# EVALUATION OF SITE PREPARATION WITH YOUNG'S TEETH ON SITES WITH DENSE RESIDUAL POPLARS

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## ABSTRACT

Young's Teeth were evaluated in Ontario on boreal mixedwood sites with dense residual stands of poplars. All residuals, stumps and slash were windrowed in preparation for planting of jack pine. The implements produced from 42% to 56% plantable disturbance (corresponding closely to receptive seedbed) and from 1965 to 2438 plantable and marginally plantable spots per hectare within the cleared corridors, exclusive of windrows. Silvicultural productivity on a gross hectare basis was low, at 884 plantable and marginally plantable spots per productive machine hour (PMH), as a result of time lost through reversing while windrowing, treatment of the entire area, and a 20-37% loss of plantable area within the windrows. The low silvicultural productivity and loss of plantable area are indicative of the difficulty and expense associated with this stand conversion treatment.

## RÉSUMÉ

Les dents d'Young (Young's Teeth) ont été évaluées en Ontario dans des peuplements résiduels denses de peupliers de la forêt boréale mixte. Tous les arbres résiduels, toutes les souches et tous les débris de coupe ont été mis en andains en vue de la plantation en pin gris. Le matériel utilisé a permis d'obtenir un sol perturbé apte à la plantation avec une perturbation variant de 42 à 56% (correspondant étroitement à un lit de germination réceptif) et de produire de 1965 à 2438 placeaux plantables ou marginalement plantables par hectare dans les corridors coupés, non compris les andains. La productivité sylvicole brute à l'hectare a été faible, soit de 884 placeaux plantables ou marginalement plantables par heure machine de fonctionnement. On attribue cette faible productivité au temps perdu à faire marche arrière pendant la mise en andains, au fait que tout le terrain a été traité et à une perte de 20 à 37% de l'espace plantable occupé par les andains. La faible productivité sylvicole et la perte d'espace plantable font voir la difficulté et l'importance des coûts de ce traitement pour la conversion de peuplements.

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Cover photo: Two Young's Teeth mounted on Caterpillar D7G bulldozer.

## INTRODUCTION

In boreal mixedwoods, the artificial establishment of conifers on sites that would normally revert to poplar *(Populus* sp.) and white birch *(Betula papyrifera* Marsh.) after harvesting is an expensive and difficult task. Intensive site preparation, planting and tending are essential for success (Heikurinen 1981). Site preparation on such areas may often be further complicated by the presence of a residual stand of hardwoods not fully utilized during logging because of the absence of markets.

When the density of residual hardwoods is high, access to the site by mechanical site preparation equipment is impeded. Simply knocking the residuals down during site preparation exaggerates the problem by seriously impeding the movement of tree planters. In mixedwood stands with between 35 and 85 $m^3$/ha of residual hardwoods, E.B. Eddy Forest Products Ltd. of Espanola, Ontario uses bulldozers equipped with Young's Teeth to uproot and push the residual hardwoods into windrows together with stumps and other slash[2]. The cleared corridors between the windrows not only improve access for tree planters but also facilitate subsequent tending operations such as the application of herbicides, which may be necessary as part of the conversion process.

The first use in Canada of ripper teeth similar to Young's Teeth is reported in trials near Prince George, British Columbia between 1956 and 1959 (Decie and Fraser 1960). Young's teeth have been used in Ontario since 1962 (Brandes and Scott 1975). Their use is described in Smith (1980) and Kelertas[3] respectively. In 1984, Young's Teeth mounted on D7 and D8 caterpillar tractors were evaluated by the University of Toronto under contract to the Great Lakes Forestry Centre (GLFC) in cooperation with E.B. Eddy Forest Products Ltd. on sites located in boreal mixedwoods near Ramsay in northeastern Ontario. The Young's Teeth and prime movers were supplied under contract to E.B. Eddy Forest Products Ltd. E.B. Eddy provided the sites, supervisors and mechanical support for the study.

The purpose of the evaluation was to determine the ability of the Young's Teeth to facilitate stand conversion on a range of sites with dense residual poplars. Merchantable softwoods had been full-tree logged and a portion of the residual poplar had been tree-length logged. The results were evaluated against the same criteria for quantity and quality of microsite preparation and in the same vicinity as evaluations of the TTS-35 disc trencher, Leno 77 patch scarifier and Bräcke cultivator (2-row) carried out in 1982 (Smith et al. 1985) and the Donaren 180D powered disc trencher in 1984 (Puttock and Smith 1986).

Standard assessment procedures developed at GLFC (Sutherland 1986) were applied to allow reasonable comparisons between these and other equipment evaluations carried out across Canada. It is hoped that these case studies will provide sound technical information on equipment performance under defined conditions for the benefit of forest managers across Canada.

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[2]Boddy, C. Forest Management Supervisor, E.B. Eddy Forest Products Ltd., Espanola, Ont., 1985 (pers. comm.).

[3]Kelertas, R.A. 1978. Mechanical site preparation in the boreal forest with special reference to Ontario. Univ. Toronto, Fac. For., Toronto, Ont. M.Sc. Thesis. 278 p.

## LOCATION AND SITE DESCRIPTION

Timber rights for the trial areas were held by E.B. Eddy Forest Products Ltd. under a forest management agreement (FMA). Three sites were selected for the study. Sites 1 and 2 were adjacent to one another in Alcona Township approximately 23 km east of Ramsay, Ontario. Site 3 was located 35 km northeast of Ramsay in Yeo Township (Fig. 1). The areas are in the boreal forest region (Missinaibi-Cabonga Sec. B.7 [2] West) (Rowe 1972), and lie within the Precambrian Shield. The soils consist of a thin mantle of glacial moraine over bedrock and small lacustrine deposits in lowland areas and are classified as sandy loam tills.

Sites 1 and 2 were upland sites with flat to gently rolling topography and well drained, deep, sandy loam soils. Prior to harvesting, Site 1 supported a mixedwood stand of jack pine *(Pinus banksiana* Lamb.), trembling aspen *(Populus tremuloides* Michx.), black spruce *(Picea mariana* [Mill.] B.S.P.) and white birch. Site 2 supported jack pine and trembling aspen in equal proportions. Both stands were approximately 80 years old and 80% stocked.

Site 3 was also an upland site with gently rolling, broken topography. In contrast to the deeper soils found on the other two sites, the sandy loam on Site 3 was shallow in places with some bedrock outcrops.

Prior to harvesting, Site 3 supported a mixedwood stand composed of black spruce, trembling aspen, jack pine and balsam fir *(Abies balsamea* [L.] Mill.). The stand was approximately 75 years old and 70% stocked.

Full-tree logging of merchantable softwood (Fig. 2) from the first two areas was undertaken in 1983 by means of the cut and skid system with roadside mechanical delimbing. During the spring of 1984, some of the hardwood was harvested by means of a cut and skid tree-length method, with the tops and limbs left at the stump.

Merchantable softwoods from Site 3 were full-tree logged in May and June, 1984 and some aspen was tree-length logged in July. The same harvesting methods were employed as on the other two sites, but after harvesting, considerably more residual hardwoods were left standing on sites 2 and 3 than on Site 1.

The silvicultural prescription called for the conversion of the sites to jack pine plantations through the removal of slash, stumps and residual hardwoods with heavy site preparation implements such as Young's Teeth followed by planting. The slash, stumps and residual timber were to be bulldozed into windrows with the ground surface between the windrows exposed to mineral soil. Corridors were located parallel to one another and generally ran perpendicular to the road. The minimum desired net corridor width was 6.6 m. No maximum width was specified. Planting of jack pine paperpot stock by means of Pottiputki planting tubes at 2-m x 2-m spacing was scheduled for the spring of 1985.

