## TECHNICAL NOTE

# Effectiveness of a Winged Subsoiler in Ameliorating a Compacted Clayey Forest Soil

Scott Davis[1]

Machine piling of slash and brush after harvest is commonly practiced when establishing new conifer plantations. However, it can result in increased soil bulk density, decreased soil macroporosity, and increased soil strength, thus reducing conifer root development and above-ground growth (Froehlich 1979, Sands and Bowen 1978).

Because natural recovery of soil from compaction is slow, ways have been sought to restore compacted soils through tillage. Brush rakes, rock rippers, and disk harrows have not been successful in creating proper soil conditions for optimum tree root growth, because they push soil aside and turn it over, often while fracturing less than 40% of the compacted layers. In the early 1980s the effectiveness of four types of tillage implements were tested on compacted soils by Andrus and Froehlich (1983). They found that brush rakes, rock rippers, and disk harrows were seldom effective; but that the winged subsoiler showed promise, sometimes fracturing 80% of the compacted soil layers (Froehlich and Miles 1984).

More recently, when the winged subsoiler was compared to rock rippers on compacted soils, it provided superior profile shatter of 137% versus 26% based on 12-in. depths (Carr 1989). The objectives of this study were to determine if brush-piling machinery caused significant soil compaction and to determine if soils compacted during brush piling could be tilled to achieve a bulk density similar to that of undisturbed soil. Further, these soil conditions were compared with these soils in a nearby unit that had been tractor-logged 22 years previously and that had not been tilled.

## METHODS

A 50-ac site, about 3 miles NW of Cottage Grove, OR, was clearcut using a cable system with partial suspension, in winter, 1985–86. Trees were 170-yr-old Douglas-fir (*Pseudotsuga menziesii*) averaging 40,000 bd ft/ac. Soils, predominantly of the Jory series, are clayey, mixed, mesic Xeric Haplohumults and are over 3 ft deep. The Al horizon (0–4 in.) consists of a granular-structured, brown, silty clay loam and overlies an A3 horizon (4–16 in.) of subangular, blocky-structured, dark, reddish brown clay. Slash on the harvest unit was uneven, varying between 20 and 50 tons/ac. Vine maple (*Acer circinatum*), hazel (*Corylus cornuta var. californica*), and ocean spray (*Holodiscus discolor*) were the major brush species and occurred with assorted grass species on the S and W slopes. A 180-hp crawler tractor with a brush blade and 24-in. wide tracks was used to pile the slash and brush. Approximately 35 ac were piled in October 1986. Soil moisture ranged 30–35% by weight at 6-in. depths. Slash and brush piles were later burned.

Tilling was done with a winged subsoiler equipped with 3 narrow shanks, spaced 3-ft apart, mounted on a rigid frame and pulled by a 180-hp crawler tractor. The subsoiler had a self-drafting design, and a hydraulic tripping mechanism to enable tilling close to stumps. Wings were fastened to the curved shanks and were 22-in. wide. Wing geometry has been designed so that fracturing of the compacted soil layers results in lifting and shattering, helping to minimize soil clod size while leaving the topsoil in place. The subsoiler assembly was adjusted to till to depths of 15–18 in. with a lift of 1 in. About 30 ac were tilled after piling operations in October 1986. Soil moisture ranged 28–34%. Piling and tilling costs were \$120 and \$160/ac, respectively.

The layout of sampling points consisted of a predetermined systematic square grid with 100-ft line transects originating from the grid intersections. Both grid and transect orientation were randomly chosen. Bulk density measurements were recorded at 10-ft intervals along transects (Howes et al., 1983). Bulk density measurements were taken at depths of 0–4 and 0–8 in. with a Troxler 3411-B single probe nuclear gauge.

An analysis of variance was used to test if soil density for the four treatments were equal at the 0–4 and 0–8 in. soil depths. Fisher's protected LSD was used to detect differences between treatment effects using two group means as a basis for comparison (Table 1).

