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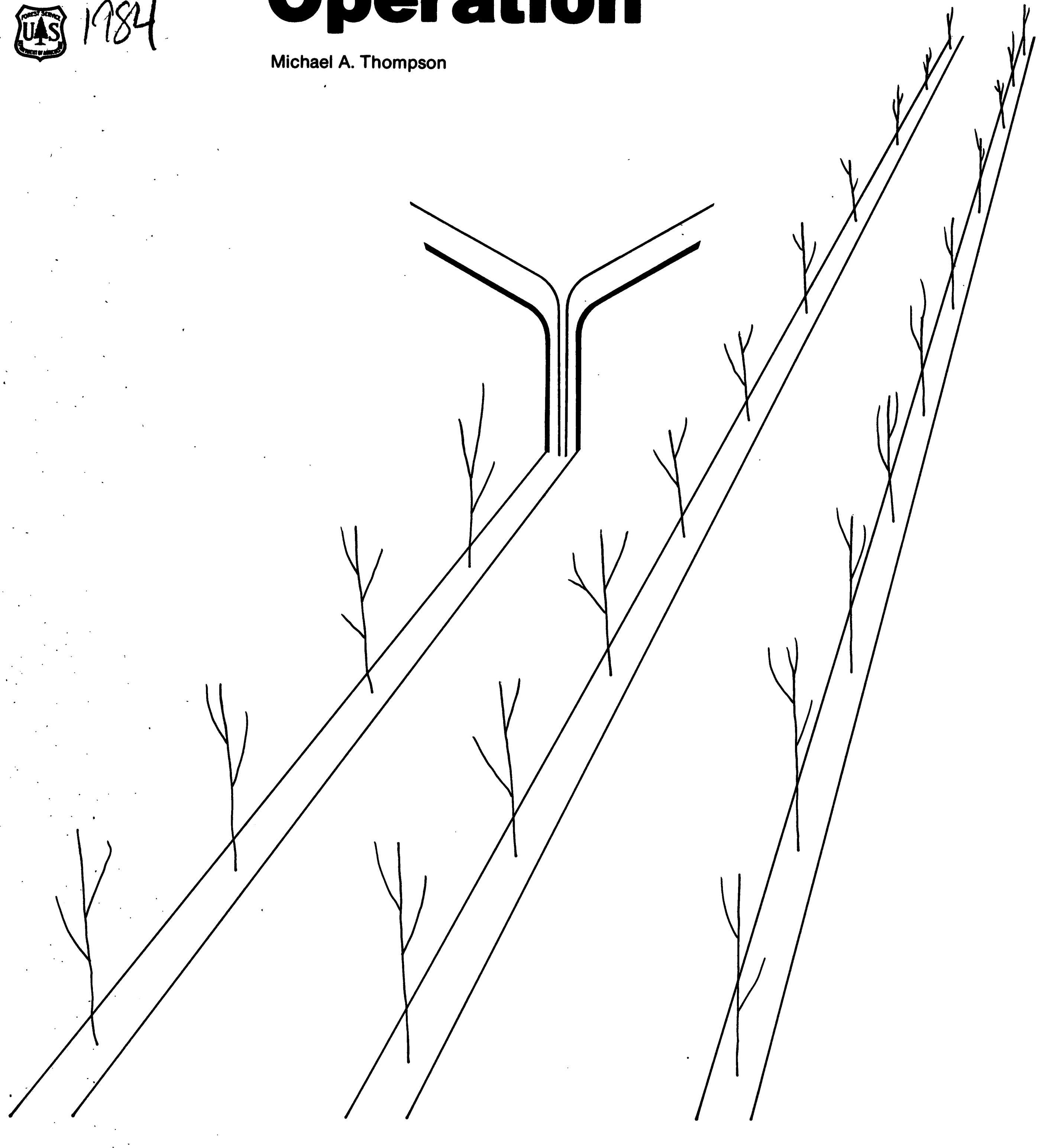
Evaluation of a Mechanized Tree-Planting Operation

Michael A. Thompson



CONTENTS

North Central Forest Experiment Station
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EVALUATION OF A MECHANIZED TREE-PLANTING OPERATION

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Establishing a stand of preferred species is often the most important goal in forest land management. The degree to which this goal is achieved will determine the future growth, yield, and economic return from the stand. It will also determine the recreational, wildlife, and watershed value of the developing forest. Conifer species may be established by natural seeding (if suitable seed trees are present), artificial seeding, or planting (either bareroot or container – grown tree seedlings). Problems with seeding methods have caused widespread interest in planting tree seedlings. Forest planting can be expensive due to the costs of site preparation, planting stock, the planting operation, and the subsequent control of competing vegetation. However, stand density and composition can be controlled to a much greater extent than with seeding methods. This may make planting cheaper than seeding in the long run if seeding methods delay stand establishment, result in establishment of undesirable species, or require precommercial treatment to control stand density and composition.

Seedlings can be planted by hand or by machine. Each method has advantages and disadvantages. In general, machines should be used on large, flat tracts having deep soils. Small tracts and steep slopes should be planted by hand (Benson 1982). This general guideline is sensitive to local conditions, however. The land manager must try to attain the optimal combination of hand and machine planting based on site conditions, availability of local labor, areas to be planted, and many other factors. To make informed decisions, productivity, cost, and operational information for a variety of operating conditions must be available.

In this study I evaluated the productivity and cost of a mechanized red pine (*Pinus resinosa*) planting operation on four sites. In preparation for planting, the slash on each site was treated differently. A large portion of the analysis will focus on differences in productivity due to these treatments. A specially designed V-blade was used to clear debris from the planting path. The utility of this blade is also evaluated.