## IMPLEMENT AND PRIME MOVERS

Each Young's Tooth consists of a solid steel shaft that is secured to the top of the bulldozer blade by an adjustable head clamp and to the bottom by a V-shaped notch. The bottom tip of the shaft is normally fitted with a wear point that is either welded on or replaceable. The lower portions of the teeth were reinforced against wear with a criss-cross pat-

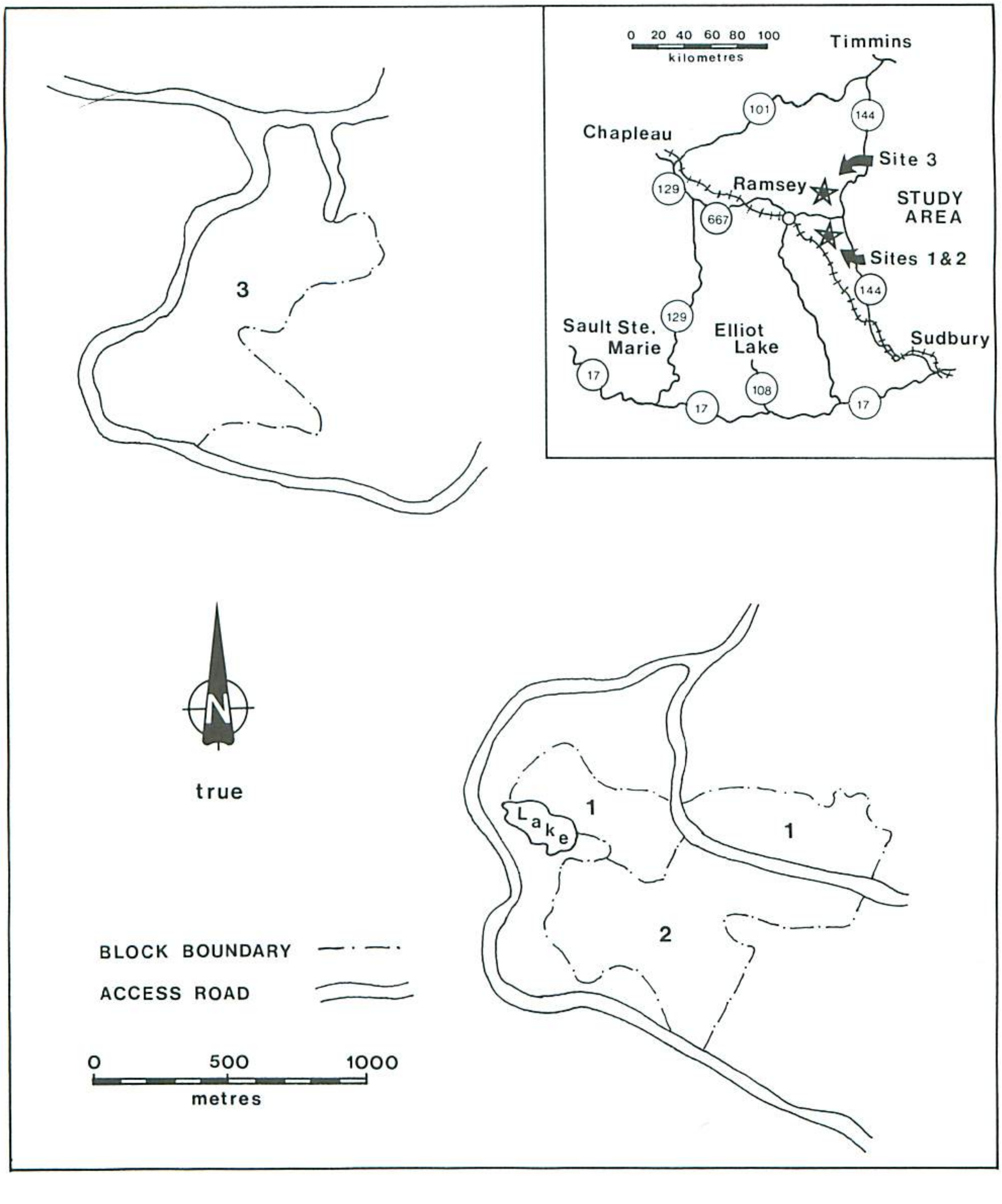


Figure 1. General location of study area and configuration of sites

Figure 2. Site 2 after full-tree logging of merchantable softwood

tern of hard surface welding. Two Model #4A Young's Teeth were mounted on each bulldozer blade (Fig. 3 and 4). (See Appendix A for additional specifications.)

The prime movers were two 1981 Caterpillar D7G bulldozers (149 kW) (Fig. 4) and a 1981 Caterpillar D8K bulldozer (224 kW). All were equipped with standard track shoes, which were 510 mm wide on the D7Gs and 560 mm on the D8K. The angle blades on the D7Gs and D8K were 4.3 and 4.7 m wide, respectively. (See Appendix A for additional specifications.) One of the D7Gs and the D8K were evaluated during the continuous time study. The prime movers were leased by E.B. Eddy Forest Products Ltd. and were operated by hourly rated employees.

The Young's Teeth plus the blade and tracks of the bulldozer work together as a site preparation tool, with movement of the tracks causing additional mixing. The degree of disturbance can vary considerably and is controlled by raising and lowering the blade. A full blading effect or the much less severe effect of raking and scarification combined can be achieved by setting the blade at the top of the humus layer with the teeth extending approximately 40 cm into the soil (Model #4A) and ripping out roots and stumps. Debris accumulating in front of the blade contributes to the scraping action. In this trial, all debris was pushed into windrows to facilitate access to tree planters. Where slash is lighter it is possible to create more or less continuous, single-pass, blade-width corridors by using the "dip and dive" method. When further forward motion is hindered by the accumulation of debris, the tractor is reversed, the blade is raised and the unit then continues forward over the pile.

## ASSESSMENT PROCEDURE

Data were collected according to standard assessment procedures developed at GLFC (Sutherland 1986). The field work was divided into three

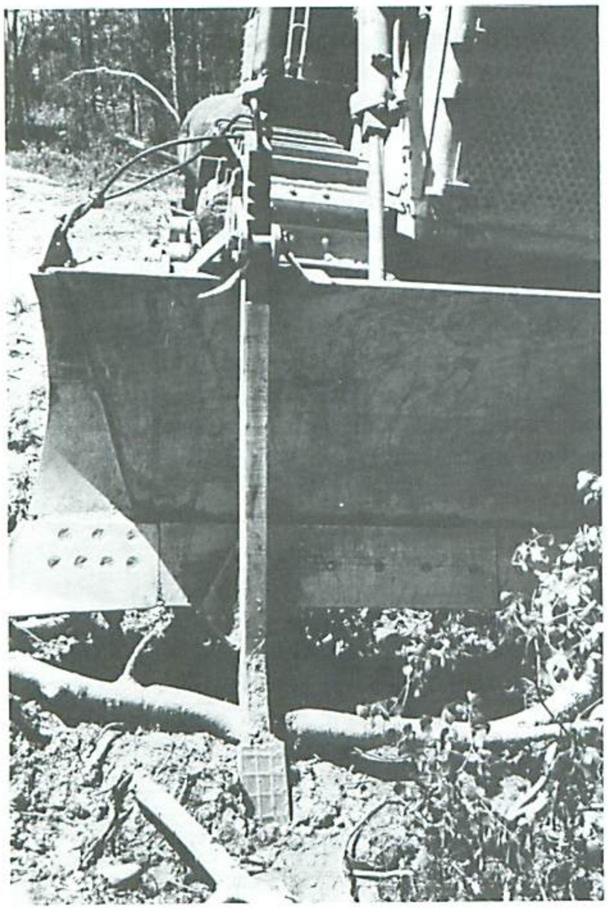

Figure 3. Model #4A Young's Tooth mounted on bulldozer blade (Cable attached to top of tooth and blade prevents loss should the tooth become detached.)

