SILVICULTURE

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TRIAL OF THE TILTH WINGED SUBSOILER WORKING ON NATURALLY COMPACT SOILS IN NORTH CENTRAL BRITISH COLUMBIA

Deborah L. De Long, R.P.F.*
P. Martin Osberg, M.Sc., R.P.F.
Curt Clarke
Winn Hays

Abstract

In the fall of 1989 FERIC monitored the self-drafting winged subsoiler built by Tilth Inc. of Monroe, Oregon. The machine has already become established as a soil tillage implement for treating artificially compact soils. The objective of this trial, near Prince George, B.C., was to determine if this tool can be used effectively on naturally compact soils. Pretreatment assessment, time analysis, and post-treatment assessment were completed. The results are presented in this report. The B.C. Ministry of Forests (Forest Sciences Section) will publish a comprehensive research report after the biological and pedological results have been compiled and analyzed. Other recent B.C. trials are also discussed.

Introduction

General concern over the long-term effects of soil compaction on forest productivity has led to the development of post-harvest soil-tillage treatments. Tillage breaks up the soil mass, increases rooting depth, and allows freer movement of water and air. Brush blades, disc harrows, and rock rippers have been used as soil-tillage implements, but their effectiveness has been questioned (Carr 1989; Andrus and Froehlich 1983). As early as 1978, wing-shaped shoes were added to the ends of agricultural tines to increase soil loosening (Andrus and Froehlich 1983). Tilth Inc. of Monroe, Oregon, in cooperation with Oregon State University, designed, patented, and produced a self-drafting winged subsoiling attachment. This implement is specifically designed for use on compact soils and has been used extensively for rehabilitating landings and skid trails in northern California, Oregon, and Washington (Davis 1989; Froehlich and Miles 1984).

In some areas of British Columbia, the bulk density of soil increases rapidly with depth. Very dense soil horizons, resulting from an accumulation of clay particles 10 to 30 cm below the mineral-soil surface, often develop on glacial till deposits. This compact layer restricts root growth and drainage, both of which contribute to a reduction in overall forest productivity. Since the Tilth subsoiler is effective in ameliorating man-made or artificial compaction, it should be equally effective on naturally compact soils. If the soils are sufficiently tilled, the rooting zone should increase and drainage should improve.

In September 1989, Prince George Forest Region of the B.C. Ministry of Forests initiated and set up a trial to evaluate the effectiveness of the Tilth subsoiler; the objective of the treatment was to improve the long-term productivity of a lodgepole pine/black spruce site having naturally compact soils. The Silviculture Branch of the B.C. Ministry of Forests provided technical support and FERIC was on site to evaluate the machine's produc-

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*Authors: Deborah L. De Long is a Researcher in Silvicultural Operations, Western Division. P. Martin Osberg is the Research Pedologist for the B.C. Ministry of Forests, Prince George Forest Region. Curt Clarke is a Technician, Site Preparation, B.C. Ministry of Forests, Silviculture Branch. Winn Hays is a Forest Sciences Assistant, B.C. Ministry of Forests, Prince George Forest Region.

FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
INSTITUT CANADIEN DE RECHERCHES EN GENIE FORESTIER

143 Place Frontenac
Pointe Claire, Québec
Canada H9R 4Z7
(514) 694-1140

2601 East Mall
Vancouver, B.C.
Canada V6T 1W5
(604) 228-1555

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tivity. This report is a standard FERIC equipment description and evaluation. The Prince George Forest Region (Forest Sciences Section) will publish a comprehensive research report after the biological and pedological results have been compiled and analyzed.

Site Description

The block chosen for the trial is located 70 km northwest of Prince George in the Mossvale variant of the Moist Cool Sub-Boreal Spruce zone (SBS MK1). The 65-ha block was harvested from 1983 to 1986 with a feller-buncher and grapple skidders. In 1986, the block was drag-scarified to promote natural regeneration, and then treated with hack-and-squirt herbicide for the purpose of aspen control. Natural regeneration was not successful and the aspen was aerially sprayed with Vision®[1] in 1989. The block was not satisfactorily restocked (NSR) at the time of this trial. Disc trenching is scheduled for the remainder of the block outside the trial area in 1990. In the spring of 1991, the entire block will be planted with copper root-pruned PSB 313A pine stock.