BACKGROUND

The planting operation was contracted by the Ottawa National Forest[1] to a bulldozer owner with no previous mechanical tree planting experience. The contractor supplied the prime mover and labor whereas the National Forest supplied the planter, V-blade, and seedlings.

The capital cost of the equipment used in this operation was $199,000 using 1983 purchase prices:

Equipment	**1983 purchase price**
D5B Caterpillar Dozer with V-blade	$110,000
Whitfield Forestland Transplanter with single crank axle	8,000
	55,000
International Transtar II Tractor	15,000
Heavy-duty, low-boy trailer	11,000
Heavy-duty ½-ton pickup truck	$199,000

The Whitfield Forestland Transplanter[2] is a continuous-furrow bareroot stock mechanical tree planter (fig. 1). The operating principle of the planter is as follows (fig. 2): the packing wheels roll along the ground and cause the planting chain to rotate; the operator places a seedling in the fingers of each planting arm as it rotates past; this arm carries the seedling down into the furrow created

[1]*The Ottawa National Forest is located in the western section of Michigan's Upper Peninsula.*

[2]*The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. It does not constitute an official endorsement or approval of any product or service by the United States Department of Agriculture to the exclusion of others which may be suitable.*

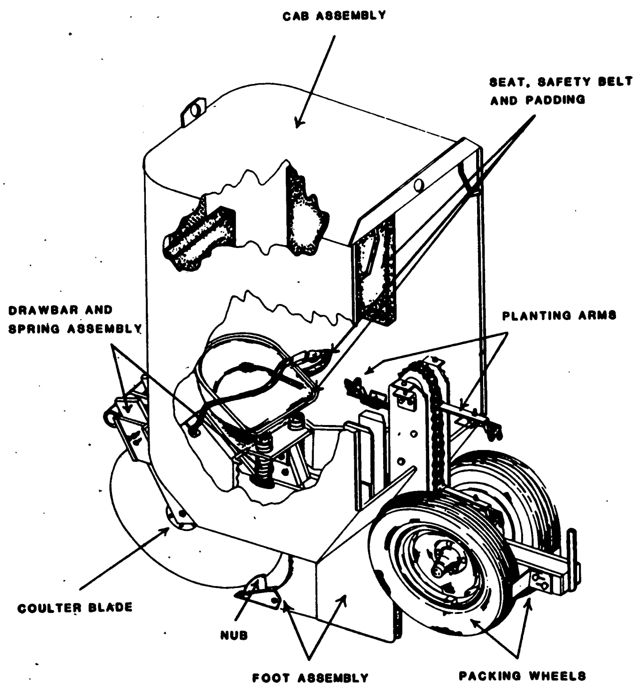

Figure 1.--*Whitfield Forestland Transplanter (assembly view courtesy of Whitfield Manufacturing Company).*

by the shoe; the packing wheels pack soil around the roots, and the seedling is released. The coulter blade breaks the soil ahead of the foot, cuts through roots and small stumps, and allows the planter to roll up over impenetrable objects, such as rocks and large stumps (fig. 1).

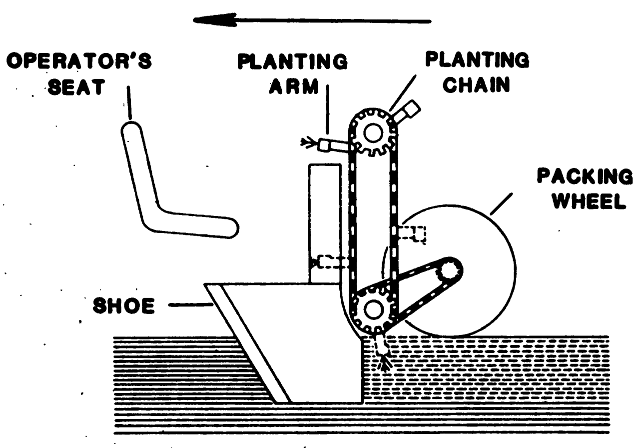

Figure 2.--*Operating principle of the Whitfield Forestland Transplanter. The packing wheels roll along the ground causing the planting chain to rotate. The operator places a seedling in each planting arm as it rotates past. The arm releases the seedling in the furrow created by the shoe, and the packing wheels pack soil around the root collar. (courtesy of Whitfield Manufacturing Company).*

Figure 3.--*Dozer with V-blade towing the Whitfield planter.*

The transplanter was towed by a D5B Caterpillar dozer with a V-blade mounted on the front (fig. 3). The V-blade was designed to clear a path through the slash and debris at least as wide as the bulldozer. A scalping foot on the V-blade was designed to scalp 4 inches of topsoil from an area at least as wide as the packing wheels of the planter (fig. 4). A float pad was added to allow for adjustment of the scalping depth and to free the operator from having to continuously adjust the blade.

Four men were required for the operation - one to operate the bulldozer, one to feed (load) the planter, and two to follow the planter and replant poorly planted trees.