Figure 4. Two Young's Teeth mounted on Caterpillar D7G bulldozer

components: (i) pretreatment assessment, (ii) continuous time study, (iii) post-treatment assessment. Key parameters in the pre- and post-treatment assessments included slash volume, soil depth, duff depth, plantable disturbance, and number of plantable spots. These were sampled at a minimum level of 10% significance with a 15% confidence interval. Sample size for the key parameters was determined according to Payandeh and Beilhartz (1978) with data collected in a presample.

Post-treatment assessment was carried out by means of 20-m-long transects containing 10 2-m x 2-m quadrats. The plots were established perpendicular to the corridors. Windrows were excluded from the assessment.

In each quadrat the quality and quantity of soil disturbance were estimated. Though not part of the prescription, the amount of receptive seedbed for jack pine (Riley 1980) was determined from the disturbance assessment. Plantability (opportunities for planting) was assessed in each quadrat lying within the corridor. Planting spots measuring 30 cm x 30 cm were assessed as plantable, marginally plantable or non-plantable on the basis of established criteria for duff depth, amount of debris and vegetative competition, and type of soil disturbance. A Pottiputki planting tube was used to test if the selected spot was penetrable. The reasons for non-penetration as well as microrelief class were also recorded (Smith et al. 1985). If the spot with the best type of soil disturbance was not plantable because of difficulty of penetration, duff thickness, debris or vegetative competition, it was described as a first choice and a second spot was then described.

## RESULTS

### *Pretreatment Assessment*

Soil and ground conditions: Site 3 was different from sites 1 and 2 in terms of soil depth, duff depth and stoniness. Average mineral soil depth within the top 30 cm of the surface was approximately 27 cm on sites 1 and 2, and 20 cm on Site 3 (Table 1). Shallow soils (0-10 cm) were more prevalent on Site 3 (Fig. 5).

The average duff depth was 6.1 and 7.2 cm on sites 1 and 2, respectively, and 5.5 cm on Site 3 (Table

Table 1. Average soil and ground conditions

| Site | Mineral soil depth (cm)[a] | Duff (LFH) depth (cm) | Stoniness[b] (%) | Ground roughness class[c] |
|---|---|---|---|---|
| 1 | 27.4 | 6.1 | 12.5 | 1 (2) |
| 2 | 27.6 | 7.2 | 15.8 | 3 (2) |
| 3 | 19.5 | 5.5 | 66.7 | 1 (2) |

[a]within 30 cm of the surface
[b]the percentage of soil depth measurement in which stony material is encountered when the measurement probe is inserted in the first 30 cm of mineral soil
[c]Numbers within parentheses refer to a ground roughness class that accounts for more than 10% of the sample area.

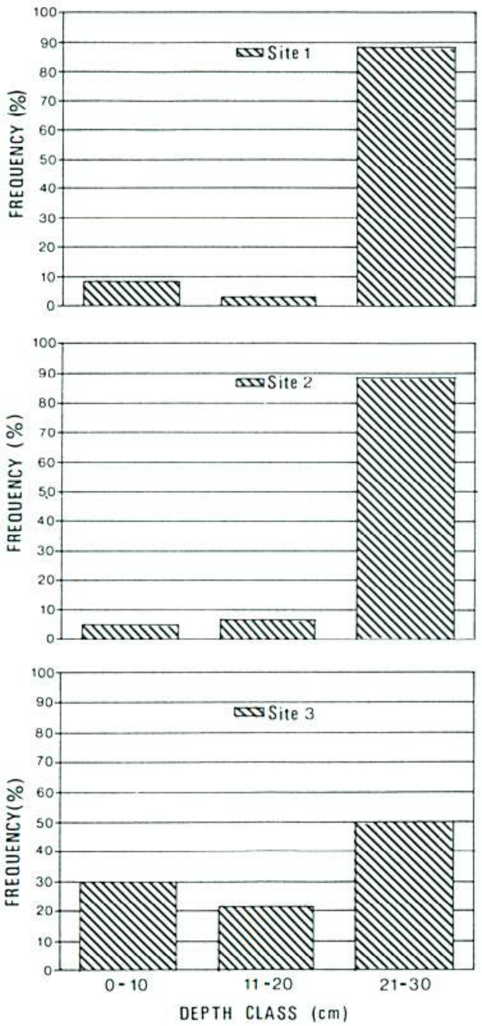


Figure 5. Mineral soil depth

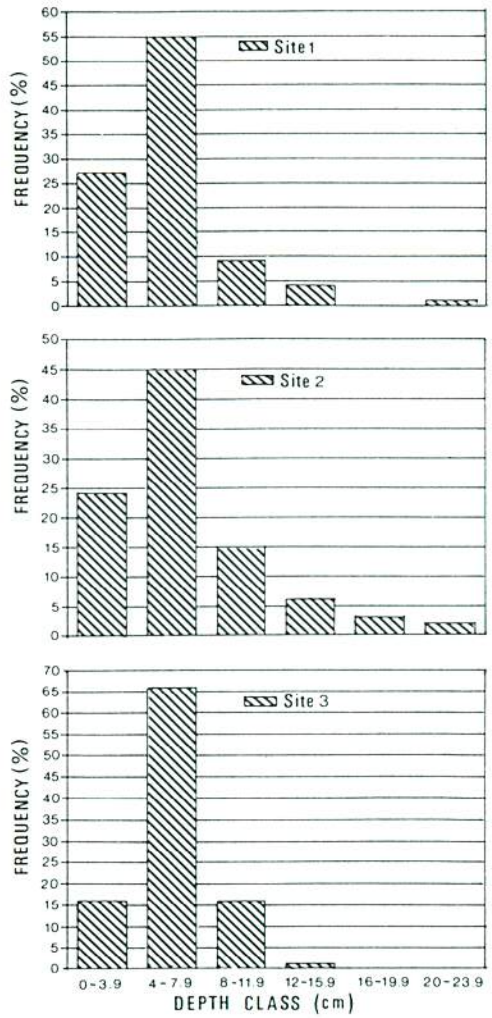


Figure 6. Duff (LFH) depth

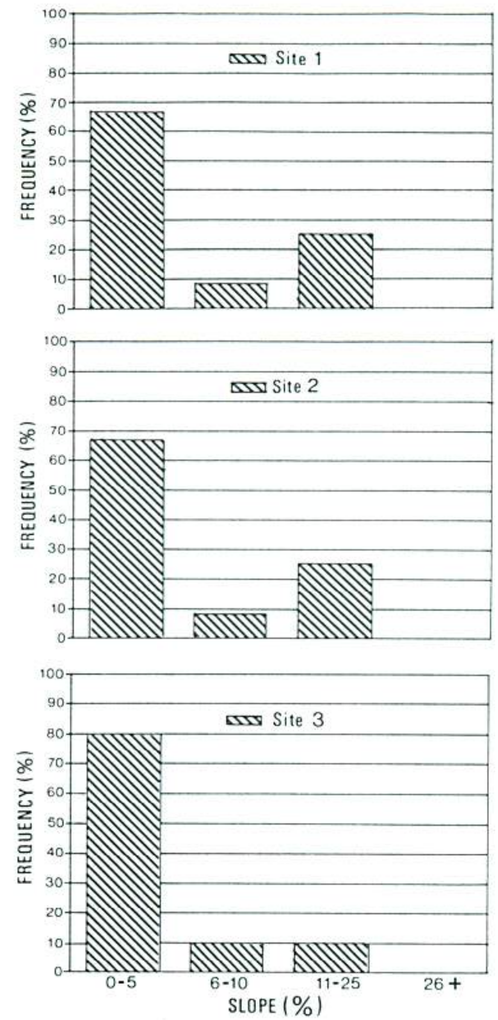


Figure 7. Maximum slope

1). Sites 1 and 2 contained duff up to 24 cm in some places whereas on Site 3 the duff never exceeded 16 cm (Fig. 6).

Stoniness, a measure of buried stones and boulders within 30 cm of the surface, averaged 12.5% and 15.8% on sites 1 and 2, respectively, while stoniness on Site 3 averaged a much higher 66.7% (Table 1).