## RESULTS

Visual observations along the transects showed that 49% of the samples fell within areas that had been tilled 15% had brush piling but no tilling, and 14% of the samples fell within undisturbed areas. An additional 16% of the samples were outside the harvest unit in dense 22-yr-old second-growth Douglas-fir with an understory of brush. The remaining 6% of the samples fell on stumps, slash, and debris piles where bulk density measurements were unobtainable.

An analysis of variance rejected the probability that all four treatments are equal ($P < 0.001$) for both soil depths.

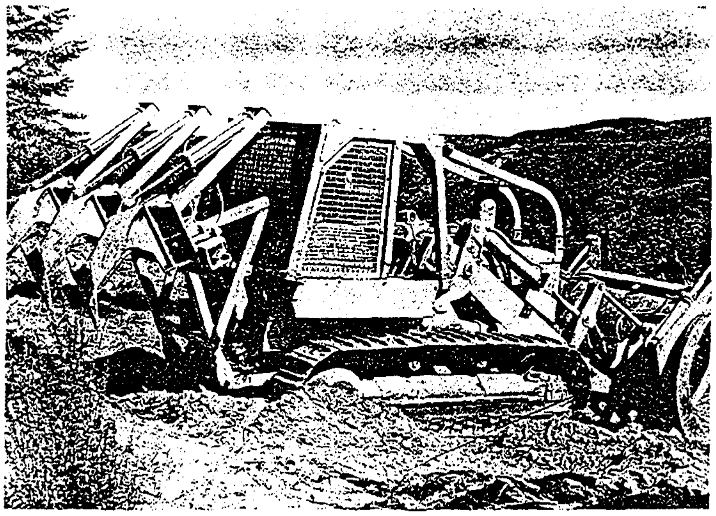

Figure 1. Winged subsoiler pulled by a crawler tractor.

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Bureau of Land Management, Eugene District Office, 1255 Pearl Street, Eugene, OR 97401. For their constructive reviews, the author thanks Henry Froehlich, Chip Andrus, Byron Thomas, and Tom Sabin. I also thank Tom Small, for his field assistance, and Jeane Hutcheson for her invaluable assistance in editing and typing the manuscript.

**Table 1. Least squares mean soil bulk densities among treatments at two depths.**

| Soil depth (in.) | Soil treatments | Number of samples | Mean soil bulk density (g/cm³) | S.E. |
|---|---|---|---|---|
| 0–4 | Machine piled only | 42 | $1.04^{A}$ | 0.0198 |
| | Old clearcut | 43 | $0.99^{B}$ | 0.0196 |
| | Undisturbed | 39 | $0.91^{C1}$ | 0.0206 |
| | Machine piled and tilled | 134 | $0.91^{C1}$ | 0.0111 |
| 0–8 | Machine piled only | 41 | $1.12^{a}$ | 0.0197 |
| | Old clearcut | 43 | $1.06^{b}$ | 0.0192 |
| | Undisturbed | 39 | $1.00^{c1}$ | 0.0202 |
| | Machine piled and tilled | 134 | $0.99^{c1}$ | 0.0109 |

[1] Means with the same letter are not significantly different at the $\alpha = 0.05$ level.

For all of the four treatments, significant differences ($\alpha = 0.05$) did not change between 0–4 and 0–8 in. depths. Fisher's protected LSD failed to detect a difference ($\alpha = 0.05$) between soil bulk densities of undisturbed areas and areas that had been machine piled and tilled. However, significant differences ($\alpha = 0.05$) were found between all other treatments. Soil density measurements averaged 13% more for machine piled areas than for undisturbed areas. Soil densities also were 13% less for tilled areas than for piled areas that had not been tilled. Soils within the 22-yr-old clearcut stand were 7% denser than soils in undisturbed areas and 6% less dense than soils that had been compacted by machine piling.

