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Contents

Evaluation of a four-row disc trencher prototype in western Canada

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Abstract

A custom built four-row disc trenching machine was evaluated in the southern interior of British Columbia in 2010. Its productivity, treatment quality, and cost were compared over a short-term period in two different size blocks (2 ha and 13 ha). Overall, a 20% increase in productivity (1.8 ha/PMH) was achieved by working in the larger block versus the smaller one (1.5 ha/PMH). Site conditions were the same between the blocks and the final treatment quality was unaffected by block size and met the prescription for the number of available plantable spots.

In the longer-term study, production was lower overall at an average 1.1 ha/PMH. The work patterns indicated high incidences of short passes, manoeuvring, and slower vehicle speeds, which are indicative of broken terrain and more confined treatment areas probably more suited to a smaller machine.

In the current state of development, this machine is well adapted to large, gently sloped blocks with few obstacles, which will allow it to achieve good quality for a low operating cost. As site conditions become more difficult, it forces the machine to be run slower, which significantly reduces productivity.

Introduction

Disc trenching is the most widely used mechanical scarification treatment in Canada. The popularity of this site preparation technique comes from its ability to produce continuous trenches offering good microsites for seedling establishment, while providing easier and safer access to the planter at a reasonable cost. To reduce treatment costs, developments have been made by the Scandinavian manufacturer, Bräcke Forest AB, to produce three- or four-row disc trenchers instead of the conventional two-row model. A three-row disc trenching implement is currently being used in Quebec, but data documenting its cost effectiveness have not yet been published. These types of implements should be successful if the expected increases in productivity compensate for higher hourly operational costs.

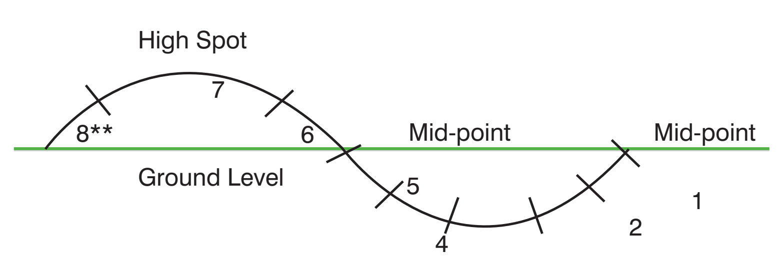
In the summer of 2010, in cooperation with Weyerhaeuser Company, FPInnovations studied a custom-built, four-row disc trenching machine to determine its productivity, treatment quality, and cost over a short-term period. In addition, longer-term productivity data were collected from other areas with Weyerhaeuser Company and Tolko Industries over a period of three months.

Figure 1. WG Shaw & Son's four-row disc trencher.

Machine description

The four-row disc trencher was custom built by a site preparation contractor, WG Shaw & Son Ltd. of Vernon, B.C. This contractor is experienced in site preparation and operates two-row crawler-mounted disc trenchers and excavator mounding equipment. The four-row machine is an operational prototype and uses a customized Timberjack 933C clambunk skidder, with the grapple crane removed, as the prime mover. The implement was assembled from a two-row Donaren 180 unit (inner discs) and a two-row TTS Delta unit (outer discs) (Figure 1). The TTS Delta reach arms were separated from its intended two-row design and attached at the outer disc positions of the four-row arrangement. The inner discs were adjustable and set at 2.7-m spacing, while the outer trenching discs were permanently set at 2.2 m relative to the inner ones. Potential improvements considered include adjustable spacing on the outer discs and hydraulic improvements to increase the overall operating speed of the machine in broken terrain. There are currently no plans to build another trencher.

Figure 2. Microsite position selection on site-prepared ground (diagram courtesy of Weyerhaeuser Company, Princeton, B.C.).



Study methods

FPInnovations completed a detailed short-term trial based on the methodology in Sutherland (1986). Additionally, shift-level data were collected over the remainder of the site preparation season to evaluate machine productivity over a longer period.

Pre-treatment assessment

The pre-treatment assessment was carried out using a series of randomly placed transects over each treatment area. The line-intersect method was used to assess the volume of slash and slash height. Stump heights, their diameters, and stoniness were measured within a fixed-area rectangular plot placed around the transect to assess ground roughness.

Time-and-motion studies

Detailed time-and-motion studies using an electronic datalogger were carried out on the machine as it scarified each of the two sites. The machine was monitored for the entire time it worked in each area to calculate the short-term productivity. Differences in the productivity between the blocks were compared with attention given to how it differs for a wider scarifier in a small block versus a larger one.