Sites 1 and 3 were both placed in ground roughness class 1 while Site 2 was placed in class 3 because it had a higher proportion of surface boulders (Table 1).

Slope: Sites 1 and 2 had similar distributions of slope with approximately 65% in the 0%-5% slope class, 9% in the 6%-10% class, and 26% in the 11%-25% class (Fig. 7). Site 3 was generally flat to gently rolling, with 80% in the 0%-5% slope class.

Logging slash: All three sites averaged between 63 and 70 pieces of slash per 20 m of lineal tally in the 1- to 5-cm diameter class[4] (Table 2, Fig. 8).

The number (Fig. 9) and volume of pieces of slash more than 5 cm in diameter show differences among the three areas. Site 2 contained the most pieces more than 5 cm in diameter, while Site 1 had fewer but larger pieces of slash than sites 2 and 3. On sites 1 and 2 hardwoods accounted for approximately 50% of the slash, whereas they accounted for 30% on Site 3. The hardwood slash consisted of large tops and branches and was randomly scattered throughout the cut-over area, often in large clumps. Frequency distributions of slash volume for the three areas are shown in Figure 10.

Stumps: Because of a higher level of utilization, Site 1 had the highest density of stumps at 3409/ha, in comparison with 2083 and 2143/ha on sites 2 and 3, respectively. On Site 3 the average height of stumps was less than on the other two areas (Table 3).

Residual vegetation: The average diameter (DBH) of residual timber was very consistent from site to site (Table 4). Site 1 exhibited the lowest residual stocking at 14.5%, in comparison with 28.3% and 25.8% on sites 2 and 3, respectively. The stocking of brush was high on all sites, with Site 1 supporting the greatest mean frequency of brush (Table 5). Site 1 also supported the highest percentage of areal coverage of minor vegetation (Table 6).

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[4]Estimation of slash pieces in the 1- to 5-cm diameter class is subject to error because the diameter of the smallest pieces in this class is usually estimated by eye.

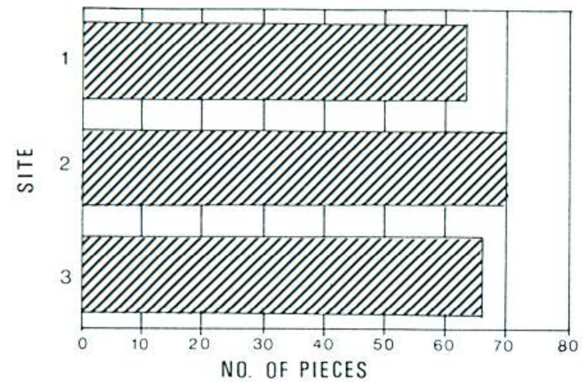


Figure 8. Slash pieces per 20-m lineal tally 1-5 cm in diameter

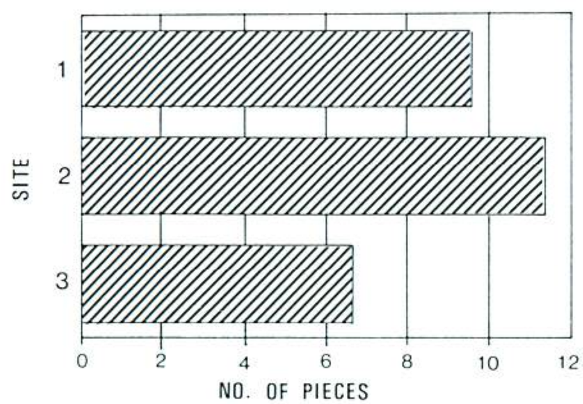


Figure 9. Slash pieces per 20-m lineal tally more than 5 cm in diameter

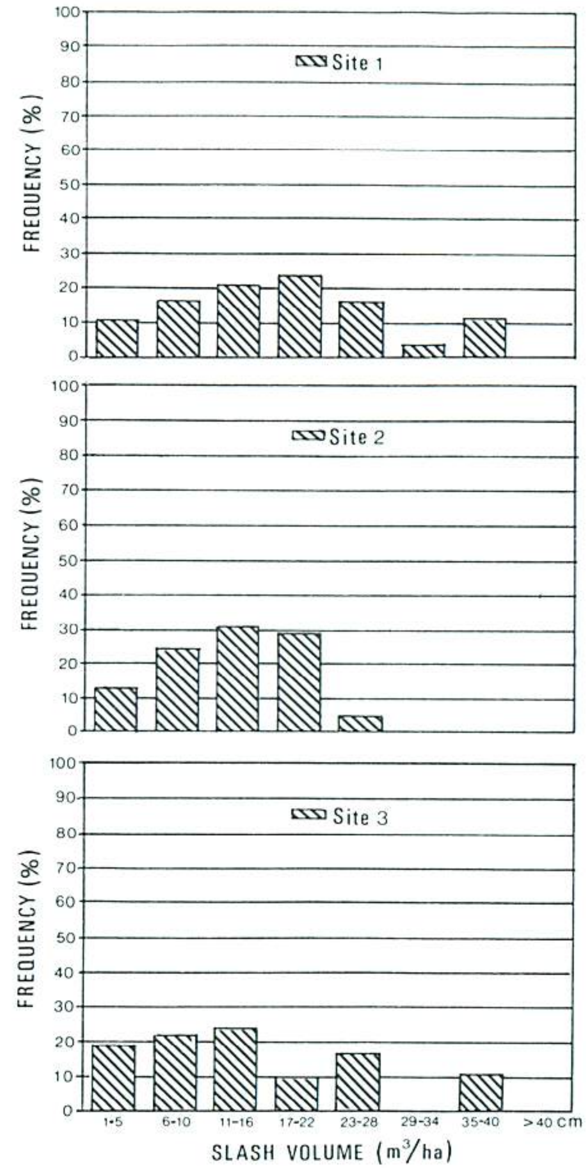


Figure 10. Slash volume frequency distribution by diameter

Table 2. Slash

| | Pieces per 20 m of lineal tally | | Diameter | Depth | | Volume | | | Species | |
|---|---|---|---|---|---|---|---|---|---|---|
| Site | 1-5 cm (no.) | >5 cm (no.) | Avg >5 cm (cm) | Avg (cm) | Range (cm) | Avg 1-5 cm ($m^3$/ha) | Avg > 5 cm ($m^3$/ha) | Total ($m^3$/ha) | Conifer (%) | Hardwood (%) |
| 1 | 63.2 | 9.6 | 13.0 | 18.0 | 0 - 110 | 14.4 | 127.8 | 142.2 | 50.8 | 49.2 |
| 2 | 69.8 | 11.3 | 11.3 | 18.9 | 0 - 131 | 15.3 | 107.0 | 122.3 | 44.2 | 55.8 |
| 3 | 65.9 | 6.7 | 10.0 | 14.5 | 0 - 91 | 14.3 | 63.7 | 78.0 | 70.0 | 30.0 |

Table 3. Stumps

| | | Height | | Diameter | |
|---|---|---|---|---|---|
| Site | Frequency (no./ha) | Avg (cm) | Range (cm) | Avg (cm) | Range (cm) |
| 1 | 3409 | 48.3 | 32-99 | 23.2 | 13-39 |
| 2 | 2083 | 42.9 | 30-62 | 19.2 | 10-38 |
| 3 | 2143 | 30.8 | 14-73 | 23.3 | 7-47 |

Table 4. Residual timber left on sites

| Site | Stocking[a] (%) | Avg DBH (cm) | DBH range (cm) |
|---|---|---|---|
| 1 | 14.5 | 22.5 | 10-35 |
| 2 | 28.3 | 23.3 | 12-38 |
| 3 | 25.8 | 23.9 | 4-46 |

[a]Plonski (1974)

Table 5. Brush

| Site | Stocking (%) | Frequency (no./ha) | Species[a] |
|---|---|---|---|
| 1 | 100.0 | 6250 | Mr, Ha |
| 2 | 93.0 | 4500 | Mr, Ha, A |
| 3 | 88.0 | 3750 | Mr, Sb, A |

[a]Mr = red maple *(Acer rubrum* L.), Ha = hazel *(Corelus cornuta* Marsh.), Sb = black spruce, A = mountain-ash *(Sorbus americana* Marsh.)

