In press]. Bulk density and soil resistance to penetration as affected by commercial thinning in northeastern Washington. Res. Pap. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

McMahon, S. 1995. Accuracy of two ground survey methods for assessing site disturbance. Journal of Forest Engineering. 6(2): 27-33.

Miller, J.H.; Sirois, D.L. 1986. Soil disturbance by skyline yarding vs. skidding in a loamy hill forest. Soil Science Society of America Journal. 50: 1579-1583.

Miller, R.E.; Scott, W.; Hazard, J.W. 1996. Soil compaction and conifer growth after tractor yarding at three coastal Washington locations. Canadian Journal of Forest Research. 26: 225-236.

Powers, R.F.; Fiddler, G.O. 1997. The North American long-term soil productivity study: progress through the first 5 years. In: Proceedings of the 18th annual forest vegetation management conference. Redding, CA: Forest Vegetation Management Conference: 88-102.

Seixas, F.; McDonald, T.P.; Stokes, B.J. [and others]. 1995. Effect of slash on forwarder soil compaction. In: Proceedings of the Council on Forest Engineering's 18th annual meeting: sustainability, forest health and meeting the nation's needs for wood products. [Raleigh, NC]: [North Carolina State University]: 77-86.

Sullivan, T.E. 1988. Monitoring soil physical conditions on a national forest in eastern Oregon: a case study. In: Lawson, T., tech. coord. Proceedings of the Alaska forest soil productivity workshop. Gen. Tech. Rep. PNW-GTR-219. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 69-76.

U.S. Department of Agriculture, Forest Service. 1998. Watershed protection and management. FSM 2520, R-6 Supplement 2500-98-1, effective August 24, 1998. 6 p.

Wass, E.F.; Smith, R.B. 1997. Impacts of cross-contour skidroads on properties of a gravelly sandy loam soil and on planted seedling performance. Inf. Rep. BC-X-369. Victoria, BC: Canadian Forest Service, Pacific Forestry Centre. 38 p.

Youngblood, A. 2000. Damage to residual trees and advance regeneration from skyline and forwarder yarding in mixed-conifer stands of northeastern Oregon. Western Journal of Applied Forestry. 15(2): 101-107.

Zulauf, A.; Starr, W.A. 1979. Soil survey of North Ferry area, Washington, parts of Ferry and Steven Counties. Pullman, WA: U.S. Department of Agriculture, Soil Conservation Service and Forest Service; Washington Agricultural Experiment Station. 121 p. (plus 73 maps.)

This page has been left blank intentionally.
Document continues on next page.

This page has been left blank intentionally.
Document continues on next page.

This page has been left blank intentionally.
Document continues on next page.

Pacific Northwest Research Station

Web site	http://www.fs.fed.us/pnw
Telephone	(503) 808-2592
Publication requests	(503) 808-2138
FAX	(503) 808-2130
E-mail	pnw_pnwpubs@fs.fed.us
Mailing address	Publications Distribution Pacific Northwest Research Station P.O. Box 3890 Portland, OR 97208-3890

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208-3890