Observed Scarification Rates And Contract Costs For the TTS-35 Disc Trencher in Interior Alaska

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Introduction

The regeneration of interior Alaska's commercial forest lands is mandated by Alaska's Forest Resources and Practices Act (1979). This act requires that regeneration be established adequate to ensure a sustained yield on forested lands from which the timber has been harvested. Post-logging regeneration efforts now are aimed at exposing mineral soil for the natural seeding of white spruce. Soil exposure has been accomplished by blade scarifying with a crawler tractor which provides large seed sites or by using a Bracke-type patch scarifier which produces small seed sites of about 2 ft^2. Arlidge (1967) reports that larger seedbeds have greater regeneration success than smaller ones. Some researchers have found that the regeneration of the larger plots may be too successful, requiring weeding and precommercial thinning to bring stocking to satisfactory levels (Zasada and Grigal 1978). The Alaska Division of Forestry (DOF) has not been satisfied with the cost or effectiveness of either of these site-preparation practices.

In an effort to introduce and evaluate alternative types of site-preparation equipment, DOF and the University of Alaska-Fairbanks (UAF) entered into an agreement to purchase jointly a TTS-35 Disc Trencher Scarifier. The TTS-35 is a relatively new piece of site-preparation equipment developed in Finland. It exposes mineral soil by slicing through the organic layer of the forest floor and casting it aside (fig. 1). A sketch of the TTS-35 is shown in Figure 2.

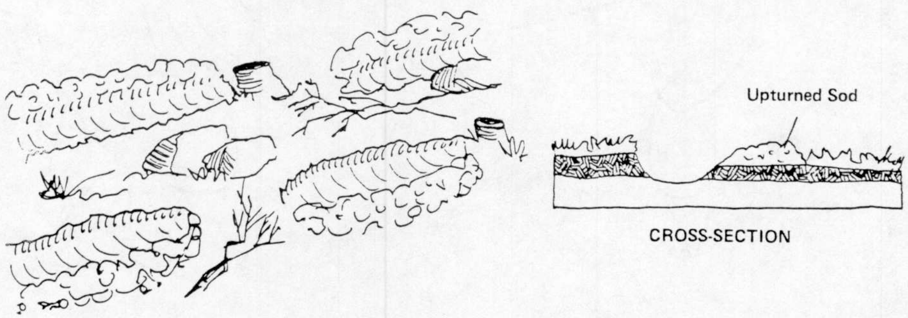

Figure 1. An example of the work performed by the TTS-35 Disc Trencher.