A total of 4.8 ha within the 65-ha cutblock were designated for the study. One-half of the area, 2.4 ha, consisted of silty-clay soil (Area 1) and 2.4 ha consisted of fine sandy soil (Area 2). Each 2.4-ha parcel was subdivided into twelve 20-m x 100-m treatment units. Six of the treatment units were randomly selected for treatment with the subsoiler; the remaining six were untreated and designated as controls.

Equipment Description

The Tilth subsoiler (Figures 1 and 2) is a passive site-preparation implement designed to be pulled by a prime mover. The winged shoes (Figure 3), together with the forward motion of the prime mover, enable the tines to "self-draft" or move down through the soil to a preset depth. The tines and winged shoes break up the soil as they are pulled through the ground, creating a fractured soil profile. A passive closed-loop hydraulic system allows each tine to independently "trip" over obstacles and then automatically return to the original depth. In this trial, the centre tine of the subsoiler was removed in an attempt to reduce slash buildup in front of the tines, leaving a space of 2.3 m between the two remaining tines. A Caterpillar D7F tractor with a V-blade attachment was the prime mover.

The winged shoes are interchangeable and are available in 35- to 60-cm widths. Wing "angles," or the angle at which the wing is attached to the shoe, can also be varied. Smaller angles or "flat" wings are more effective in wet soils, while larger angles or "steep" wings are more effective in drier soils (Figure 4). Winged shoes

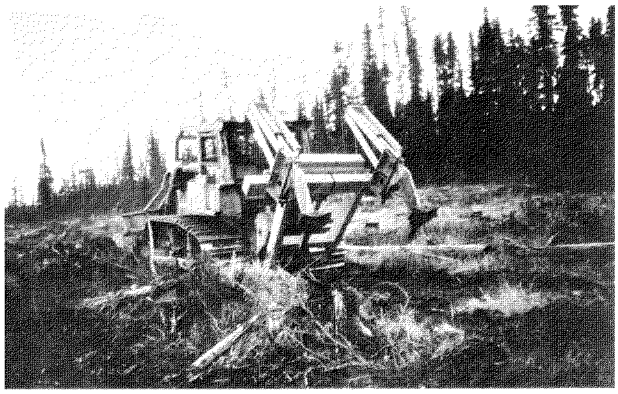

Figure 2. The Tilth winged subsoiler at the study site.

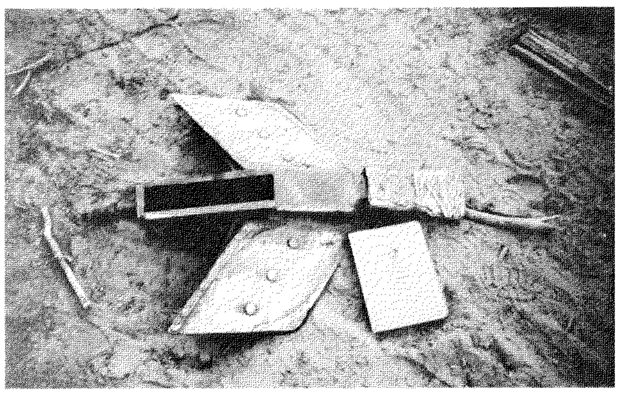

Figure 3. Winged shoes.

