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SOIL DISTURBANCE MONITORING FOR THE SMALL-PARCEL MECHANIZED FUEL REDUCTION DEMONSTRATION PROJECT USING SMALL MECHANICAL HARVEST EQUIPMENT

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Abstract

Soil resistance to penetration was measured with a Lang Penetrometer[tm] and soil surface disturbance was monitored prior to and following mechanical fuel reduction thinning on small-parcels (5-10 acres) in the northern Sierra Nevada. The mechanical fuel reduction thinning was performed using a small skid-steer with interchangeable attachments for mastication of brush and small trees, small tree (6-10 inches dbh) falling, log processing and grapple skidding of logs.

The monitoring was conducted at seven sites and found that there was a small increase of 1.6 pounds of increased resistance to penetration caused by the equipment used to perform the fuel reduction. The rubber-tracked skid steer caused minimal ground surface disturbance with 92 percent of the sample locations still covered with duff and litter.

Background

While the primary goal of the Small-Parcel Fuel Reduction and Utilization demonstration project was to demonstrate the suitability of a small skid-steer and attachments for fuel reduction thinning near homes, a secondary goal was to describe the disturbance of the mechanized thinning on the soil. The skid-steer used was an ASV Posi-Track HD4520[1]. The ASV Posi-Track HD 4520 is a small, light-weight, all-purpose rubber-tracked crawler with a ground pressure rating of less than 3.0 psi. These characteristics are thought to minimize soil disturbance as well as be more acceptable to the owners of small forested parcels conducting fuel reduction.

Another secondary goal of the project was to develop simple and inexpensive monitoring techniques that can be used to characterize the impacts of mechanized fuel reduction thinning.

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Soil disturbance caused by mechanized forest thinning is an important environmental concern. Significant soil disturbance may result in a decrease of biological productivity and it may contribute to erosion and water course sedimentation as a result of soil compaction that may decrease water infiltration. Significantly compacted soil associated with skid trails has been found to inhibit tree establishment and stunt growth (Froelich 1979).

Bulk density is the standard measure of soil compaction. Bulk density describes the soil's relative air space or water retention capacity (Nelson, 1994). Soil bulk density is defined as the ratio of the mass of dry solids to the bulk volume of the soil occupied by those dry solids. Bulk density of the soil is an important site characterization parameter since it changes for a given soil. It varies with structural condition of the soil, particularly that related to packing. However, for simple monitoring purposes it can be difficult and expensive to quantify bulk density because of the number of samples required, the logistics of managing the samples and the requirement for laboratory analysis of soil samples.

Penetrometers can be used to quantify soil compaction in terms of the soil's resistance to penetration. Concurrent measurements of bulk density and resistance to penetration have been compared in a few soil studies. Resistance to penetration was found to be related positively to soil bulk density by Allbrook (1986), Clayton (1990), and Sands and others (1979). They also reported that compacted soils can show strong increases in soil strength, yet only small increases in bulk density.

Lang Penetrometer use has been documented in a limited number of soil compaction studies. The Lang Penetrometer measures penetration resistance to a depth of 3.5 inches in pounds. There is a good relationship between soil bulk density and soil surface resistance to penetration as a measure of soil surface compaction as measured with a Lang Pentrometer unless the soil is sealed or crusted (Ziegler pers. comm. 2004).

Ziegler et al (2001) determined soil bulk density and used a Lang Penetrometer to measure road resistance to penetration and the effect on runoff. Ziegler found that both bulk density and penetration resistance are negatively correlated with time to runoff. Buckley et al (2003) used a Lang Penetrometer to measure compaction in forests with haul road and skid trails where they found that compaction was greatest in the haul roads, then the skid trails with little in the forest without soil disturbance.

Soil moisture will influence resistance to penetration. Wet soils generally are more easily penetrated; while resistance to penetration and bulk density increases with soil drying in most soils with clay types and organic matter, which shrink when dried (Landsberg et 2003). Because of the influence of soil moisture on resistance to penetration it is important to take measures when the soil moisture is similar.