SITE INFORMATION

Five sites in Ontonagon County, Michigan, were planted under this contract. However, in an attempt to minimize the effect of operator inexperience, we did not collect data at site number 1 and limited

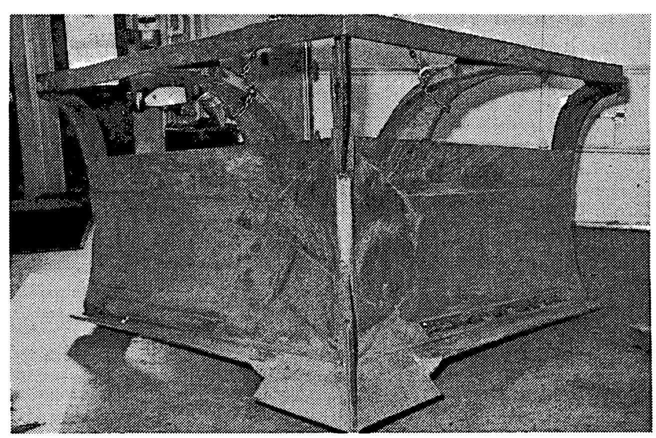

Figure 4.--*Front view of specially modified V-blade.*

the analysis to the remaining four sites. All sites have sandy loam soil and flat to gently rolling topography.

Site No. 2

The logging slash had been partially burned in place leaving a light layer of slash on the site. The 15-acre-(6.1-hectare) pure jack pine (*Pinus banksiana*) stand previously occupying the site was harvested in 1981 (2 years prior to planting), leaving 6-inch (15-cm) tall, 6- to 10-inch-(15- to 25-cm) diameter stumps. Several large, decaying stumps from an earlier stand were also scattered throughout the area. A portion (3.5 acres: 1.4 hectares) of the clearcut area supports dense aspen (*Populus* spp.) regeneration and was not planted. A 20-foot-(6-m) wide woods road through the site was also not planted.

Site No. 3

The slash had been piled and burned leaving the site free from debris and standing timber. The piles were not completely burned, however, and occupied a significant portion of the planting area. The 20-acre-(8.1-hectare) mixed jack/red pine stand previously occupying the site was harvested in 1981, leaving 6-inch-(15-cm) tall, mainly 6- to 10-inch-(15- to 25-cm) diameter stumps, with some red pine stumps as large as 20 inches (51 cm) in diameter. A few large, decaying stumps were also scattered throughout the area. A portion (7.5 acres: 3.0 hectares) of the clearcut area was on the side of a ridge so was planted by hand.

Site No. 4

The slash on the site had been windrowed for burning; however, a large amount of slash was left in place. The 19-acre-(7.7-hectare) mixed jack/red pine stand previously occupying the site was harvested in 1981, leaving 6-inch-(15 cm) tall, 6- to 12-inch-(15- to 30-cm) diameter stumps.

Site No. 5

No slash treatment had been done on this site, and therefore heavy slash was found throughout the area. The 25-acre-(10.1-hectare) mixed jack/red pine stand previously occupying the site was harvested in 1981, leaving 12- to 24-inch-(30-to 61-cm) tall, mainly 6- to 14-inch-(15-to 36-cm) diameter stumps, with some red pine stumps up to 24 inches (61 cm) in diameter.

OPERATIONAL EFFICIENCY

Land Utilization

The proportion of forest land area in an unproductive state is an important management consideration. Large roads, landings, and brush piles reduce the available land base, lowering the net productivity of the forest. This area should be minimized from an economic standpoint. Similarly, stand density should be maintained between minimum and maximum recommended stocking levels to ensure favorable tree growth and quality and to discourage the establishment of undesirable species. The combination of these two factors--nonplantable areas and stand density--determines the degree of land utilization.

The area utilized on each site was estimated by multiplying the number of seedlings planted on that site by the nominal area per seedling (assuming perfect 6-foot by 10-foot spacing). This nominal planted area was computed for each site along with the total area clearcut and the net area available for planting (table 1). The total areas differed from the net areas for sites 2 and 3 because portions of these sites were not intended to be machine planted.

The area planted (as calculated from the nominal spacing) was less than the area available for planting on all four sites. There are several reasons for this. First, machine planting was not possible in certain localized areas due to the existing landform, such as large depressions, old railroad beds, woods

Table 1.--*Total area, net area, and planted area*[1] *by site*

Site no.	Total area	Net area	Seedlings planted	Planted area[1]
	Acres (ha)	*Acres (ha)*	*No.*	*Acres (ha)*
2	15 (6.1)	11.5 (4.7)	8,250	11.36 (4.60)
3	20 (8.1)	12.5 (5.1)	8,250	11.36 (4.60)
4	19 (7.7)	19.0 (7.7)	11,250	15.50 (6.27)
5	25 (10.1)	25.0 (10.1)	17,250	23.76 (9.62)

[1]*Based on an assumed spacing of 6 feet by 10 feet (1.8 by 3.0 m)*

roads, sloping ground, and wet areas. This was significant on sites 3 and 5--on each site more than an acre (0.4 hectare) was removed from the available land base. Second, rows meandered around obstructions such as high stumps, standing trees, and large slash piles causing inconsistent row spacing and wasted land area. This was an important factor on site 4 where 3.5 acres (1.4 hectares) of the available land was not planted. Third, tract shape and severity of site conditions affects the ability of the dozer operator to lay out well-spaced rows. And finally seedling spacing within each row depends on proper operation of the planter. Within-row spacing increases if the packing wheels lose contact with the ground or if debris interferes with the planting mechanism. Random seedling counts on 15 rows in site 2 showed that the average within-row spacing was 6.2 feet (1.9 m)--close to the nominal spacing of 6 feet (1.8 m).

Productivity Analysis

The productivity of this planting operation was evaluated on each of the four sites through use of continuous time-study techniques. A total of 19.6 hours were observed out of the 94.9 hours spent planting these sites.

The observed components of the scheduled planting time show 75 percent as productive (table 2). In addition to these times, some time will be spent daily on personal breaks. Also, time will be spent setting up, taking down, and traveling between sites. The average amount of time spent on these activities will depend on tract size, the distance between tracts, and road conditions, among other things. In this study, 58 minutes were required to prepare for planting and 36 minutes to prepare for leaving the site, on the average.