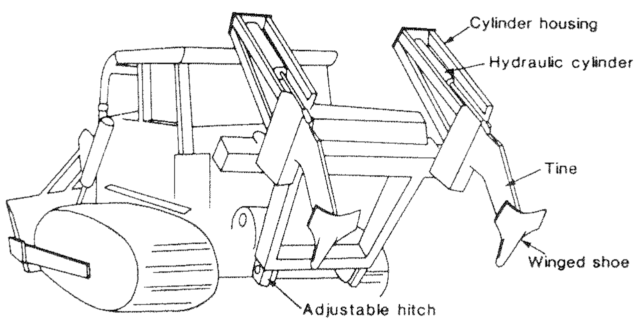

Figure 1. The Tilth winged subsoiler as used for the trial.

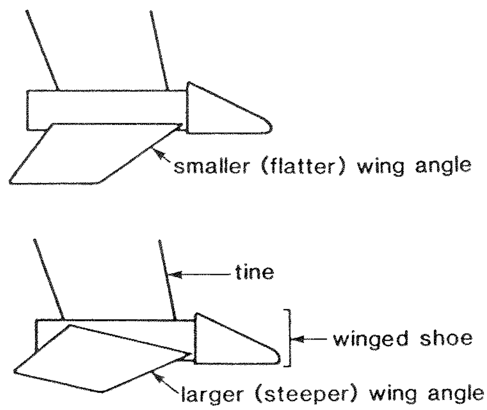

Figure 4. Wing angles.

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[1] Vision® is a registered trademark of Monsanto Company U.S.A. Monsanto Canada Inc. is a registered user.

can be custom-made to suit specific soil types, site conditions, and treatment objectives. Specifications of the Tilth subsoiler are listed in Table 1.

Evaluation

Pretreatment

A modified version of the Standard Assessment Procedure for evaluating silviculture equipment was used for collecting pretreatment data (Sutherland 1986; Hedin 1986). LFH[2] horizon depth, soil depth, frequency of stones (using soil-probes[3]), and vegetative cover were measured along transects. Ground roughness and stumps were sampled using circular 100-m^2 plots, and slash loading was sampled using the line-intercept method (Tables 2 and 3).

Table 1. Specifications of the Tilth Winged Subsoiler

Total height	2.5 m
Total width	3.0 m
Tillage depth range	30-85 cm
Tine height	87 cm
Tine spacing range (plumbed for four shanks)	60-240 cm
Winged shoe sizes	35-60 cm width
Wing angle	Available in a range
Weight	2 045 kg
Approximate price [a]	C$32 000

[a] Until March 31, 1990.

There were no significant differences in the pretreatment characteristics of the two areas. However, Area 2, with sandy soil, had scattered wet depressions.

Treatment and Productivity

The equipment was timed in detail for a total of 8.3 productive machine hours (PMH) over 2.5 days, on a total of 2.4 hectares. Because of heavy slash loading (an average of 161 m^3/ha) and high stump frequency (an average of 740 stumps/ha), the operation was done in two passes. During the first pass, the operator used the V-blade to attempt to break apart stumps and push most of the slash to the side while he kept the subsoiler in the raised position. The objective was to move the

Table 2. Site Descriptions

Area	Average soil penetration (cm)	Average LFH depth (cm)	Stoniness (% probe encounters)	Ground moisture	Ground roughness [a]	Vegetation: % cover	Vegetation: Leading species
1 Silty clay loam 2.4 ha	29	6	3	Moist	Very even	13	Grasses *Spirea densiflora* *Epilobium angustifolium* *Salix* *Populus*
2 Sand 2.4 ha	35	11	2	Moist to very moist (depressions)	Very even	14	Grasses *Spirea densiflora* *Epilobium angustifolium* *Lonicera involucrata* *Salix* *Populus*

[a] P.G. Mellgren. 1980. Terrain classification for Canadian forestry. Can. Pulp and Paper Assoc., Montreal, Que. 13 pp.

Table 3. Slash and Stump Data

Area	Slash loading (m^3/ha)	Avg no. pieces/20-m lineal tally: Diameter <5 cm	Avg no. pieces/20-m lineal tally: Diameter >5 cm	Average slash height (cm)	Average stump density (no./ha)	Average stump size: Diameter (cm)	Average stump size: Height (cm)
1	162	44	9	7	783	36	35
2	161	40	12	8	700	38	30

[2] LFH includes undecomposed, partly decomposed, and highly decomposed organic layers.