Methods

Two approaches were used to characterize the effect of the thinning on the soil with the ASV Posi-Track harvest system (Table 1).

Table 1. Approaches used to describe soil effects.

Soil Parameter	Method	Variable(s)	Units
1. Penetration Resistance (PR)	Lang Penetrometer	Force	Lbs
2. Surface Disturbance	Visual Soil Assessment Protocol	Disturbance Class	Value of 0-12

A Lang Penetrometer (Figure 1) was used to test the hypothesis that surface soil resistance to penetration (PR) was not significantly increased by thinning for fuel reduction using the skid-steer based harvest system.

Soil monitoring was conducted at seven of the nine fuel reduction demonstration sites immediately prior to and immediately following treatment so that soil moisture would be nearly the same. At least one monitoring point was established for each acre of treatment

Figure 1 Lang Penetrometer used to measure soil resistance to penetration.

area (Figure 2). Each monitoring point included three 100-foot transects for soil resistance to penetration sampling and soil surface disturbance monitoring. The first transect was selected by observing seconds displayed on a wrist watch upon arrival at the plot and converting it to azimuth. For example arrival with 10 seconds displayed would result in a transect bearing of 60 degrees. The second and third transects were located 90 degrees from the previous transect. Along each transect there were 10 sample points, spaced approximately 10 feet apart, where both resistance to penetration was measured and soil surface disturbance was assessed. The sample point was not the exact same location during the pre-treatment and post-treatment sampling; however they were generally within a few feet. Five measurements of resistance to penetration were collected at each of the sample points which were then averaged for analysis. Thus, a total of 50 penetration resistance measurements were collected from each transect yielding 150 measurements at each plot. In some cases 50 samples could not be collected because the transect was located near the treatment area boundary, crossed a driveway or access road or the soil was too rocky. All measurements were averaged for each demonstration site for comparison. Soil moisture and soil bulk density was not determined because of limitations associated with the wide distribution of the demonstration sites and additional complexities beyond that of conducting the equipment time and motion study.

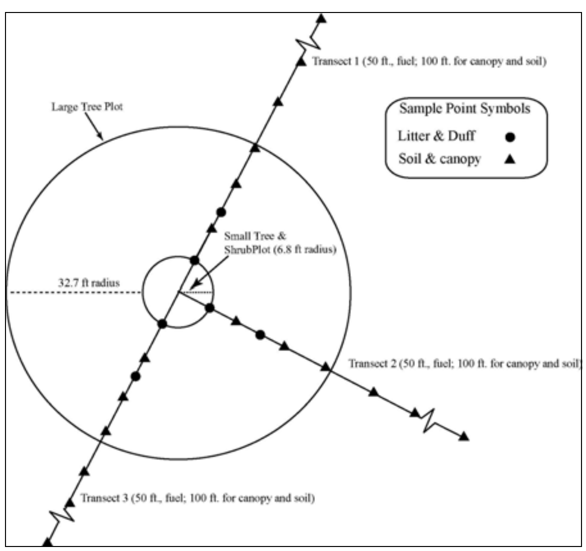

Figure 2 Soil monitoring transect layout.