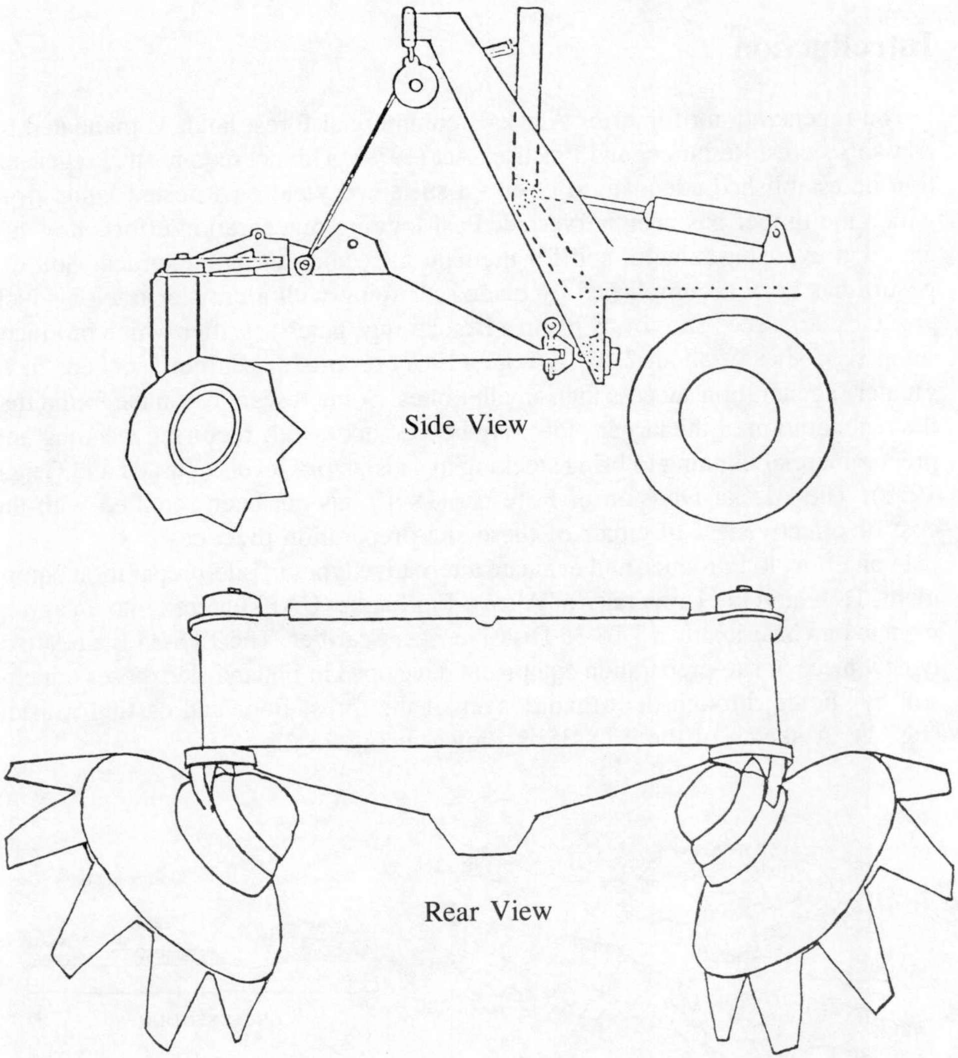

Figure 2. Sketch of the TTS-35 Disc Trencher.

It can be towed by either a crawler tractor or rubber-tired skidder with a minimum rating of 135 horsepower. The two 48-inch discs are positioned 6.6 feet apart and can make furrows 18 inches wide on which natural seeding, broadcast seeding, or planting can be performed. The TTS-35 is being evaluated to determine if it will provide more mineral soil exposure per acre than the patch scarifier for the same amount of equipment time. The pattern of furrows produced is expected to give better spacing for natural regeneration than occurs on the large seedbeds produced by blade scarification.

The purpose of this paper is to inform potential users of the 1985 hourly scarification rates and per acre costs of performing site-preparation work using the TTS-35 Disc Trencher. These rates and costs were based on initial contract results. This information will give forest managers a basis on which to estimate site-preparation costs after logging. The costs and rates reported will provide prospective contractors with information they can use in determining bids for future scarification contracts.

Methods

During the summer of 1985, the first large scarification contract was awarded by DOF for site preparation on 415 acres burned during the 1983 Rosie Creek Fire near Fairbanks, Alaska. The contracted work was to prepare cut-over and burned forest lands for hand planting. The contract area was divided into administrative units of 35 to 228 acres. These units were further divided into subunits, each of which was fairly uniform as to site conditions. This allowed the contractor greater control of the scarification operation. The subunits contained varying amounts of logging slash and from light to heavy grass cover. The topography of the subunits varied from smooth, relatively flat, 5 percent slopes to steep, 20 percent slopes on rolling terrain.

Three contractors were used to complete the scarification work. Contractor #1 found that his rubber-tired skidder, though technically having the minimum horsepower, was unable to operate at the 2-acre-per-hour rate required by the contract. Contractor #2, using a D-6 Caterpillar Crawler (fig. 3), was able to complete 148 acres before he had to relinquish the contract due to unanticipated maintenance costs. Contractor #3 was able to complete the contract using a Clark 668 rubber-tired skidder (fig. 4). Due to the short amount of time that Contractor

Figure 3. Photo showing the TTS-35 being towed behind the D-6 Caterpillar crawler used by Contractor #2.

#1 operated, data were collected only on the work performed by Contractors #2 and #3.