[3] A soil probe is a steel rod measuring 1 m in length and 1 cm in diameter. It is manually pushed into the ground to measure soil penetration depth and stone encounters.

larger slash and stumps out of the way but to avoid windrowing all of the debris. The actual subsoiling was completed during the second pass. The productivity data are summarized in Table 4.

Machine productivity on the two areas did not differ significantly. In Areas 1 and 2, 51% and 57% of the total time, respectively, was spent on the first pass (clearing slash) while less than 30% was spent subsoiling. With the two-pass system, the overall productivity was about 0.29 ha/PMH. The first pass, i.e. V-blading alone, achieved a productivity of approximately 0.45 ha/PMH. This is about one-half of the productivity achieved in a larger operational V-blading trial near Vavenby, B.C. in 1987 (Forrester and Hedin 1987). The lower productivity at the Prince George site may have occurred because the area is small and the operator took great care to clear the slash and keep the passes straight. Subsoiling alone achieved a productivity of 0.80 ha/PMH. On both areas, approximately 9% of the total time was spent turning, because the pass length was only 100 m. This percentage would be lower and productivity would be higher for larger operations.

The causes of minor delays are summarized in Table 5. An average of 11% of the total productive time was spent in minor delays. Overall, 46% of the minor delay time was due to the accumulation of slash in front of the tines and maneuvering around the remaining stumps during the second pass. The other delays were evenly distributed throughout the treatment period. Miscellaneous delays include reconnaissance and moving to the next treatment unit.

Post-Treatment

The results of the subsoiling treatment were assessed by establishing 50-m transects along the treated passes. At 10-m intervals, soil penetration of the left and right tines and at the centre of the pass were measured using a soil probe. Distance between passes (i.e. distance between tine penetration of adjacent passes) and length of pass not treated were also recorded. The post-treatment data are summarized in Tables 6 and 7.

As indicated in Table 6, the tines were not in the soil continuously. Even though each tine is self-tripping, a slow buildup of debris at ground level did not trip the tines and the operator periodically lifted the Tilth subsoiler out of the ground to clear the debris. When the tines were lifted, the winged shoes left holes in the treatment pass. The operator did not necessarily stop the machine when the tines were lifted; therefore, the treatment was not continuous. An average of 22% of the passes sampled were not treated.

Table 7 shows that overall soil-penetration depth increased in both soil types. In the silty clay loam soil (Area 1) the depth of penetration with the soil probe increased from an overall average of 29 cm to 37 cm, while the depth of penetration in sandy soil (Area 2) increased from an average of 35 cm to greater than 46 cm. Because the middle tine was removed, the soil-penetration depth at the centre of the pass did not significantly increase. Figures 5 and 6, derived from the soil-depth measurements, illustrate the "W" shaped soil profile results.

Table 6. Post-Treatment Summary

Area	Transect not treated: Percentage	Transect not treated: Range (%)	Increase in soil depth [a] (%)	Average distance between passes (cm)
1	22	10-38	28	230
2	21	9-34	31+	230

[a] (Average overall post-treatment − Average control) / Average control • 100

Table 4. Distribution of Productive Time

Area	Clear slash, first pass (min)	(%)	Subsoil, second pass (min)	(%)	Turn and maneuver (min)	(%)	Minor delays (min)	(%)	Total productive time (min)	(%)	(h)	Productivity: First pass (ha/PMH [a])	Second pass (ha/PMH [a])	Overall (ha/PMH [a])
1	120	51	66	28	20	9	28	12	234	100	3.9	**0.50**	**0.80**	**0.31**
2	148	57	63	24	25	9	28	10	264	100	4.4	**0.41**	**0.80**	**0.27**
									Overall average			**0.45**	**0.80**	**0.29**

[a] Ha/PMH does not include delays >15 minutes.