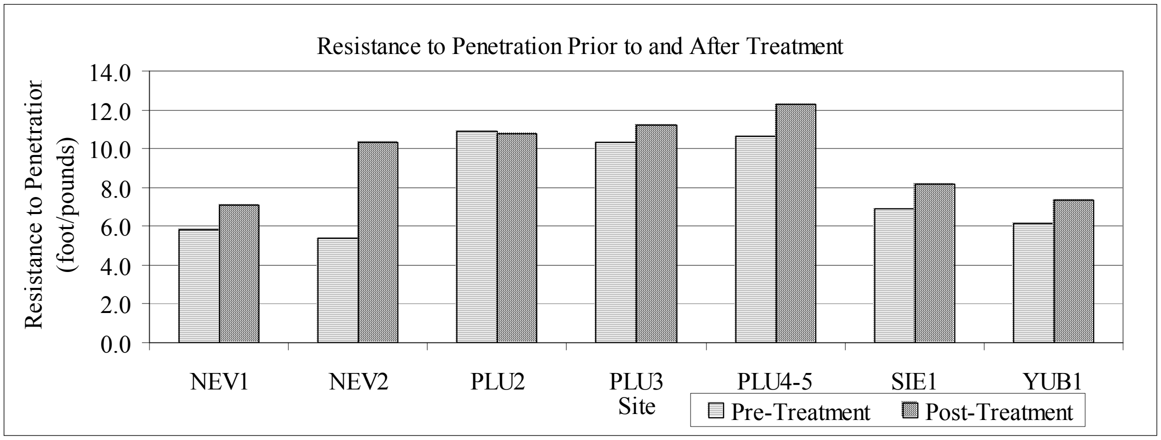

Figure 3. Composite resistance to penetration prior to and following treatment by site.

and modified by Howes (2002) USFS Soils Program Manager for Washington and Oregon. The soil disturbance class values range from “0” to “6.” Increasing values represent greater levels of soil disturbance. Soil surface conditions were observed and segregated into categories ranging from no soil disturbance to massive, drainage altering disturbance. The disturbance categories are described in Appendix A. The disturbance

Surface disturbance was described using a qualitative system, developed by Weyerhauser class distribution was summarized for both pre- and post-treatment.

Results

1. Soil Resistance to Penetration

The spring of 2003 was exceptionally wet. Precipitation in the form of rain or snow was experienced at all sites except PLU2 and PLU3 which were treated in the fall.

Soil surface resistance to penetration, at least to a depth of 3.5 inches, was increased following treatment. The composite average resistance to penetration for all sites before treatment was 8.5 pounds (Table 2). After treatment the resistance to penetration was 10.1 pounds. The average pre- and post-treatment difference for all sites ranged from 0.1 pound to 4.9 pounds (Figure 3).

Table 2. Summary statistics for soil penetration resistance by site.

		Pre-Treatment				Post-Treatment				
Site	No. of Plots	Date	Mean	Std. Dev.	n	Date	Mean	Std. Dev.	n	Difference
NEV1	3	4/28	5.8	4.6	83	5/2	7.1	4.2	80	1.3
NEV2	3	4/17	5.4	4.3	90	6/25	10.3	5.9	89	4.9
PLU2	5	10/16	10.9	5.5	138	10/28	10.8	5.1	141	-0.1
PLU3	3	10/19	10.3	5.7	72	10/29	11.2	5.3	71	0.9
PLU4-5	3	4/9	10.7	5.1	73	6/5	12.3	5.3	73	1.6
SIE1	3	5/8	6.9	4.5	31	5/14	8.2	4.9	26	1.3
YUB1	1	5/5	6.1	6.1	25	5/8	7.3	6.1	25	1.2
All Sites			8.5	6.1	512		10.1	5.7	505	1.6

2. Soil Disturbance Assessment

Many of the sites had been logged in the past so the soil was not “undisturbed” or in a “natural state”. Characterizing a site as “undisturbed” was based upon the presence of intact and well-established duff and litter layers and intact surface soil (A horizon) with no exposed surface soil and no signs of past equipment use.