Two sampling procedures were used to determine scarification rates due to differences in the scarification patterns used by the two contractors and in the speed of the equipment used to tow the TTS-35. Under the initial method, scarification-rate data were obtained by measuring the distance traveled by the scarifier during a 15-minute time period (D). One sample was taken every hour while the machinery was in operation. The beginning and ending points were marked so that the amount of mineral soil exposed could be measured. Sample measurements were taken within each subunit of the contract area to determine the average distance between pairs of furrows (FS). This was accomplished by counting the number of furrows crossed by a transect line laid down perpendicular to the furrow orientation. The

Figure 4. Photo showing the TTS-35 being towed behind the Clark 668 rubber-tired skidder used by Contractor #3.

length of the transect lines depended on the size of each subunit. Scarification rates per productive machine hour (PMH), the time actually spent scarifying, were calculated for each sample using the following formula:

$$(D \times FS \times 4)/43560 = PMH \tag{1}$$

In order to determine an average scarification rate for the entire contract period, records were kept on the amount of time lost to delays and breakdowns. This information was used to determine the percentage of every contract machine hour (CMH) actually spent scarifying. The rate in terms of acres per PMH (A/PMH) was multiplied by this percentage to yield acres per CMH (A/CMH). This provided a scarification rate which allowed for delays and breakdowns. Scarification rate estimates for Contractor #2 were obtained in this manner.

The first attempts to collect data on Contractor #3 revealed that the skidder was too fast for the timer to keep up with. This made it difficult to identify the end point of the 15-minute timing periods as well as measure the distance traveled. As a result, the beginning and ending points were marked and the measurement for distance taken while the operator finished the unit. The contractor's equipment operator preferred to break the large scarification units into small subunits which could be done in an hour or less. He was often finished with the unit before the timer had finished collecting data. This meant that some of the units had to be skipped to keep up with the skidder. As a record of equipment operating time was being kept, we decided to estimate scarification rates based on the times required to scarify each subunit. Records were kept on the distance covered in 15 minutes on four of the subunits so that a comparison could be made of the relative differences between the estimates obtained by the two methods.

Acreage estimates were obtained by using a microcomputer program and measurements obtained with a hipchain and compass for each of the contract subunits. Scarification rates were determined by dividing the scarification time into the acreage estimate for each subunit. This provided rates on an A/CMH basis, as delays and breakdowns were included in the time for each subunit. Furrow-spacing data were obtained using line transects. The percent of mineral soil exposure within furrows was obtained from measurments of two randomly selected pairs of furrows 328 feet long.

Results and Discussion

Contractor #2

Observations made on Contractor #2 from June 21 to July 12, 1985, are summarized in Table 1. A statistical analysis was made to determine whether there were significant differences between the scarification rates for the four subunits. At the 95 percent confidence level, subunits 1 and 3 were found to be significantly different, therefore a weighted average based on percent of total acreage scarified within each unit was calculated to check the simple average of 2.91 A/PMH. As the difference between the weighted and simple averages was only 0.004 A/PMH, we accepted the average in Table 1 as a good estimate of A/PMH.

Table 1. Scarification rates observed for the D-6 Caterpillar Crawler using the distance-per-15-minute time period sampling procedure.

Sample	Subunit	Distance	Soil Exposure	Furrow Spacing	Scarification Rate
		(ft)	(%)	(ft)	(A/PMH)
1	2	2,032	-[2]	14.8	2.76
2	2	2,123	98	14.8	2.89
3[1]	3	1,618	-	14.1	3.01
4	3	1,269	-	14.1	1.89
5	3	1,370	-	14.1	2.04
6	3	2,031	-	14.1	3.02
7	3	1,854	-	14.1	2.76
8	3	1,765	-	14.1	2.63
9	1	1,948	95	15.3	2.74
10	1	2,225	-	15.3	3.13
11	1	2,062	98	15.3	2.89
12	1	2,378	99	15.3	3.34
13	1	2,314	97	15.3	3.25
14	1	2,124	95	15.3	2.98
15	1	2,269	95	15.3	3.34
16	4	2,380	98	16.8	3.54
17	4	2,248	98	16.8	3.34
18	4	2,024	96	16.8	3.01
19	4	1,794	96	16.8	2.67
Ave.		1,991[3]	96.8	15.2	2.91

[1]Sample time was only 12 minutes long.
[2]Exposure information not obtained.
[3]At the 95% confidence level the standard error of the estimate for the simple average was 0.20 A/PMH, or 6.87% of the mean.