The condition of the planting site is an important determinant of planting productivity. Several of the elements that interact to determine productivity are directly affected by site conditions. For example, the incidence of site-related delays is greater on difficult-to-plant sites. This greatly slows down production. Three delay times were identified as being related to the site--maneuver, clear, and back up. The magnitude of these delays per 1,000 planted feet (305 m) ranged from about 1 to 3 minutes (table 3). The major component of the site--related delay is the time it takes to clear debris caught beneath the planter. Site 5 (the slashiest site) had the least problem with this (table 3). This was because the heavy slash tended to mat together, which made it easier for the V-blade to shed it from the planting path.

Table 2.--*Observed components of the scheduled planting time for the operation*

Component times		Observed time	Total time
Productive time		*Hours*	*Percent*
Get seedlings		0.10	0.8
Load seedlings		.67	5.4
Travel		.39	3.2
Plant		6.15	49.8
Turn around		2.00	16.2
	Total	9.31	75.4
Mechanical delay time			
Adjust and inspect planter		.11	.9
Repair planter		.69	5.6
	Total	.80	6.5
Nonmechanical delay time			
Clear debris from planter		2.02	16.4
Maneuver		.10	.8
Back up		.12	1.0
	Total	2.24	18.2

Total observed time = 12.35 hours

Also, debris that did get underneath the planter did not get jammed between the coulter blade and foot assembly as easily as it did on sites 2 and 3. This is because the Whitfield planter used on sites 4 and 5 had a nub on the foot assembly (figure 1). This nub was missing from the Whitfield planter used on sites 2 and 3. The positive effect of this nub on sites 4 and 5 is supported by the lower average clear time per stop on these sites as compared to that of sites 2 and 3.

Two important conclusions can be drawn from this portion of the analysis. First, based on the planting efficiencies observed on these sites, site preparation in the form of slash treatment is not advantageous and may actually be detrimental to the efficiency of the planting operation (this does not pertain to lowering stump height or spreading out large slash piles). This can be attributed to the tendency for the slash to mat together and shed easier. Leaving the slash in place on the site also may be preferable from a silvicultural standpoint. The decomposing slash adds to the nutrient supply of the site. It also holds moisture in the soil, provides partial shade for the seedlings in the heat of the summer, and reduces competition by undesirable species. Another benefit of leaving the slash in place is that less land area would be taken out of production by large, unburned slash piles. Finally, there would be no slash disposal costs, lowering the total cost of stand conversion. One disadvantage to

Table 3.--*Site-related delay times per 1,000 planted feet by site.*

Site no.	Site related delay time per 1,000 planted feet: Maneuver	Clear	Back up	Total	Clear stops per 1,000 planted feet	Ave. clear time per stop
	- - - - - - - - - *Min.*	- - - - - - - - -			*No.*	*Min.*
2	0.05	3.34	0.00	3.39	1.7	1.95
3	.04	2.65	.20	2.89	1.2	2.20
4	.39	2.65	.25	3.29	2.0	1.30
5	.00	1.03	.12	1.15	1.2	.85

leaving the slash in place is that it provides protection for rabbits and other rodents that may destroy the planted seedlings.

The second conclusion made from this analysis is that, when planting with a Whitfield Transplanter, the nub on the foot assembly should be in place and as close to the coulter blade as possible. This reduces the chances for debris to get caught between the coulter blade and the foot assembly and thereby reduces delay time.

The condition of the planting site also affects the rate of travel that the prime mover can achieve when crossing the site. Difficult sites require slower travel speeds due to the greater resistance to forward movement. Also, the frequency of stops on difficult sites lowers the average travel speed because of the time required to accelerate and decelerate. The average travel rate observed on these sites ranged from 123 to 147 feet/minute (27.5 to 44.8 m/min), and the nominal planting productivity ranged from 1,230 to 1,468 seedlings per hour (table 4). The travel rate across site 3 was somewhat faster than that on the remaining three sites. This can most likely be attributed to the lack of slash and debris on this site which made it easier to move forward as well as to avoid stumps. The number of within-row stops per 1,000 planted feet does not help explain this difference (table 4).

The pattern followed during planting also affects the productivity of the planting operation by determining the between-row travel distances. Extra time spent traveling between rows is reflected in the productivity of the planter. Three unique patterns were followed during this planting operation (patterns 1, 2, and 3 in fig. 5). An additional pattern (pattern 4) that was not used in the study is suggested as an improvement. It consists of two passes over the site, planting every other row on each pass. To alleviate problems caused by other sources of variation, I compared these four patterns on a purely theoretical basis. A 500- by 1,000-foot (152- by 305-m) block was conceptually planted using each pattern. Travel rate during planting was assumed to be 130 ft/min (40 m/min), which is the observed average for all sites rounded to the nearest 5 ft/min. Travel rate between rows was assumed to be 155 ft/min (47 m/min), which is the average (rounded to the nearest 5 ft/min) of a sample of 16 observations taken on two sites (table 5). Following pattern 1 results in the minimum amount of between-row travel. Under the assumed conditions, the travel time for this pattern is small. However, in practice, this travel time would be somewhat greater because the dozer cannot make right angle turns as is assumed in the analysis. Due to an insufficient turning radius, the dozer would have to swing around in a large arc to plant in this pattern.