About 20% of the samples in the 22-yr-old clearcut exceeded bulk densities of 1.05 g/cm³ at 0–4 in. depths and 1.15 g/cm³ at 0–8 in. depths. Such bulk densities exceed Bureau of Land Management bulk density standards of typical undisturbed Jory soils at specified depths by 15% and are considered to represent heavy compaction. About 15% of the samples measured in the undisturbed soil condition had bulk densities that exceeded 1.05 g/cm³ at 0–4 in. and 1.15 g/cm³ at 0–8 in. Forty percent of the samples measured under machine piled soil conditions had bulk densities exceeding 1.05 g/cm³ at 0–4 in. depths and 30% exceeded 1.15 g/cm³ at 0–8 in. depths. In contrast, only 7% of the soil conditions where machine piling and tilling occurred exceeded 1.05 g/cm³ at 0–4 in. depths, and only 2% exceeded 1.15 g/cm³ at 0–8 in. depths.

## DISCUSSION

While machine piling creates surface compaction from 0–8 in., tilling with a winged subsoiler restored increased soil bulk densities to undisturbed levels. This was accomplished under moist soil conditions. The soils were fractured in place as opposed to being turned over.

The percentage of soil bulk densities measured under the four treatments which exceeded 1.05 and 1.15 g/cm³ at 0–4 and 0–8 in. depths (15% over natural or typical bulk densities for Jory soils) suggests other significant findings. First, significant surface soil compaction, representing 20% of an old harvest area, has a duration of at least 22 years. The author suggests that this occurred in places which were compacted during past logging but could not be visually identified at the time of sampling. The 15% of the samples which had high bulk densities in the undisturbed treatment also probably resulted during yarding due to only partial log suspension under wet conditions. The 40% of the samples which had high bulk densities in the machine piled and not tilled areas suggests that machine piling creates considerable widespread surface soil compaction. In contrast, the higher bulk densities recorded on 2 and 7% of the samples from machine piled and tilled areas probably represent areas where fracturing of compacted soils did not occur. However, these figures do provide evidence that tilling creates more uniform soil bulk densities.

An overall objective of this soil-monitoring project was to provide land managers with information to better assess site-preparation alternatives. Most other site-preparation treatments, such as broadcast burning and hand piling, have costs that exceed $360/ac. They also can have restricted timeframes of operation during the year. Tilling with a winged subsoiler is cost effective and creates suitable soil conditions for conifer growth. It also is needed only on areas subjected to compaction, which usually represents only a portion of a harvest area. Further studies are needed to evaluate changes in planting costs as well as plantation survival and growth. ☐

## LITERATURE CITED

Andrus, C. W., and H. A. Froehlich. 1983. An evaluation of four implements used to till compacted forest soils in the Pacific Northwest. Res. Bull. 45. For. Res. Lab., Oregon State Univ., Corvallis. 12 p.

Carr, W. W. 1989. An evaluation of the forest soil tillage using the winged subsoiler on landings in the Prince George Forest District. Prepared for TERRASOL, Contract Rep. Silvic. Branch Ministry of For., Victoria, BC. 19 p.

Froehlich, H. A. 1979. The effect of soil compaction by logging on forest productivity. Final Rep. U.S. Bureau of Land Manage. for Contract 53500-CT4-5(N). Oregon State Univ., School of For., Corvallis. 19 p.

Howes, S., J. Hazard, and J. M. Geist. 1983. Guidelines for sampling some physical conditions of surface soils R6-RWM-146. USDA For. Serv., Pac. Northwest Reg. 34 p.

Sands, R., and G. D. Bowen. 1978. Compaction of sandy soils in radiata pine pine forests II. Effects of compaction on root configuration and growth of radiata pine seedlings. Aust. For. Res. 8:163–170.

Wert, S., and B. R. Thomas. 1981. Effects of skid roads on diameter, height, and volume growth in Douglas-fir. Soil Sci. Soc. Am. J. 45(3):629–632.