The results of the machine-hour analysis indicated that productive scarification time amounted to only 67.16 percent of machine time. As the rate of 2.91 A/PMH could only be sustained for this percentage of time, the overall scarification rate for the D-6 was reduced to 1.95 A/CMH. The observed productive machine time was lower than the 75.84 percent figure obtained from the contractor's records. Studies performed on disc trenchers in Finland have found scarification time percentages of 68.2 percent (Putkisto 1980). As a check on the A/CMH estimate, the number of machine hours paid for by DOF was divided into the estimate of acreage scarified to yield a figure of 1.75 A/CMH. This rate was 10.3 percent less than the overall scarification rate of 1.95A/CMH. Most of this difference can be explained by the fact that within the 147.72 acres scarified there were some areas that were scarified twice due to terrain conditions or movement of the scarifier from one unit to the next. The overall scarification rate obtained from studies by the Forest Engineering Research Institute of Canada (FERIC) for the TTS-35 was 1.88 A/CMH when towed by a crawler tractor in the D-6 or D-7 size class (Breweth, personal communication[1]). This figure falls between the observed rate and the contract rate for the D-6.

The contract cost for the acreage scarified was $8,252.90, or $55.87/A. The contractor was paid $74.15/CMH and $24.72 for every hour of standby time caused by a mechanical problem with either the hitch or the scarifier. The contractor ran his crawler for 84.55 hours and had 81 hours of standby time. The large number of standby hours was due primarily to problems with the drop-pin hitch used to attach the scarifier to the crawler. This resulted in a contract average of $97.83/CMH. Based on the observed scarification rate of 1.95 A/CMH, this converted to $50.17/A. This cost estimate was 10.2 percent less than the contract cost. Most of this difference can be explained by the difference between the contract acreage and the estimate of the acreage actually scarified.

The D-6 crawler had low ground pressure tracks so that it could work in areas with wet soils. Due to the fact that the track pads were extra wide, they had a tendency to ride up on stumps which put too much stress on them and resulted in many being broken. The total cost of replacing the broken pads and the fact that breakage would continue were the primary reasons Contractor #2 relinquished the contract. The contract price of $74.15/CMH did not allow the contractor to recover these additional maintenance costs and still make a profit.

The quality of the scarification work accomplished with the crawler was very good. Based on the observed values for percent soil exposure in each furrow (96.8 percent) and the average spacing for each furrow (7.6 feet), the amount of mineral soil exposure was calculated to be 8,322 ft^2/A, or 17.9 percent. This figure was obtained in the following manner:

$$(43560/7.6) \times 1.5 \times 0.968 = 8,322 \text{ ft}^2/\text{A} \qquad (2)$$

where 1.5 is the mineral soil width in feet within each furrow.

[1]Breweth, Douglas. 1985. British Columbia Ministry of Forestry.

Contractor #3

Observations on the performance of Contractor #3 began on August 8 and were completed on September 11, 1985. The observations made on the Clark 668 are summarized in Table 2. The scarification rate for the skidder was calculated two ways. The first yielded a rate based on the total machine hours required to scarify a given unit; this averaged 3.34 A/CMH. The second rate was based on productive machine hours with no delay time; this was 3.72 A/PMH. Both of these rates were considerably lower that the 4.10 A/CMH observed in Canada (Breweth 1985).

The cost of the scarification work performed by Contractor #3 was $36.64/A. This figure was based on the total amount of $7,987.50 paid to Contractor #3 for the completion of the remaining 218 acres in the contract. The contract cost per machine hour was $100/CMH with an additional standby cost of $25/hour. Based on the contract records, there was a standby charge of 0.61 hour for every machine hour during the period of observation, for a total of $115.25/CMH. When divided by the observed scarification rate of 3.34 A/CMH this converted to a cost of $34.51/A. The difference between this cost and the contract cost was 5.8 percent, well within the confidence limits of the scarification rate estimate.

The quality of the scarification work performed with the rubber-tired skidder was good. Based on nine observations, the soil exposure for this equipment com-

Table 2. Scarification rates observed for the Clark 668 rubber-tired skidder using the time-per-unit sampling method.