The soil surface disturbance assessment results are summarized in Figure 4. Prior to treatment 87 percent of the sample locations were characterized as “undisturbed” and 13 percent were characterized as showing “slight disturbance” (Figure 5). Following treatment 35 percent of the sample locations were classified as “undisturbed” while 40 percent were characterized with “slight disturbance” because of slight depressions from

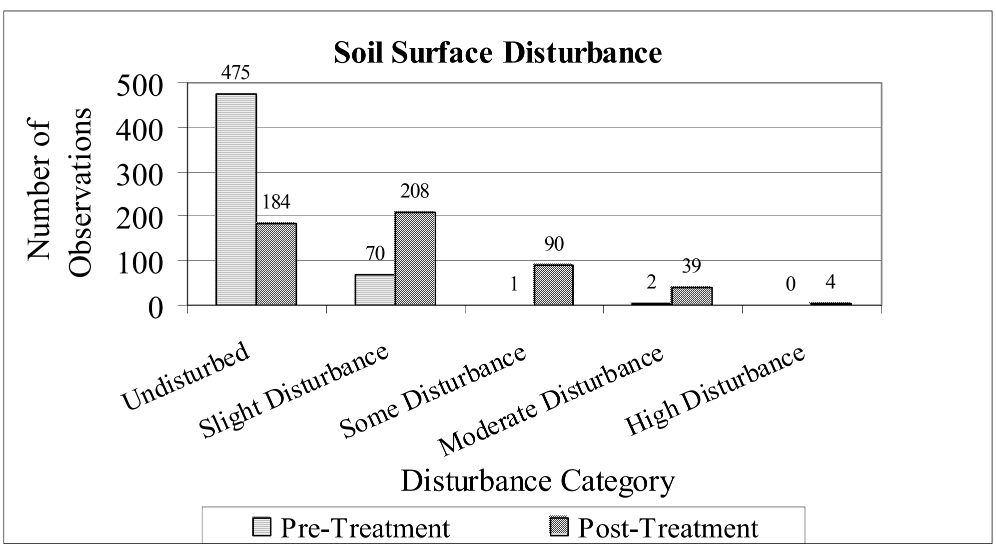

Figure 4 Soil surface disturbance classification prior to and following treatment.

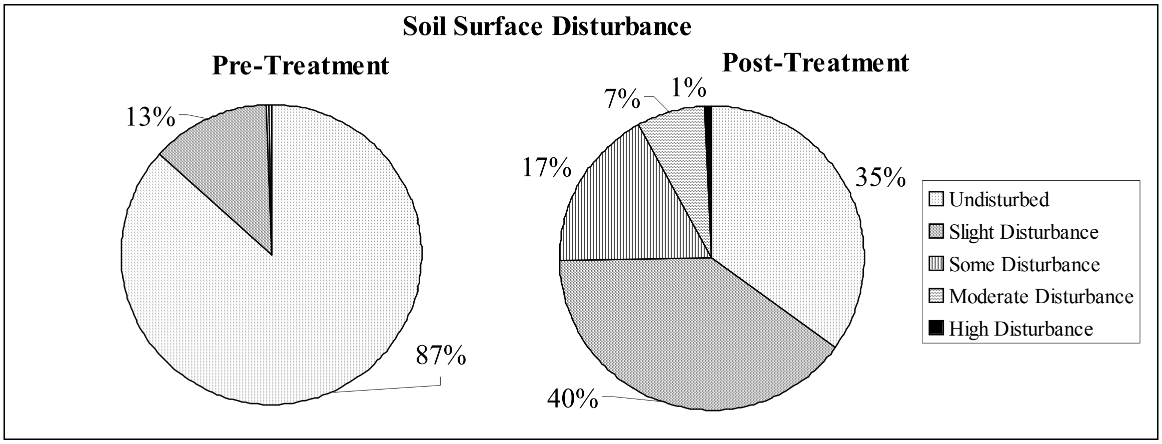

Figure 5 Pre- and post-treatment soil surface disturbance.

the tracks with the litter and duff layers still intact. "Some disturbance" was identified on 17 percent of the sample sites following treatment while 7 percent were determined to display "moderate disturbance" characteristics because litter and duff was only partially intact or missing and equipment tracks were clearly evident. Only 1 percent of the sample locations were determined to be "highly disturbed".

Conclusions

The fuel reduction thinning using a skid-steer did cause soil compaction and soil disturbance. However, the compaction appears to be minimal with an average increase in resistance to penetration 1.6 pounds for all sites and a range of 0.1 to 4.9 pounds.