Table 5. Causes of Minor Delays

Area	Slash/stumps (min)	(%)	Visitors (min)	(%)	Miscellaneous (min)	(%)	Mechanical (min)	(%)	Total (min)	(%)
1	13.4	48	1.2	4	7.7	28	5.7	20	28	100
2	12.4	44	7.3	26	8.3	30	-	-	28	100

Table 7. Soil Penetration Depths

	Tine spacing (2.3 m)												Overall average depth, post-treatment		
	Control			Left track			Centre			Right track					
Area	Sample size	Avg	S.D.[a]	Sample size	Avg	S.D.[a]	Sample size	Avg	S.D.[a]	Sample size	Avg	S.D.[a]	Sample size	Avg	S.D.[a]
1	30	29	10	30	43	11	30	29	11	30	44	10	90	37	12
2	30	35	8	30	>50	5	30	41	8	30	>50	9	90	≈46+	8

[a] S.D. = standard deviation = $\sum_{i=1}^{n} \frac{(x_i - x)^2}{n - 1}$

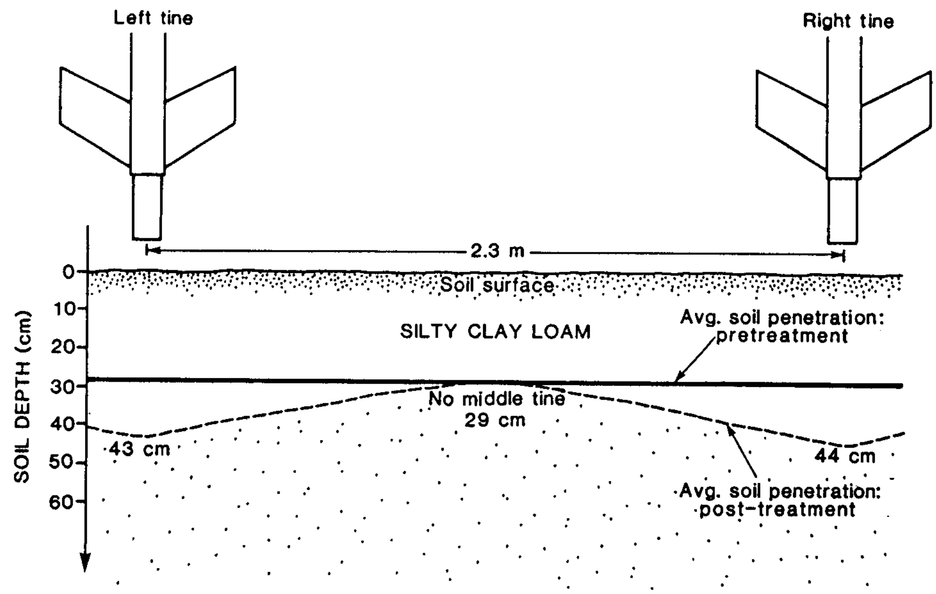

Figure 5. Soil profile of Area 1 (silty clay loam).