Subunit	Size	Machine Time Productive	Machine Time Delay	Furrow Spacing	Scarification	Rates
	(A)	(min)	(min)	(ft)	(A/CMH)	(A/PMH)
A	4.40	76	9	16.4	3.11	3.47
B	3.52	62	3	15.9	3.25	3.41
C	3.60	48	1	18.9	4.41	4.50
D	1.72	30	3	13.5	3.13	3.44
E	2.14	32	5	18.1	3.47	4.01
F	5.50	73	0	17.8	4.52	4.52
G	3.90	70	12	16.3	2.85	3.34
H	3.02	51	23	18.3	2.45	3.55
I	3.06	57	7	17.0	2.87	3.22
Ave	3.43	55.7	6.8	16.9	3.34[1]	3.72[2]

[1]At the 95% confidence level the standard error of the estimate as 0.54 A/CMH, or 16.17% of the mean.
[2]At the 95% confidence level the standard error of the estimate was 0.39 A/PMH, or 10.48% of the mean.

bination was 85.2 percent. With an average spacing of 8.45 feet per furrow, the amount of mineral soil exposed per acre was 6,588 ft^2, or 15.1 percent. This value was calculated using the same formula as for Contractor #2.

Comparisons

In order to determine whether or not the two sampling methods provide similar results for a given sample, four time-distance samples were taken on units scarified with the skidder. The scarification-rate estimates obtained by this method were compared to the estimates made by the time/unit method. Table 3 summarizes the results of the comparison. A statistical analysis of the difference between two dependent means was made to determine whether the difference was significant. At the 95 percent confidence level, the difference between the two means was not statistically significant. It was therefore assumed that the estimated rates for scarification obtained by the two methods used could be compared directly.

On the basis of productive machine hour rates observed, the rubber-tired skidder was found to be 0.82 A/PMH faster than the D-6 crawler. This difference becomes 1.39 A/CMH when contract machine hour rates are compared, due primarily to the difference in delay times experienced by the two machines. The crawler was lower to the ground than the skidder and was operating in an area having a larger number of high stumps. This required the operator to be more careful about where he drove the crawler. Even with care he had several large delays caused by stump hang-ups and mud.

Table 3. Comparison of scarification-rate sampling methods.

Sample	Subunit	Distance	Furrow Spacing	Scarification	Rates
		(ft)	(ft)	(A/CMH[1])	(A/PMH[2])
1	E	2,575	18.1	4.27	4.01
2	F	2,745	17.8	4.49	4.52
3	G	2,228	16.3	3.33	3.34
4	H	2,168	17.0	3.38	3.22
Ave.		2,429	17.3	3.87	3.77

[1]Obtained using the time-distance sampling method.
[2]Obtained using the time/unit sampling method.

The TTS-35 did a good job of exposing mineral soil in all units. The equipment operators learned quickly how to obtain good spacing between the furrows (fig. 5). The scarifier did not cut continuous furrows in the organic layer because logging slash and stumps forced one or both discs out of the ground. Even so, the skidder was able to expose 85.2 percent mineral soil in the furrows while the crawler exposed 96.8 percent. There are two likely explanations for the difference in exposure percentages, the first being the relative speeds of the machines. We noted that the faster the skidder moved, the more the discs bounced when they hit a major root or stump. This caused the scarifier to 'walk,' alternately having one disc in the ground and one out, for distances up to 50 feet. Areas where this occurred were not scarified as well as those where both discs were in contact with the ground. A possible solution to this problem would be to operate the skidder at no more than 4 A/PMH or put additional weight in the ballast compartment of the scarifier.