The soil surface was disturbed, however the disturbance was minimal. Overall 92 percent of the sample locations were either "undisturbed", showed "slight disturbance" or "some disturbance" with old litter and duff layers remaining intact. Another 7 percent of the sample points indicated "moderate disturbance" with old litter and duff partially intact or missing and evidence of equipment tracks.

The techniques used to monitor the project would seem to be appropriate for low cost monitoring of soil impacts caused by harvest activities. The Lang Penetrometer seems to be a useful tool to measure resistance to penetration. However, additional work should be done to better quantify the relationship between the Lang Penetrometer and soil bulk density and perhaps a cone penetrometer.

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Appendix A: Visual Soil Assessment Class Descriptions

Existing (Pre-thinning) Soil Disturbance:

Class 0	Undisturbed	No evidence of past equipment operation. Soils are undisturbed or considered to be in a natural state.
Class 1	Slight Disturbance	Site is virtually undisturbed. Old litter and duff layers intact. Vegetation present or redeveloping with well established root systems. Some faint impressions of heel tracks or slight depressions evident. Surface soils (A horizons) intact. Surface soil structure unaffected by past equipment operation. No evidence of platiness developing in surface soils.
Class 2	Some Disturbance	Site is virtually undisturbed. Old litter and duff layers intact. Vegetation present or redeveloping with well established root systems. Some visible indications of past equipment operation. Surface soils (A horizons) intact but may show some signs of compaction (i.e. minor amounts or discontinuous platiness at soil surface). No evidence of surface soil removal.
Class 3	Moderate Disturbance	Old litter and duff layer partially intact or missing. New litter layer developing. Vegetation present or redeveloping. Surface soils (A horizons) intact but show evidence of compaction and puddling (surface platiness or lack of structure). Depressions of old wheel tracks evident. Small amounts of surface soil removal.
Class 4	High Disturbance	Old litter land duff layer removed. New litter layer may be redeveloping. Surface soils (A horizons) partially or totally removed or mixed with subsoil material. Evidence of surface soil removal. Some pedestalling at base of trees.
Class 5	Severe Disturbance	Old litter and duff layer removed. New litter layer redeveloping or absent. Evidence of excessive or extreme surface soil removal. Surface soils (A horizon) absent. Subsoils exposed, compacted, or removed.
Class 6	Altered Drainage	Alteration of internal soil drainage characteristics. Results in permanently saturated soils or standing water.

New (Post-treatment) Soil Disturbance:

Class 0	Undisturbed	No evidence of equipment operation. Soils are undisturbed or are considered to be in a natural state.
Class 1	Slight Disturbance	Site is virtually undisturbed. Litter and duff layers intact. Surface soil (A horizons) intact. Impressions of wheel tracks or slight depressions in surface soils may be present. No exposed surface soils (unless natural). No exposed subsoils.
Class 2	Some Disturbance	Litter and duff layers generally intact. Surface soils (A horizon) intact but may show some evidence of platiness. No evidence of surface soil removal or deposition.
Class 3	Moderate Disturbance	Litter and duff layers only partially intact or missing. Surface soil (A horizons) intact but shows evidence of platiness or lack or structure. Equipment tire tracks or cleat marks evident.
Class 4	High Disturbance	Litter and duff layers totally removed. Surface soils (A horizons) partially removed or may be mixed with subsoil material. Surface soil structure destroyed (large, thick plates instead of granular or crumb structure). Some shiny or slick appearing soil surfaces may be present.
Class 5	Severe Disturbance	Litter and duff layers totally removed. Surface soils (A horizons) nearly all or completely removed. Evidence of topsoil removal and/or gouging. Subsoils partially or totally exposed.
Class 6	Altered Drainage	Alteration of internal soil drainage characteristics by equipment operation. Results in permanently saturated soils or standing water.