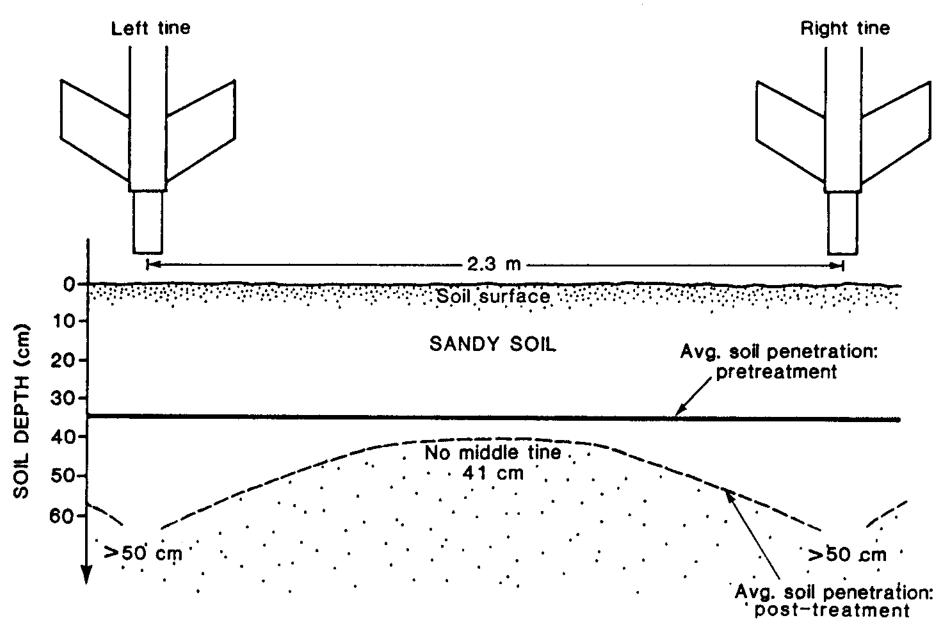

Figure 6. Soil profile of Area 2 (sandy soil).

Machine Cost Analysis

The owning and operating costs of the winged subsoiler are presented in Table 8; FERIC's standard costing procedure is used. The overall productivity (including first pass or clearing slash) was approximately 0.29 ha/PMH. If the first pass is not included in the calculation, productivity of the subsoiling treatment alone was 0.80 ha/PMH. The productivity of the first pass alone (clearing slash) was 0.45 ha/PMH.

When a machine utilization of 80% is used, the productivities are reduced to 0.36 ha/h for clearing slash, 0.64 ha/h for subsoiling, and 0.23 ha/h overall. Based on these figures and a total operating cost of $101/h, the projected cost of the operation was $439/ha for both passes, i.e. $158/ha for the subsoiling treatment and $281/ha for clearing the slash. The overall productivity depends directly on slash loading, block size and shape, and the treatment objectives.

Table 8. Machine Cost Analysis

Item	Winged Subsoiler	D7G Caterpillar [a]
Ownership costs		
Purchase price (P) $	32 000	328 000
Salvage value (S) $	8 000	82 000
Expected life (yr)	9	9
Expected life (h)	10 000	10 000
Interest rate (I) %	14.50	14.50
Insurance rate (Ins) %	1.5	1.5
Average investment (AVI) = (P + S)/2	20 000	205 000
Loss in resale value = (P - S)/h $/h	2.40	24.60
Insurance (Ins • AVI)/h $/h	0.03	0.31
Interest = (I • AVI)/h $/h	0.29	2.97
Operating and repair costs		
Average diesel consumption (L/h)	-	28
Diesel fuel cost ($/L)	-	0.40
Operating supply cost per year (O) $/yr	1 000	3 500
Annual winged shoe consumption (W)	6	-
Winged shoe replacement cost ($/W)	250	-
Annual repair and maintenance cost (R) $/yr	1 000	30 000
Wages ($/h)	-	18.00
Wage benefit loading (WBL) %	-	35
Fuel cost = (L/h) • ($/L) $/h	-	11.20
Lube and oil cost = 10% • fuel cost $/h	-	1.12
Operating supply cost = O/(h/yr) $/h	0.90	3.18
Winged shoe replacement cost per hour = W • [($/W)/(h/yr)] $/h	1.36	-
Repair and maintenance cost = R/(h/yr) $/h	0.90	27.00
Labour cost $/h	-	24.30
Operating and repair costs $/h	3.16	66.80
Total costs		
Operating and repair costs $/h	3.16	66.80
Loss in resale value $/h	2.40	24.60
Insurance $/h	0.03	0.31
Total cost (interest not included) $/h	5.59	91.17
Plus interest $/h	+ 0.29	+ 2.97
Grand total $/h	= 5.88	= 94.68
Winged subsoiler + D7G Caterpillar rate per hour $/h	101.00 [b]	