Table 4.--*Average planting rate (seedlings per hour[1]) by site (not including delays)*

Site no.	Total plant distance	Total plant time	Travel rate	Planting rate	Within-row stops/1,000 planted feet
	Ft (m)	*Min.*	*Ft/min (m/min)*	*Seedlings/hr*	*No.*
2	11,666 (3,556)	90.56	128.8 (39.3)	1,288	1.8
3	14,924 (4,549)	101.64	146.8 (44.8)	1,468	2.1
4	12,233 (3,729)	99.46	123.0 (37.5)	1,230	2.7
5	9,861 (3,006)	75.89	129.9 (39.6)	1,299	1.5

[1]*Based on an assumed 6-foot (1.8-m) spacing between seedlings.*

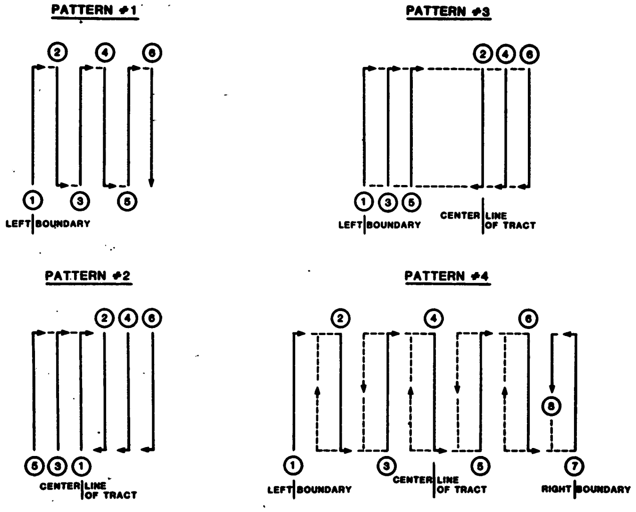

Figure 5.--*Planting pattern--patterns 1, 2, and 3 were used in this study, and pattern 4 is suggested as an improvement. The circled numbers indicate the order in which the rows are planted.*

This is the problem the dozer operator encountered in this study when planting with this pattern. Therefore, because of the difficulty in backing up on these sites, he followed planting pattern 3. Unfortunately, a large portion of time is spent traveling between rows with patterns 2 and 3 (table 5). The result is a decrease in productivity of equal proportion (considering plant and between-row travel time only). This proportion will increase as the width of the site increases for patterns 2 and 3, whereas it will remain constant for patterns 1 and 4. To maximize productivity, this between-row travel time must be minimized. Therefore, pattern 4 is the best pattern to follow because it is fairly simple, minimizes travel time, and provides an adequate turning radius at the ends of rows. One disadvantage to this pattern is that the chances of pushing slash over onto previously planted rows is greatest, especially on sites where there has not been any slash disposal.

The overall productivity of this operation ranged from 99 to 139 seedlings per scheduled hour (table 6). The productivity on sites 4 and 5 was somewhat greater than on sites 2 and 3 for three main reasons. First, as the proficiency of the crew increased with experience, less time was spent on avoidable delays, such as preparation and planning. Second, the greater amount of area planted on sites 4 and 5 resulted in proportionately less time being spent on preparation. Finally, having the nub in place on the foot assembly for the planter used on sites 4 and 5 lowered the amount of delay time encountered on these sites. I expect that the overall productivity of this operation will improve further as experience is gained for a variety of site conditions.

Cost Analysis

Tree planting is an annual investment in sustained yield forest management from which returns will not be realized for many years. To maximize the return on this investment, the cost of the planting operation must be minimized while ensuring planting quality. The purpose of this analysis was to determine the costs that might be expected for a planting operation using this particular equipment mix. It was not an attempt to estimate the contractor's actual planting cost.

Purchase prices for 1983 were used to develop machine rates for each piece of equipment used in the planting operation (table 7). Other assumptions made in deriving these machine rates can be deduced from the calculation sheets presented in the Appendix. The costing procedure used is similar to that described by Miyata (1980). This information was then used to develop overall costs (table 7). The calculated cost of $239 per thousand seedlings planted shows that machine planting can be expensive. The cost of a given operation will depend heavily on the equipment used, site conditions, local labor conditions, and crew efficiency.

Table 5.--*Travel time by planting pattern*

Pattern no.	Total between row: Travel distance	Total between row: Travel time[1]	Percent of total time[2]	Productivity[3]
	Ft. (m)	*Min*	*Min*	*Seedlings/hr*
1	470 (143)	3.03	0.8	1,289
2	10,580 (3,225)	68.26	15.6	1,097
3	11,280 (3,438)	72.77	16.5	1,086
4	930 (283)	6.00	1.6	1,279

[1]*Assuming a between-row travel rate of 155 ft/min.*

[2]*Total plant time is a constant by pattern at 369.23 min. assuming 130 ft/min travel rate while planting and forty-eight 1,000-foot rows.*

[3]*Considers plant and between-row travel time only.*

Table 6.--*Overall planting productivity by site*

Site no.	Seedlings	Total SH[1]	Seedlings/SH	Seedlings/ scheduled man-hour[2]
	No.			
2	8,250	20.3	406	102
3	8,250	20.8	397	99
4	11,250	22.8	493	123
5	17,250	31.0	556	139
Total	45,000	94.9	475 (ave.)	119 (ave.)