Table 6. Minor vegetation

| Site | Areal coverage (%) | Species[a] |
|---|---|---|
| 1 | 18.2 | Bl |
| 2 | 3.3 | Lt |
| 3 | 4.5 | Bw, Ha |

[a] Bl = blueberry *(Vaccinium angustifolium* Ait.), Lt = Labrador tea *(Ledum groenlandicum* Oeder.), Bw = white birch, Ha = hazel

### *Continuous Time Studies*

Continuous time studies were conducted to determine how the scheduled operating time of the implement was used and to identify any problems and sources of unproductive time.

Time studies of one of the D7G bulldozers and the D8K were conducted while the equipment was working on sites 1 and 2. The time study results of each prime mover and implement combination are shown in Figure 11. Time elements are defined in Appendix B. Of note is the effective productive time, which reflects the proportion of scheduled time when the implements were actually engaged in site preparation, i.e., only forward time when the bulldozer is piling debris. The technique of windrowing requires constant changing from moving forward when piling debris to backing up in preparation for another "push". An average 36.5% of total time was spent pushing forward, while time in reverse averaged 26.2% of total time (Table 7).

Table 7. Forward (effective productive time) versus backup time as a percentage of total productive machine time

| Site | Forward (%) | Backup (%) |
|---|---|---|
| D7 (1) | 38.7 | 25.3 |
| D8 (1) | 27.7 | 18.9 |
| D7 (2) | 39.4 | 30.3 |
| D8 (2) | 36.8 | 26.3 |
| Combined | 36.5 | 26.2 |

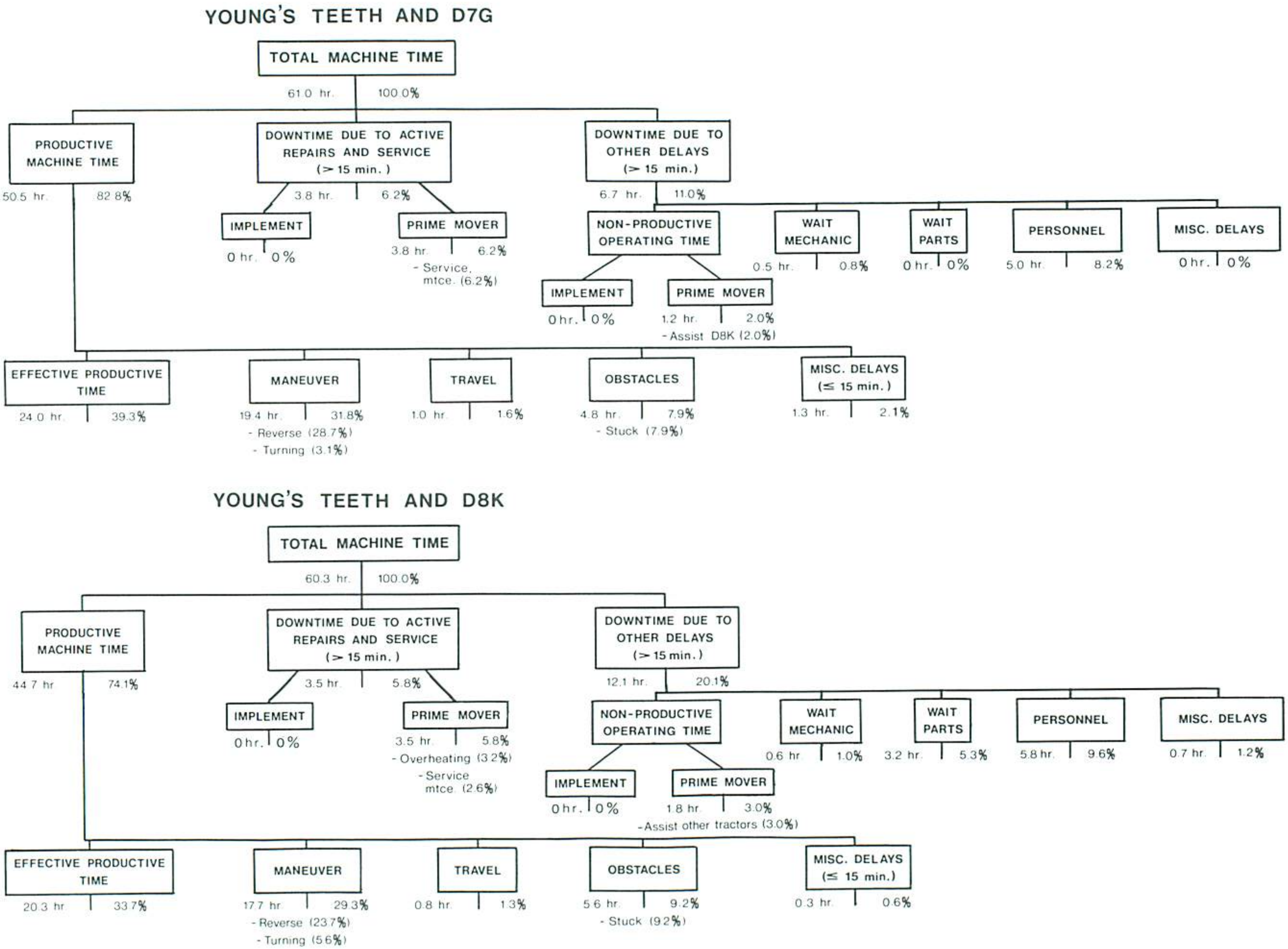


Figure 11. Results of continuous time study

Personal time accounted for major delays with both implements. This may be partially attributable to the inexperience of the operators in site preparation as their supervisor frequently found it necessary to interrupt the operation and provide instructions.

Rain fell on most days during the time studies. This resulted in wet site conditions, which caused the bulldozers to become stuck frequently. Often the operator was unable to free the bulldozer, and one of the other bulldozers was required to provide assistance.

Machine productivity on sites 1 and 2 was 0.67 and 0.47 ha per productive machine hour (PMH), respectively (Table 8).

Utilization and mechanical availability are measures that reflect both the reliability of the machine and the effectiveness with which it is used. Utilization of the Young's Teeth was somewhat below what might otherwise be expected owing to the relatively high number of delays during the operator's training period. The implement and D7G achieved 82.8% utilization while the utilization of the Young's Teeth on the D8K was 74.1% (Table 9). The mechanical availability of the Young's Teeth was 100%, reflecting favorably on the simple design and durability of the implement. The prime movers also achieved high levels of availability, 92.8% for the D7G and 93.0% for the D8K.

### *Post-treatment Assessment*

The effectiveness of the site preparation treatment is reflected in four ways: (1) corridor and windrow widths, (2) overall soil disturbance including receptive seedbed, (3) plantability, i.e., the proportion of the area treated that is suitable for planting, and (4) the distance between plantable spots within the scarified areas.

Corridor and windrow widths: The mean gross corridor widths ranged from 32.3 to 39.3 m and the mean net widths from 24.7 to 27.1 m (Table 10). Windrow widths averaged 6.8, 7.0 and 14.6 m on sites 1, 2 and 3, respectively, and the proportion of area lost to windrows ranged from 20 to 37.2%.