	Clearing slash alone	Subsoiling alone	Total treatment (clearing slash and subsoiling)
Machine productivity achieved at trial ha/h	0.45	0.80	0.29
Machine productivity based on 80% utilization ha/h	0.36	0.64	0.23
Total average production cost (for implement and prime mover) $/ha	281	158	439 [c]

[a] Costing is based upon a new Caterpillar D7G.
[b] This figure is based on a standard FERIC accounting formula for determining ownership, repair, and operating costs. Actual hourly rates may vary for this machine configuration.
[c] This is a projected cost of treatment based on the productivities achieved in this trial only.

Other Recent Trials

The B.C. Ministry of Forests owns a subsoiler which recently underwent a trial in the Okanagan region of B.C. The Tilth subsoiler also underwent another trial on Vancouver Island (Figure 7).

Figure 7. Map of study sites.

Okanagan

In July and August of 1989, the Lumby Division of Weyerhaeuser Canada Limited in the Okanagan region of B.C. evaluated the effectiveness of the Ministry of Forests' subsoiler[4] in creating plantable microsites on NSR sites.[5] Four NSR sites, ranging from 10 to 12 years old and located in the Englemann Spruce Subalpine Fir zone were chosen for the trial. All the sites had heavy slash and brush loading which precluded disc trenching. A Caterpillar D7F tractor with a V-blade was used as the prime mover and two tines were mounted on the subsoiler at 2.5-m spacing. Table 9 summarizes the trial.

Overall, the plantability increased from an average of 423 spots/ha to an average of 1156 spots/ha on the treated areas. Planting on these sites will be less costly than on untreated sites. As well, better survival and growth rates are expected.

Vancouver Island

In September of 1989, the Kelsey Bay and Menzies Bay Divisions of MacMillan Bloedel Limited evaluated the effectiveness of the Tilth subsoiler in tilling two areas designated to be planted with poplar.[6] The objective of the subsoiling treatment was to increase the rooting depth on compact marine silts and to increase growth performance of planted poplars. These areas were severely compacted, and penetration with a shovel was difficult. The areas were cleared before tilling with a Caterpillar D7 and a D8 tractor, each equipped with brush blades.

Table 9. Lumby Trial Summary

Area	Equipment	Primary objectives	Productivity [a] (ha/day)	Availability [b] (%)	Plantable spots/ha: Before treatment	Plantable spots/ha: After treatment	$/ha [c]
1	V-plow	Create plantable spots.	0.49	100	500	1 550	216.30
2	V-plow/subsoiler	Create plantable spots. Tillage.	0.36	96	855	1 533	294.00
3	V-plow/subsoiler	Create plantable spots. Remove herbaceous competition.	0.26	94	232	1 580	407.40
4	V-plow/subsoiler	Create plantable spots. Remove Rhododendron grass.	0.22	92	104	1 560	484.05

[a] Based on a 10-h day.
[b] Any significant downtime was recorded to determine machine availability. Approximately one hour of regular maintenance per day was not included as downtime.
[c] Cost provided by Weyerhaeuser. The costs are based on an all found machine rate of $105/h. Includes: wages, fuel, minor maintenance, and repair.

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[4] Subtle differences exist in the design specifications of the B.C. Ministry of Forests' subsoiler as compared to Tilth Inc.'s self-drafting winged subsoiler. Contact Ed Fields of Tilth Inc. for more information (see Acknowledgements).

[5] Nick Kleyn, Weyerhaeuser Canada Limited, Lumby, B.C.; personal communication, Jan. 1990. Contact for more information.

[6] Cees van Oosten, R.P.F.; Poplar Project Coordinator, MacMillan Bloedel Limited, Nanaimo, B.C.; personal communication, Jan. 1990. Contact for more information.