[1]*SH = Scheduled Hour: time during which equipment is scheduled to do productive work (Miyata 1980). Times start at initial departure of equipment to site and end at time of departure from site.*

[2] *Average crew size = 4 persons; scheduled man-hour = scheduled hours divided by average crew size.*

However, this cost can be reduced in several ways. Equipment utilization can be increased through experience. Secondhand equipment, having lower investment and depreciation costs, can be used. The need for follow-up hand planters can be alleviated by using a well-designed V-blade and the appropriate planting accessories for soil conditions. Turnaround time can be reduced by using less time-consuming planting patterns. Small sites can be avoided to decrease the proportion of time spent moving. As an example, if the utilization of the equipment used in this planting operation was increased to 75 percent and both follow-up hand planters were eliminated, the cost would be reduced from $239 to $143 per thousand seedlings planted, or from $174 to $104 per acre at 6- by 10-foot (1.8- by 3.0-m) spacing. This reduces the planting cost by 40 percent. Cameron (1976 and 1977) reported costs of $40 to $70 per acre ($99 to $173 per hectare) for one-pass machine planting. Projecting these costs to 1983 dollars at an inflation rate of 5 percent results in planting costs of $50 to $98 dollars per acre ($124 to $242 per hectare).

Table 7.--*Observed times, machine rates, labor costs, and overall costs for the planting operation*

Machine type	Observed time		Machine rate		Cost						
	SH[1]	PH[2] or mi[3]	Fixed ($/SH)	Operating ($/PH or mi)	Labor ($/SH)	Total fixed	Total operating	Total labor	Total	Per thousand seedings planted	Percent of total cost
Caterpillar D5B dozer w/V-blade	94.9	45.0[4]	$20.71	$25.92	$15.00	$1,965	$1,166	$1,424	$4,555	101	42.3
Whitfield Forestland planter	94.9	45.0[4]	5.31	4.10	11.25	504	185	1,068	1,757	39	16.3
Lowboy trailer	94.9	1,000 mi[5]	2.08	0.06/mi	0.00	197	60	0	257	6	2.4
Pickup truck	94.9	2,000 mi[5]	1.71	0.24/mi	0.00	162	480	0	642	14	6.0
International truck-tractor	94.9	1,000 mi[5]	7.16	0.75/mi	0.00	679	750	0	1,429	32	13.3
Two follow-up hand planters	94.9	NA[6]	NA	NA	22.50	0	0	2,136	2,136	47	19.7
Totals:						3,507	2,641	4,628	10,776	239	100.0

[1]*SH = scheduled hour.*

[2]*PH = productive hour: time during which equipment is actually operated (Miyata 1980).*

[3]Mi=mile.

[4]*Based on an observed productive time of 9.31 hours out of a total observed time of 19.64 hours.*

[5]*Estimated amount of travel during planting period.*

[6]*NA = not applicable.*

Blade Evaluation

A subjective evaluation of the V-blade used in this planting operation uncovered one major design flaw (fig. 4). The blade would not float unattended along the ground surface. The forward slope of the blade combined with the remote placement of the hinge point relative to the blade caused it to dive into the soil, regardless of the float pad adjustment. To alleviate this problem, the forward slope of the blade should be reduced (i.e., closer to the vertical) and the float pad enlarged or replaced with a rolling drum. It is important that the blade remain on the ground surface; otherwise, debris will get jammed beneath the planter and cause delays. This was impossible for the operator to attain under his control, however, because of the topography, slash conditions, and his other responsibilities.

A few other deficiencies in the blade were uncovered in this evaluation. The scalping foot on the front of the V-blade removed too much soil from the planting path as indicated by the poor packing of soil around the seedlings. This could be corrected by cutting the wings off the foot to form a V-shaped point. Also, the float pad adjustment bolt was not protected from abrasion, making adjustment difficult when the threads became worn.

Cameron (1978) discusses a unique V-blade design that seems to have great potential. The concept is to have the blade float over the ground surface removing only the debris in the planting path (i.e., the outside width of the packing wheels on the planter). Material outside this range is removed only if its depth exceeds the clearance of the prime mover being used. This approach minimizes the amount of material being moved and therefore lowers the power requirements of the prime mover, making smaller, less expensive machines possible. In addition to this, significant fuel savings could be realized. Another advantage of this approach is that there is less chance of pushing debris onto the previously planted row, which can be a serious problem on sites with heavy slash. The normal recourse is to widen the row spacing, which affects the utilization of the land and the future limbiness of the trees.

DISCUSSION

The results of this study pose an interesting question; namely, "Is slash disposal prior to machine planting necessary, or can single-pass planting be equally efficient?" There is no simple answer to this question. The answer will vary considerably depending on many factors. However, under the conditions encountered in this study, I feel that slash disposal was an unnecessary expense (from an operational point of view only) that could have been avoided. This hypothesis should be tested further under controlled conditions.

Other hypotheses suggested by this study that warrant further investigation include:

- The design of the V-blade used in this study is inadequate. Alternative designs should be tested.
- Planting pattern 4 (fig. 5) seems to be the most appropriate for this operation. This should be documented in field trials.
- Machine planting can be an expensive proposition. Methods are needed to improve the profitability of these operations (e.g., crew training, tract size, equipment mix, etc.).

In addition to these hypotheses, the results of this study show the importance of having the nub on the foot assembly in place to minimize delays associated with debris becoming jammed between the foot and the coulter blade.