Table 8. Productivity summary

| Site | Total machine time (hr) | Productive machine time (hr) | Area (ha) | Productivity: Per effective productive time (EPT) (ha/hr) | Productivity: Per PMH (ha/hr) |
|---|---|---|---|---|---|
| 1 | 42.2 | 29.3 | 19.76 | 1.39 | 0.67 |
| 2 | 79.1 | 65.1 | 30.77 | 1.02 | 0.47 |
| Comb. | 121.3 | 94.4 | 50.53 | 1.14 | 0.54 |

Table 9. Machine utilization and availability

| Site | Machine utilization (%) | Machine availability: CPPA[a] availability (%) | Implement and prime mover (%) | Implement (%) |
|---|---|---|---|---|
| D7 (1) | 86.0 | 100.0 | 92.0 | 100.0 |
| D7 (2) | 81.3 | 100.0 | 93.6 | 100.0 |
| D7 (Comb.) | 82.8 | 100.0 | 92.8 | 100.0 |
| D8 (1) | 56.3 | 100.0 | 84.8 | 100.0 |
| D8 (2) | 83.5 | 100.0 | 95.9 | 100.0 |
| D8 (Comb.) | 74.1 | 100.0 | 93.0 | 100.0 |
| Combined | 78.5 | 100.0 | 92.9 | 100.0 |

[a] Canadian Pulp and Paper Association

Table 10. Corridor and windrow widths

| Site | Corridors: Gross width[a] (m) | Net width[b] (m) | Windrows: Width (m) | Area lost (%) |
|---|---|---|---|---|
| 1 | 33.9 | 27.1 | 6.8 | 20.0 |
| 2 | 32.3 | 25.3 | 7.0 | 21.7 |
| 3 | 39.3 | 24.7 | 14.6 | 37.2 |

[a]distance from center of windrow to center of adjacent windrow
[b]cleared distance between windrows

Overall soil disturbance including receptive seedbed: Soil disturbance was classified on the basis of the amount of exposed mineral soil, mixture of mineral soil and duff, and thickness of reduced or compressed duff. As can be seen from Table 11, the soil disturbance classes that were used to describe plantable disturbance correspond closely to the receptive seedbed classes for jack pine in northeastern Ontario (Riley 1980).

Most of the plantable disturbance consisted of mineral soil with a firm base. Plantable disturbance within the cleared corridors (exclusive of windrows) was high, averaging 56.2%, 41.6% and 44.5% on sites 1, 2 and 3, respectively (Table 11 and Fig. 12).

Marginally plantable disturbance was predominantly mounded mineral soil on a firm base.

Plantability assessment: Plantability within the cleared corridors was high, averaging 2142, 1822 and 2250 plantable spots per ha for sites 1, 2 and 3, respectively (Table 12). The combined number of plantable and marginally plantable spots was 2285, 1965 and 2438 per ha, respectively. Of the total number of spots assessed within the corridors, 91.4%, 78.6% and 97.5%, respectively, were plantable or marginally plantable. The proportion of plantable, marginally plantable and non-plantable spots is shown in Figure 13.

Plantability is reduced considerably when the windrow-covered area is included; i.e., to 1828, 1539 and 1531 plantable and marginally plantable spots per ha (Table 12 and Fig. 13).

A summary of the relevant information concerning the microsite conditions created by the implement on the first choice planting spots is provided in Table 13.

Soil penetration with the planting tool was very good on sites 1 and 3, averaging over 91% on both areas. This was achieved on Site 3 despite the relatively high stone content. However, inadequate penetration because of stones or rocks was reported for 18.6% of the spots on Site 2 where stoniness prior to treatment was similar to that on Site 1 and much less than that on Site 3.

Distance between plantable spots: The mean distance between plantable spots across the corridors was approximately 2.0 m on sites 1 and 3, and 3.3 m on Site 2. The similar value along the corridors was approximately 2.1 m on sites 1 and 3 and 3.0 m on Site 3.

## DISCUSSION

With the exception of high residual poplar densities, site conditions on the three experimental sites may generally be described as moderately difficult, with some major differences in soil conditions, ground roughness, slash and residual stocking.

Because of the weight and size of the bulldozers, residuals stumps and slash were thoroughly cleared on all three sites. The D8K appeared to be more effective in clearing material than the D7G.

As a consequence of the clearing operations and the prescription to produce exposed mineral soil, the amount of soil disturbance within the cleared corridors was high and consisted primarily of exposed mineral soil.

A noteworthy difference in results was an excessive exposure of rock because of the treatment on Site 2, and a consequent 18.6% loss in plantability. The greater number of residuals on Site 2 than on Site 1 meant that more maneuvering and bulldozing were required and possibly more disturbance was caused. This and the greater ground roughness on Site 2 could partially explain the excessive disturbance on Site 2 in comparison with Site 1, where the soil depth was similar. However, excessive disturbance was not noted on Site 3, where residual stocking was similar to that on Site 2 but soils were shallower and stonier and therefore probably more prone to excessive disturbance. Another major difference in site conditions was the volume and type of slash. However, the quality of site preparation was probably less sensitive to differences in site conditions among the three sites than to the ability of the operators to achieve consistent results.

Table 11. Overall soil disturbance including receptive seedbed created by implement

| Site | Plantable disturbance and/or receptive seedbed[a]: Exposed min. soil with firm base (%) | Thin (<1.5 cm) duff/min. soil mix[b] (%) | Thin (<1.5 cm) duff on firm base (%) | Total (%) | Marginally plantable disturbance: Mounded min. soil on firm base (%) | Mod. thick (1.5 < 3 cm) duff/min. soil mix on firm base (%) | Mod. thick (1.5 < 3 cm) duff on firm base (%) | Total (%) | Total plantable and marginally plantable disturbance (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Within cleared corridors only | | | | | |
| 1 | 46.2 | 0.5 | 9.5 | 56.2 | 5.5 | 0.0 | 3.5 | 9.0 | 65.2 |
| 2 | 26.8 | 8.9 | 5.9 | 41.6 | 8.5 | 0.8 | 6.8 | 16.1 | 57.7 |
| 3 | 40.3 | 0.1 | 4.1 | 44.5 | 2.5 | 0.0 | 3.8 | 6.3 | 50.8 |

[a]Corresponds closely with receptive seedbed criteria for jack pine in northeastern Ontario (Riley 1980)
[b]Will settle to firm base

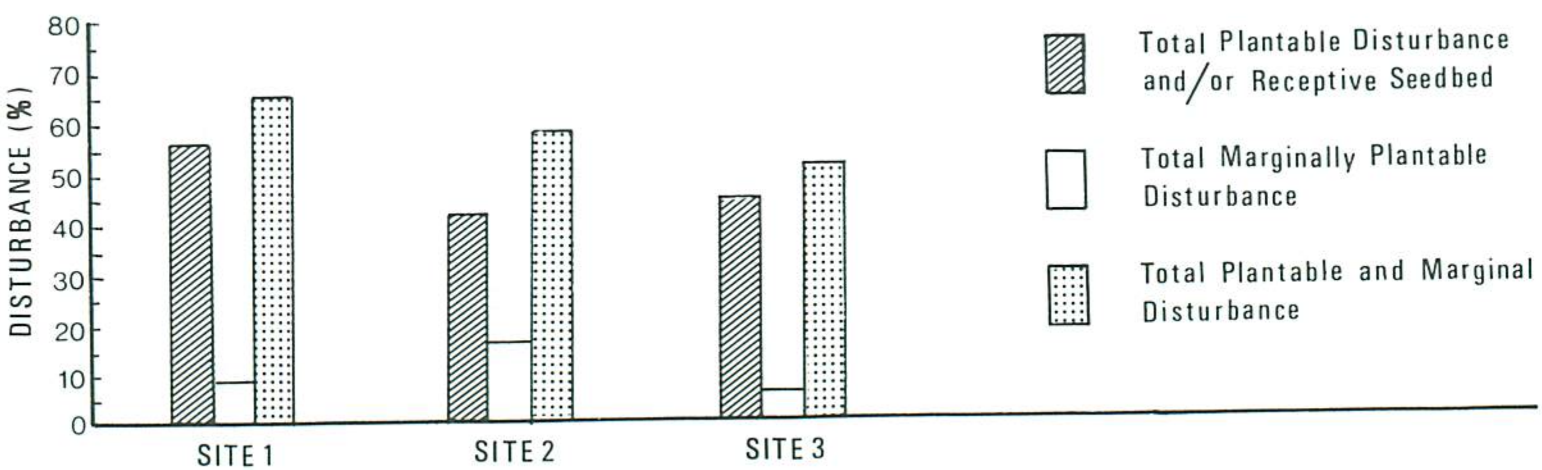


Figure 12. Overall soil disturbance including receptive seedbed created by implement (See Table 11.)