At Kelsey Bay, 4.6 ha of an alluvial flood plain were tilled with the subsoiler at a productivity of 0.60 ha/h. At the Menzies Bay site, 7 ha were tilled with the subsoiler at a productivity of 0.50 ha/h; this site had a silty loam cap on compact marine silt. Penetration of the tines was 60 to 70 cm at both sites. Soil pits showed excellent shattering of soil clods. In some places, rooting depth was increased 100 to 150%. MacMillan Bloedel Limited anticipates an increase in tree performance because of increased rooting depth, improved drainage, and increased soil temperature.

Discussion and Conclusions

Both artificially and naturally compact soils reduce forest productivity. The Tilth self-drafting winged subsoiler was designed specifically for tilling and loosening forest and agricultural soils, and it has been shown to be an effective tool for ameliorating compaction on skid trails and landings following harvesting (Davis 1989; Froehlich and Miles 1984). In B.C., soil-disturbance guidelines are still in development but compaction is recognized as an important concern. Although the Tilth subsoiler has already become established as a tool for treating artificially compact soils, the objective of the trial was to determine if the subsoiler can be used effectively on naturally compact soils.

Machine productivity was not optimum in this trial because the slash loading (an average of 161 m^3/ha) required a first-pass clearing, and because the stump density was high (an average of 740 stumps/ha). Approximately 55% of the productive time was spent clearing the debris with the V-blade. Although the subsoiler would have been more productive if this site had been previously cleared, the cost of stumping and piling slash cannot be ignored.

The physical results of the treatment were satisfactory. The rooting and drainage depths increased 28% in the silty clay and approximately 31% in the sandy soil. The compact layer was loosened in a "W" shape as shown in the soil-penetration profiles (Figures 5 and 6). The soil-penetration profile would have been more complete if the subsoiler had been fitted with three tines, but more delays would have occurred because of slash buildup. At both the Prince George and the Vancouver Island sites, holes and mounds were formed when the operator lifted the attachment out of the ground to remove debris from the tines.

The machine cost analysis shows that the projected cost for V-blading (clearing slash) and subsoiling at the Prince George trial was approximately $439/ha, while the subsoiling treatment alone cost approximately $158/ha. Thus, V-blading alone cost approximately $281/ha. This cost for V-blading may be high, as it has been demonstrated to be lower in other trials (Forrester and Hedin 1987). If a subsoiling treatment is being considered for areas other than skid trails and landings, it would be more efficient to clear debris as a separate treatment prior to subsoiling. A trial of operational size is required to verify the productivities and costs achieved in this trial. The B.C. Ministry of Forests in Prince George will continue to monitor tree growth on the sites.

References

Andrus, C.W.; Froehlich, H.A. 1983. An evaluation of four implements used to till compacted forest soils in the Pacific Northwest. Research Bulletin 45, Forest Research Lab, College of Forestry; Oregon State University, Corvallis, Oregon. 12 pp.

Carr, W. 1989. An evaluation of forest soil tillage using the winged subsoiler on landings in the Prince George Forest District. Silviculture Branch, Ministry of Forests, Victoria, B.C. 19 pp.

Davis, S. 1989. Effectiveness of a winged subsoiler in ameliorating a compacted clayey forest soil. U.S. Bureau of Land Management, Eugene District Office, Oregon. 5 pp.

Forrester, P.D.; Hedin, I.B. 1987. Site preparation with the Sanders V-blade in two sites in southern British Columbia. FERIC Technical Note TN-104. Vancouver, B.C. 8 pp.

Froehlich, H.A.; Miles, D.W.R. 1984. Winged subsoiler tills compacted forest soil. Forest Industries, Feb. 1984. 2 pp.

Hedin, I.B. 1986. Mechanical site preparation trials in British Columbia. FERIC Technical Report TR-69. Vancouver, B.C. 25 pp.

Mellgren, P.G. 1980. Terrain classification for Canadian forestry. Can. Pulp and Paper Assoc. Montreal, Que. 13 pp.

Sutherland, B.J. 1986. Standard assessment procedures for evaluating silviculture equipment: A handbook. Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ont. 96 pp.

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