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APPENDIX

MACHINE RATE CALCULATIONS
(off-road equipment)

Month: October
Year: 1983

I. Description

Type: Caterpillar Bulldozer — Model: D5B
Accessories: Specially modified V-blade — Engine: 105 HP diesel

INITIAL INVESTMENT (F.O.B. Delivered Cost)			I = $ 110,000
Estimated Life (n)	5	years	
Residual Value (R)	20	% of I	R = $ 22,000
Working Days per Year	200	days	
Scheduled Hours (SH) per Year[1]	1500	hours	
Utilization (U)	65	%	
Productive Hours (PH) per Year	975	hours	

Average Annual Investment $AAI = \frac{(I-R)(n+1)}{2n} + R$ = $ 74,800 /yr

II. Fixed Cost

Depreciation $D = \frac{I - R}{n}$ = $ 17,600 /yr

Interest 12 %
Insurance 3 %
Taxes 3 %
IIT = 18 % x AAI $ 74,800 /yr = $ 13,464 /yr

Total Fixed Cost per Year (D + IIT) = $ 31,064 /yr

TOTAL FIXED COST PER SCHEDULED HOUR = $ **20.71 /SH**

III. Operating Cost

Maintenance & Repair: $\frac{100\ \%\ \times\ (D)\ \$\ 17{,}600\ /yr}{975\ PH/yr}$ = $ 18.05 /PH

Fuel: 105 HP x 0.037 gal/HP-hr[2] x $ 1.35 /gal = $ 5.25 /PH

Oil & Lubrication: 50 % of fuel cost[3] $ 2.62 /PH

Tires: $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right)\left(\frac{1.15^{4/} \times \#\ \text{tires} \times \text{cost/tire}}{n \times PH/yr}\right)$ = $ NA /PH

TOTAL OPERATING COST PER PRODUCTIVE HOUR = $ **25.92 /PH**

IV. Labor Cost

Hourly Wage = $ 10.00 /SH
Fringe Benefits (50% of hourly wage) = $ 5.00 /SH

TOTAL LABOR COST PER SCHEDULED HOUR = $ **15.00 /SH**

1/ Not used strictly for planting.
2/ 0.037 for diesel engines, 0.050 for gasoline engines.
3/ 50% for diesel engines, 25% for gasoline engines.
4/ 15 percent labor charge to repair or replace tires.

MACHINE RATE CALCULATIONS
(off-road equipment)

Month: October
Year: 1983

I. Description

Type: Whitfield Transplanter — Model: Forestland
Accessories: w/single crank axle — Engine: NA

INITIAL INVESTMENT (F.O.B. Delivered Cost)			I =	$ 8,000
Estimated Life (n)	10	years		
Residual Value (R)	0	% of I	R =	$ 0
Working Days per Year	30	days		
Scheduled Hours (SH) per Year	300	hours		
Utilization (U)	65	%		
Productive Hours (PH) per Year	195	hours		

Average Annual Investment $AAI = \frac{(I-R)(n+1)}{2n} + R$ = $ 4,400 /yr

II. Fixed Cost

Depreciation $D = \frac{I - R}{n}$ = $ 800 /yr

Interest 12 %
Insurance 3 %
Taxes 3 %
IIT = 18 % x AAI $ 4,400 /yr = $ 792 /yr

Total Fixed Cost per Year (D + IIT) = $ 1,592 /yr

TOTAL FIXED COST PER SCHEDULED HOUR = $ 5.31 /SH

III. Operating Cost

Maintenance & Repair: $\frac{100\text{ \% x (D) \$ 800 /yr}}{195\text{ PH/yr}}$ = $ 4.10 /PH

Fuel: - HP x - gal/HP-hr[1/] x $ - /gal = $ NA /PH

Oil & Lubrication: - % of fuel cost[2/] $ NA /PH

Tires: $\left(\frac{n \times PH/yr}{\text{tire life}} - 1\right)\left(\frac{1.15^{3/} \times \#\text{ tires} \times \text{cost/tire}}{n \times PH/yr}\right)$ = $ NA /PH

TOTAL OPERATING COST PER PRODUCTIVE HOUR = $ 4.10 /PH

IV. Labor Cost

Hourly Wage = $ 7.50 /SH
Fringe Benefits (50% of hourly wage) = $ 3.75 /SH

TOTAL LABOR COST PER SCHEDULED HOUR = $ 11.25 /SH

1/ 0.037 for diesel engines, 0.050 for gasoline engines.
2/ 50% for diesel engines, 25% for gasoline engines.
3/ 15 percent labor charge to repair or replace tires.

MACHINE RATE CALCULATIONS
(on-road equipment)

Month: October
Year: 1983

I. Description

Type: Heavy Duty Low-boy Trailer — Model: -
Accessories: — Engine: NA

INITIAL INVESTMENT (F.O.B. Delivered Cost)			I =	$ 15,000
Estimated Life (n)	10	years		
Residual Value (R)	0	% of I	R =	$ 0
Working Days per Year	200	days		
Scheduled Hours (SH) per Year	1,500	hours		
Operating Miles per Year	10,000	miles		

Average Annual Investment $AAI = \frac{(I-R)(n+1)}{2n} + R$ = $ 9,000 /yr

II. Fixed Cost

Depreciation $D = \frac{I - R}{n}$ = $ 1,500 /yr

Interest 12 %
Insurance 3 %
Taxes 3 %
IIT = 18 % x AAI $ 9,000 /yr = $ 1,620 /yr

Total Fixed Cost per Year (D + IIT) = $ 3,120 /yr

TOTAL FIXED COST PER SCHEDULED HOUR = $ 2.08 /SH

III. Operating Cost

Maintenance & Repair: $\frac{25 \% \times (D) \$ 1500 /yr}{10{,}000 \text{ mi/yr}}$ = $ 0.04 /mi

Fuel: - gal/mi x $ - /gal = $ - /mi

Oil & Lubrication: - % of fuel cost 1/ $ - /mi

Tires: $\left(\frac{n \times mi/yr}{\text{tire life}} - 1\right)\left(\frac{1.15^{2/} \times \# \text{ tires} \times \text{cost/tire}}{n \times mi/yr}\right)^{3/}$ = $ 0.02 /mi

TOTAL OPERATING COST PER MILE = $ 0.06 /mi

IV. Labor Cost

Hourly Wage = $ 0 /SH
Fringe Benefits (50% of hourly wage) = $ 0 /SH

TOTAL LABOR COST PER SCHEDULED HOUR = $ 0 /SH

1/ 50% for diesel engines, 25% for gasoline engines.
2/ 15 percent labor charge to repair or replace tires.
3/ Tire life = 40,000 mi, 8 tires @ $175/tire.