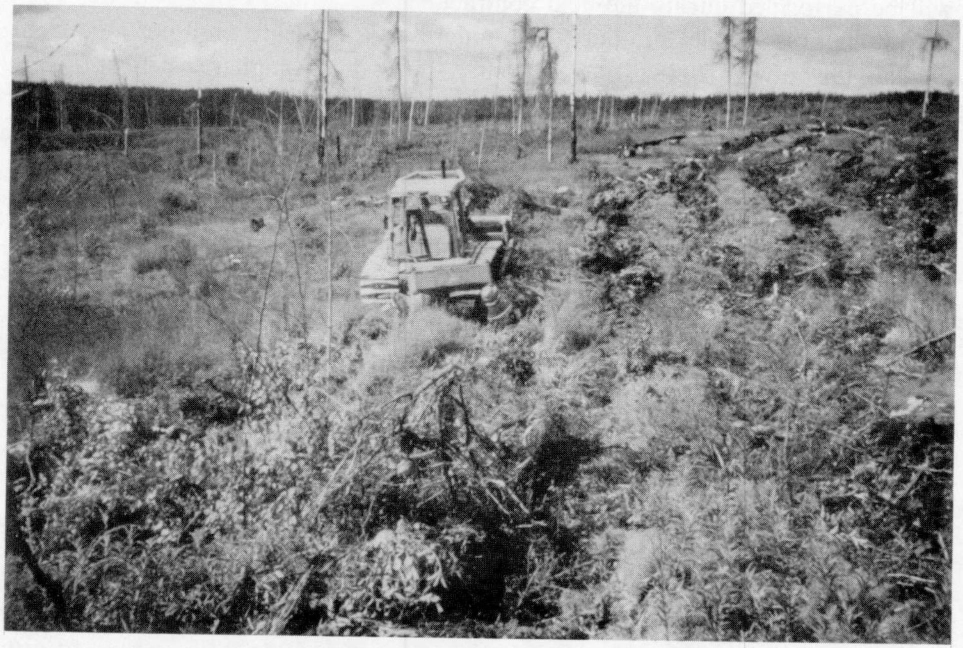

Figure 5. Photo showing the D-6 crawler and the spacing of the furrows obtained.

A second explanation for the difference in soil exposure is that the two areas the machines scarified contained different amounts of slash. Large amounts of slash reduce the effectiveness of the scarifier by preventing the discs from cutting into the organic mat. The area on which the skidder was operated had been harvested just prior to scarification so that slash had not had time to break down. Logging had been completed from 2 to 10 years prior to scarification on the area worked by the crawler. Most of the slash on the older sales was consumed in the Rosie Creek Fire.

The heavy grass cover on portions of the units appeared to reduce the effectiveness of the scarifier slightly. Though the discs cut through the root mat, they did not always cast the material far enough aside to prevent its rolling back into the furrow. This may allow the grass to be matted down into the furrows by snow during the winter, thereby causing damage to spruce regeneration. This problem may be solved by the addition of more weight to the scarifier and/or adjustment of the disc angle so that the furrows will be wider. More research on this problem will be performed during the next contract.

Although the skidder provided less mineral soil exposure on a per acre basis than did the crawler (6,588 ft^2 to 8,322 ft^2), the skidder's higher scarification rate resulted in its providing 35.6 percent more exposure per machine hour. As the contract cost of the skidder was less expensive than that of the crawler ($36.64/A to $55.87/A), the skidder was able to provide 20.1 percent more soil exposure per contract dollar. This figure should be regarded as a minimum difference due to the fact that Contractor #2 bid the contract too low.

During the course of the contract, both contractors experienced unusually high amounts of standby time due to problems with the drop-pin hitches used to tow the scarifier. Several of these hitches were manufactured locally and did not hold up well. Contractor #2 had the most problems, with 48.9 percent of his contract time comprised of standby hours. Contractor #3 fabricated a hitch which performed better than those he was given and experienced only 37.9 percent standby time. If DOF can obtain a better hitch, the overall cost of scarification should be reduced.

Conclusions

The TTS-35 performed well in its first large-scale trial in interior Alaska. The mineral soil exposure was quite good (fig. 6), and the pattern of this exposure should provide good spacing for seedlings which become established on the seedbed. The cost per acre for scarification with the TTS-35 was very good, particularly with the Clark 668 as prime mover. The scarifier appears to have provided DOF with a low-cost method of site preparation for the regeneration of white spruce.

Even though costs for operating the rubber-tired skidder were lower, crawler tractors should not be excluded from the bidding process. This is particularly true for areas having steep slopes and terrain conditions where a skidder may have trouble operating. The crawler scarified effectively in areas where the skidder could not safely operate. In future contracts consideration should also be given to the

Figure 6. Photo showing a seedling planted in the mineral soil exposed by the scarifier.

fact that the crawler provided more mineral soil exposure per acre than did the skidder. Whether this is significant in obtaining adequate regeneration of timber sales is a question to be answered by future research.

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