Table 12. Plantability assessment

| Site | Plantable spots (no./ha) | Plantable spots (%) | Marginally plantable spots (no./ha) | Marginally plantable spots (%) | Plantable and marginally plantable spots (no./ha) | Plantable and marginally plantable spots (%) | Non-plantable spots (no./ha) | Non-plantable spots (%) | Total (no./ha) | Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Within cleared corridors only | | | | | | | | | | |
| 1 | 2142 | 85.7 | 143 | 5.7 | 2285 | 91.4 | 215 | 8.6 | 2500 | 100.0 |
| 2 | 1822 | 72.9 | 143 | 5.7 | 1965 | 78.6 | 535 | 21.4 | 2500 | 100.0 |
| 3 | 2250 | 90.0 | 188 | 7.5 | 2438 | 97.5 | 62 | 2.5 | 2500 | 100.0 |
| Including area in windrows | | | | | | | | | | |
| 1 | 1714 | 68.5 | 114 | 4.6 | 1828 | 73.1 | 672 | 26.9 | 2500 | 100.0 |
| 2 | 1427 | 57.1 | 112 | 4.5 | 1539 | 61.6 | 961 | 38.4 | 2500 | 100.0 |
| 3 | 1413 | 56.5 | 118 | 4.7 | 1531 | 61.2 | 969 | 38.8 | 2500 | 100.0 |

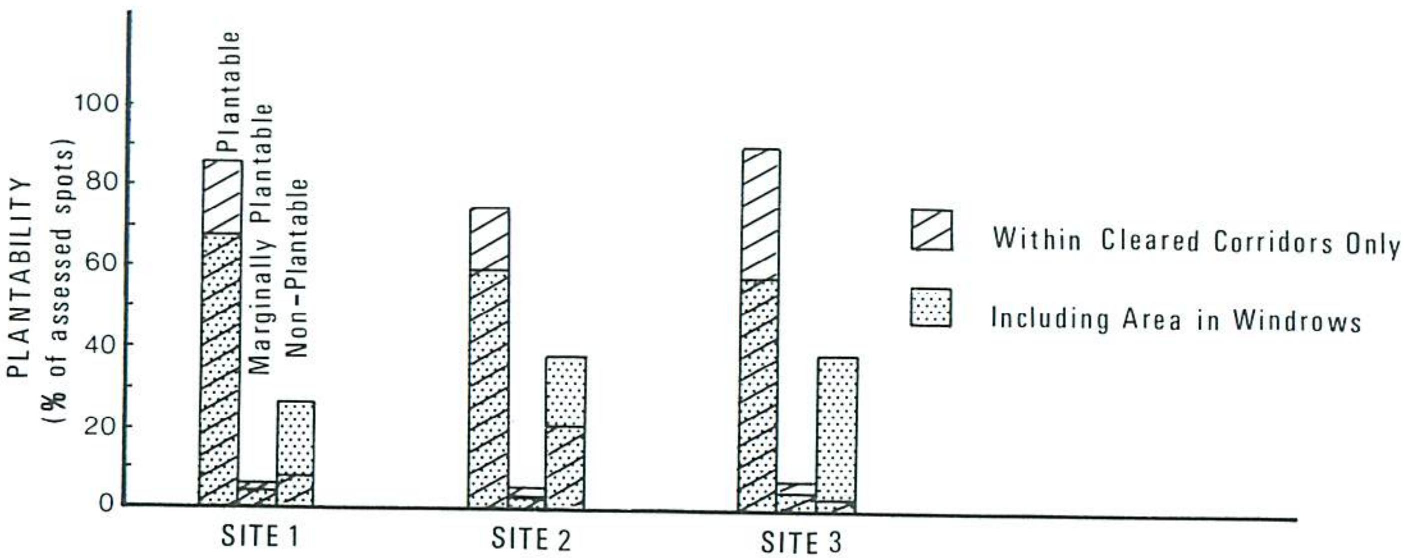


Figure 13. Plantability assessment: proportion of planting spots assessed as plantable, marginally plantable or non-plantable ( Plantable area lost to windrows is indicated. ) (See Table 12.)

Table 13. Microsite conditions for first-choice planting spots

| | Soil penetration | | | | Debris | | |
|---|---|---|---|---|---|---|---|
| Site | Penetrable[a] (%) | Rock[b] (%) | Roots[b] (%) | Others[b] (%) | None[a] (%) | Light[c] (%) | Heavy[b] (%) |
| 1 | 91.4 | 4.3 | --- | 4.3 | 100.0 | --- | --- |
| 2 | 77.1 | 18.6 | 2.9 | 1.4 | 100.0 | --- | --- |
| 3 | 97.5 | 2.5 | --- | --- | 100.0 | --- | --- |

| | Duff depth | | | Vegetative competition | Microrelief | | | |
|---|---|---|---|---|---|---|---|---|
| Site | 1.5 cm[a] (%) | 1.5 <3 cm[c] (%) | ⩾3 cm[b] (%) | None[a] (%) | Level (%) | Raised (%) | Side (%) | Hollow (%) |
| 1 | 97.0 | 3.0 | --- | 100.0 | 73.1 | --- | 26.9 | --- |
| 2 | 100.0 | --- | --- | 100.0 | 92.8 | --- | --- | 7.2 |
| 3 | 91.1 | 8.9 | --- | 100.0 | 87.3 | --- | 12.7 | --- |

[a]plantable condition
[b]non-plantable condition
[c]marginally plantable condition

As previously stated, a wide range in degree of disturbance is possible with Young's Teeth because of the potential of the equipment to achieve a full blading or a lighter raking/scarifying effect (Fig. 14 and 15). Variable results with Young's Teeth, as a consequence of varying experience and skill levels of operators, have been reported (Smith 1980). It is most likely that differences in the site preparation results of this trial were primarily the result of differences in operator experience and skill.

Effective plantability was high within the cleared corridors, where between 79% and 98% of the assessed area was plantable or marginally plantable. However, windrowing resulted in a substantial loss of plantable area on a gross hectare basis. This loss ranged from 20% to 37%.

Because of the simple design of the Young's Teeth, mechanical availability of the implements was 100%. Utilization exceeded 80% for all machines except the D8K on Site 1.

A major source of delay was the fact that the bulldozers got stuck (9% and 8% of total machine time for the D8K and D7G, respectively). To minimize such delays units had to be kept near one another to provide assistance. A higher combined productivity of the D8K and D7G on Site 1 than on Site 2 (.67 ha/PMH versus .47 ha/PMH) was probably the result of much lower stocking of residuals, lower ground roughness, and/or operator efficiency.

Figure 14. Very thorough clearing on area of deep soil

Figure 15. All debris piled in windrow ; relatively light disturbance in foreground

Three quarters as much time was spent operating in reverse as in the forward and scarifying modes. This reflects the great effort required to clear the sites for stand conversion. Further indication of this is the fact that silvicultural productivity for all treatments was 1119 plantable and marginally plantable spots/PMH within the cleared corridors only and 884 spots/PMH on the gross (windrow and corridor areas) hectare (sites 1 and 2 only). This compares with a much higher 2631 spots/PMH for a skidder-mounted powered disc trencher on comparatively residual-free, full-tree logged sites where the prescription was to create plantable spots for jack pine paperpot stock (Puttock et al. 1986).

## SUMMARY AND CONCLUSIONS

Heavy prime movers, equipped with Young's Teeth, were evaluated during a three-month period on the Upper Spanish FMA area of E.B. Eddy Forest Products Ltd. Three mixedwood sites were selected for the study. In each area the softwood had been harvested according to the full-tree logging method and some of the residual poplar was subsequently cut by conventional tree-length operation. However, a considerable volume of residual timber remained after harvesting on all three sites.