MACHINE RATE CALCULATIONS
(on-road equipment)

Month: October
Year: 1983

I. Description

Type: Heavy Duty Pick-up Truck — Model: 1/2 ton
Accessories: ____ — Engine: ____

INITIAL INVESTMENT (F.O.B. Delivered Cost)			I =	$ 11,000
Estimated Life (n)	7	years		
Residual Value (R)	20	% of I	R =	$ 2,200
Working Days per Year	200	days		
Scheduled Hours (SH) per Year	1,500	hours		
Operating Miles per Year	20,000	miles		

Average Annual Investment $AAI = \frac{(I-R)(n+1)}{2n} + R$ = $ 7,230 /yr

II. Fixed Cost

Depreciation $D = \frac{I - R}{n}$ = $ 1,260 /yr

Interest 12 %
Insurance 3 %
Taxes 3 %
IIT = 18 % x AAI $ 7,230 /yr = $ 1,300 /yr

Total Fixed Cost per Year (D + IIT) = $ 2,560 /yr

TOTAL FIXED COST PER SCHEDULED HOUR = $ **1.71 /SH**

III. Operating Cost

Maintenance & Repair: $\frac{25\ \%\times(D)\ \$\ 1{,}260\ /yr}{10{,}000\ mi/yr}$ = $ 0.06 /mi

Fuel: 0.1 gal/mi x $ 1.35 /gal = $ 0.14 /mi

Oil & Lubrication: 25 % of fuel cost[1/] $ 0.03 /mi

Tires: $\left(\frac{n \times mi/yr}{tire\ life} - 1\right)\left(\frac{1.15^{2/} \times \#\ tires \times cost/tire}{n \times mi/yr}\right)^{3/}$ = $ 0.01 /mi

TOTAL OPERATING COST PER MILE = $ **0.24 /mi**

IV. Labor Cost

Hourly Wage = $ 0 /SH
Fringe Benefits (50% of hourly wage) = $ 0 /SH

TOTAL LABOR COST PER SCHEDULED HOUR = $ **0 /SH**

1/ 50% for diesel engines, 25% for gasoline engines.
2/ 15 percent labor charge to repair or replace tires.
3/ Tire life = 40,000 mi, 4 tires @ $75/tire.

MACHINE RATE CALCULATIONS
(on-road equipment)

Month: October
Year: 1983

I. Description

Type International Truck-Tractor — Model Transtar II
Accessories ________ — Engine ________

INITIAL INVESTMENT (F.O.B. Delivered Cost)			I =	$ 55,000
Estimated Life (n)	10	years		
Residual Value (R)	20	% of I	R =	$ 11,000
Working Days per Year	200	days		
Scheduled Hours (SH) per Year	1,500	hours		
Operating Miles per Year	10,000	miles		

Average Annual Investment $AAI = \frac{(I-R)(n+1)}{2n} + R$ = $ 35,200 /yr

II. Fixed Cost

Depreciation $D = \frac{I - R}{n}$ = $ 4,400 /yr

Interest 12 %
Insurance 3 %
Taxes 3 %
IIT = 18 % x AAI $ 35,200 /yr = $ 6,336 /yr

Total Fixed Cost per Year (D + IIT) = $ 10,736 /yr

TOTAL FIXED COST PER SCHEDULED HOUR = $ **7.16 /SH**

III. Operating Cost

Maintenance & Repair: $\frac{60\ \% \times (D)\ \$\ 4{,}400\ /yr}{10{,}000\ mi/yr}$ = $ 0.26 /mi

Fuel: 0.22 gal/mi x $ 1.35 /gal = $ 0.30 /mi

Oil & Lubrication: 50 % of fuel cost1/ $ 0.15 /mi

Tires: $\left(\frac{n \times mi/yr}{tire\ life} - 1\right)\left(\frac{1.15^{2/} \times \#\ tires \times cost/tire}{n \times mi/yr}\right)^{3/}$ = $ 0.04 /mi

TOTAL OPERATING COST PER MILE = $ **0.75 /mi**

IV. Labor Cost

Hourly Wage = $ 0 /SH
Fringe Benefits (50% of hourly wage) = $ 0 /SH

TOTAL LABOR COST PER SCHEDULED HOUR = $ **0 /SH**

1/ 50% for diesel engines, 25% for gasoline engines.
2/ 15 percent labor charge to repair or replace tires.
3/ Tire life = 40,000 miles, 10 tires @ $200/tire (10.00 - 20, 12 PR tubeless).

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Thompson, Michael A.
Evaluation of a mechanized tree-planting operation. Res. Pap. NC-258. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1984. 13 p.

A continuous-furrow, bareroot-stock, mechanical planter was used to plant red pine tree seedlings on five sites in northern Michigan. Several indicators of planting efficiency were analyzed including utilization of the available land area, productivity as related to site conditions and planting pattern, cost, and effectiveness of the V-blade.

KEY WORDS: Red pine, productivity, cost, reforestation, time study, system analysis.