The silvicultural prescription called for the removal of the residual hardwoods in preparation for the conversion of the mixedwood stands to pine plantations.

With the exception of the high density of residual hardwoods, site conditions were generally moderately difficult on all three areas. The Young's Teeth appeared to be well suited to the clearing of residuals, stumps and debris and to the disturbance of soil on sites 1 and 3, where plantable disturbance (receptive seedbed) within the cleared corridors averaged 56% and 45% respectively, and where more than 90% of the assessed planting spots within the corridors were plantable or marginally plantable. However, the exposure of bedrock in some areas on Site 2, as a result of the treatment, reduced planting opportunities considerably on that site with plantable disturbance averaging 42% and only 78% of the assessed spots being plantable or marginally plantable.

A comparison of the results on the three sites with the corresponding pretreatment conditions indicates that the quality of site preparation was less sensitive to differences in site conditions than to some other factors, most likely the different experience and skill levels of the operators.

The Young's Teeth suffered no mechanical problems. However, delays did occur when the bulldozers became stuck or when one bulldozer was required to assist the other. In spite of these delays utilization generally exceeded 80%.

Conventional machine productivity averaged .54 ha/PMH while silvicultural productivity averaged 888 plantable and marginally plantable spots per PMH. The latter is quite low in comparison with less intensive types of scarification; e.g., single-pass scarification with a powered disc trencher. Low productivity appears to be the result of time lost through reversing while windrowing, treatment of the entire area, and the loss of plantable area within the windrows (from 20 to 37% of the total area).

The low silvicultural productivity and loss of plantable area are indicative of the difficulty and expense involved in stand conversion from boreal mixedwoods with dense residual poplars to jack pine plantations. As indicated in Figure 16, the rapid establishment of competing vegetation may become a problem on these sites, necessitating follow-up tending.

It is recommended that operators be trained to achieve consistent results and to ensure maximum productivity. The width of windrows should be minimized to reduce the loss of plantable area. Further investigations should include (1) determination of the optimum corridor width in relation to residual stand density, (2) reduction of the windrows through burning, and (3) the desirability and implications of felling, skidding and piling the hardwood stems during the logging operation.

Figure 16. Natural revegetation one year after treatment (Herbicide application will probably be necessary to protect planted seedlings.)

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# APPENDICES

## APPENDIX A

## MANUFACTURER'S SPECIFICATIONS

**YOUNG'S TEETH**

| | Model number | | | | |
|---|---|---|---|---|---|
| | 1A | 2A | 3A | 4A[a] | 5A |
| Fits dozer blade height (cm) | 51-58 | 61-86 | 76-102 | 91-117 | 107-132 |
| Replacement wear point (cm) | H & L22 | H & L24 | H & L25 | H & L27 | H & L27 |
| Digging depth (cm) | 25 | 33 | 38 | 43 | 51 |
| Weight (kg) | 25 | 45 | 88 | 150 | 232 |
| Shank material | - heat treated alloy steel - | | | | |
| Net power recommended (kw) | | | 52+ | 134+ | 186+ |

[a]Model 4A used in study

(cont'd)

APPENDIX A (concl.)

**CATERPILLAR D7G AND D8K BULLDOZERS**

| | D7G | D8K |
|---|---|---|
| Flywheel power (kw) | 149 | 224 |
| Operating weight (kg)[a] (power shift) | 20,230 | 32,980 |
| (direct drive) | 19,960 | 31,430 |
| Engine model | 3,306 | D342 |
| Rated engine RPM | 2,000 | 1,330 |
| No. of cylinders | 6 | 6 |
| Bore (mm) | 121 | 146 |
| Stroke (mm) | 152 | 203 |
| Displacement (L) | 10.5 | 20.4 |
| Track rollers (each side) | 6 | 7 |
| Width of standard track shoe (mm) | 510 | 560 |
| Length of track on ground (mm) | 2,700 | 3,150 |
| Ground contact area (with standard shoe) ($m^2$) | 2.76 | 3.51 |
| Track gauge (mm) | 1,980 | 2,130 |
| General dimensions | | |
| Height (to top of ROPS)[b] (mm) | 3,250 | 3,400 |
| Overall length (with blade) (mm) | 5,280 | 6,580 |
| (without blade) (mm) | 4,190 | 5,260 |
| Width (with standard shoe) (mm) | 2,620 | 2,790 |
| Ground clearance (mm) | 347 | 434 |
| Blade types and widths | | |
| Straight (mm) | 3,660 | 4,040 |
| Angled (mm) | 4,270 | 4,720 |
| Universal (mm) | 3,810 | 4,240 |
| Fuel tank refill capacity (L) | 435 | 640 |

[a]Operating weight includes lubricants, coolant, full fuel tank, straight blade, hydraulic controls and fluid, ROPS canopy and operator.

[b]Roll Over Protective Structure

## APPENDIX B

### MACHINE TIME FORMULAE

The following formulae were used to calculate utilization and mechanical availability (Folkema et al. 1981):

**Utilization** $= \left(\dfrac{\text{PMH (in shift)}}{\text{SMH}}\right)100$

**Mechanical availability** $= \left(\dfrac{\text{PMH}}{\text{PMH + repairs + service}}\right) 100$

(PMH, repairs and service include both in- and out-of-shift activities.)

**CPPA availability** $= \left(\dfrac{\text{SMH-(repairs + service + wait [parts + mechanic])}}{\text{SMH}}\right) 100$

(Repairs and service include only in-shift.)

PMH = productive machine hours
SMH = scheduled machine hours

### DEFINITION OF TIME ELEMENTS

The productive machine hours (PMH) recorded in the continuous time study were broken down into the following elements. Note that the time study data are separated into shift level availability and productivity elements (Folkema et al. 1981) for reference to day-to-day operations as well as short-term study elements (Smith et al. 1985) for more detailed analyses.

Shift level availability and productivity elements

**Scheduled machine hours (SMH):** Nominal statement of intent for regular machine activity (e.g., 8-hr shift). It usually corresponds to operator's paid on-job time.

**Productive machine time or productive machine hours (PMH):** That part of total machine time during which the machine is performing its function.

**Active repair:** Repair consists of mending or replacement of part(s) in consequence of failure or malfunction. It also includes modifications or improvements to the machine.

**Service:** Service consists of routine, preventive maintenance to ensure that the machine is in satisfactory operational condition.

(cont'd)

**Delay (more than 15 min.):** Period of SMH during which the machine is not performing its primary function for reasons other than those of active repair and service. Delay time is divided into:

**Nonproductive operating time:** Period of in-shift time during which the machine's engine is running but the machine is doing something other than performing its primary function.

**Waiting for mechanic(s):** Period of in-shift time during which the machine is broken and is not under repair because of the unavailability of mechanic(s).

**Waiting for part(s):** Period of in-shift time during which the machine is broken and is not under repair because of the unavailability of part(s).

**Miscellaneous delay:** Period of in-shift time during which the machine engine is not running for reasons other than those of active repair and service and/or waiting for repairs and service.

Short-term Study Elements

**Effective productive time (scarify):** Begins when the implement is in the soil and the prime mover starts forward travel. Does not include delays.

**Maneuver (turn):** Occurs from the time the scarifier has finished a pass until the scarifier begins the next pass. This element may include raising the implement from the ground, turning and then lowering the implement.

**Obstacle delay:** Occurs from the time the scarifier stops because of an obstruction until scarification resumes.

**Travel:** Time spent a) travelling in the block or to the roadside between breaks, and b) on repairs. It also includes travelling (if under 15 min) between sites.

**Delay (less than 15 min.):** Same as **Delay (more than 15 min.)** but includes those times less than or equal to 15 minutes. Short-term delays are part of total productive machine time, whereas delays of more than 15 minutes are not considered part of productive time.