Post-treatment assessment

Post-treatment assessments were carried out in circular plots established at the same locations as the pre-treatment plots. Detailed characteristics of trenches were measured, and plantable spot opportunities based on Weyerhaeuser's microsite definition (Figure 2) were only assessed within trenches as planting in non-scarified areas was not prescribed.

Long-term productivity data

Long-term productivity data were collected using a GPS-enabled MultiDAT datalogger installed on the machine with an accompanying download station (Figure 3) installed in the operator's vehicle. Daily downloads of the productivity and GPS data were transferred wirelessly from the machine to the download station, and then uploaded through the cellular network to a network where data were retrieved at FPInnovations. The long-term productivity data were analyzed with GeoFor, a GPS data analysis package.

Site descriptions

The two study areas for the short-term productivity study (Figures 4 and 5) were located in the Montane Spruce, dry mild sub-zone, variant 2-01 (MSdm2-01) near Princeton, B.C. The site conditions are summarized in Table 1.

Figure 3. Data download station and MultiDAT datalogger.

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Figure 4. Site 1.

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Figure 5. Site 2.

Table 1. Site conditions

	Site 1	Site 2
Size (ha)	13.1	2.2
Average slope (%)	9	15
Aspect	south	south–southeast
Soils	sandy loam	sandy loam
Average humus thickness (cm)	4.3	2.5
Drainage	well drained	well drained
Stoniness (% probes encountering stones)	81	86
Average depth of stones (cm)	20	20
Average stump height (cm)	19	20
Average stump diameter (cm)	23	21
Stumps per ha	1090	1040
Slash loading (m^3/ha)	78	117
Average slash height (cm)	16	17

Both blocks were winter logged. Slash loading was light at both locations, with concentrations along the roads and landings that had been piled and burned in the spring before the site preparation started. Rocks were close to the surface and soil probes indicated rocks at most pre-treatment measurement locations. With a thin duff layer and favourable ground and slash conditions, both sites presented no major constraints for the trencher. The two study sites allowed for a reliable comparison of productivity between the blocks.

Productivity

A short-term productivity trial (Table 2) was conducted in two blocks of different sizes using detailed timing. Site 2 was completed by an operator who was very experienced on the four-row machine. Site 1 was completed by a different operator who was less experienced with the four-row machine, but very experienced with other scarifying equipment. The second operator continued as the primary operator for the remainder of the season.

Observed short-term productivities show a significant improvement over conventional two-row trenchers, which normally get from 0.9 to 1.2 ha/PMH. Previous FPInnovations studies of scarifying equipment have shown that productivity decreases with smaller block sizes, increased slope, and number of obstacles (i.e., high stumps), especially with larger machines that require more turn-around time in tight areas. In this study, a 20% increase in productivity was achieved at Site 1 (large block) over Site 2 (small block) under nearly identical in-block conditions, due to the reduced time required to turn the machine around at the end of its passes. With the increase in productivity at Site 1, turn-around time was decreased by 46% compared to that at Site 2, as well as realizing a slight decrease in manoeuvring time.

Long-term productivities of the four-row trencher were monitored over a three-month period. GPS data were collected on a daily basis[1], using an electronic MultiDAT datalogger mounted in the machine with a GPS antenna mounted on the cab roof. The datalogger needed no operator input and logged GPS data if the machine moved more than 4 m at a time. Machine movements were analyzed using FPInnovations' GeoFor software and productivities were calculated using the GPS data.

For the long-term productivity trial (Table 3), a total of 141 ha was treated between Weyerhaeuser and Tolko over 131 h of productive time, which equated to average productivities being 42% lower

Table 2. Distribution of short-term productive time

	Scarify		Move[a]		Turn around		Manoeuvre		Minor delays		Total time	Treated area	Productivity
	min	%	min	%	min	%	min	%	min	%	min	ha	ha/PMH[b]
Site 1	325	75	11	2	30	7	50	12	14	3	430	13.1	1.8
Site 2	58	68	1	1	11	13	12	14	4	5	85	2.2	1.5

[a] Move – machine travel in forward direction with trenchers in the up position for short durations during scarifying, i.e., to avoid debris and rocks, and temporarily clear the trenchers of debris.

[b] PMH – productive machine hours, including minor delays less than 15 min.

[1] The datalogger was disconnected from power and GPS signals for a significant period of time for reasons outside the control of the study. The actual total area treated by the machine for the study period was higher than documented.

(1.1 ha/PMH) than the best short-term block of 1.8 ha/PMH. This was attributed to lower speeds attained by the machine because of a higher abundance of unfavourable site conditions, which were not captured in the short-term study but were observed in the patterns of the GPS data over the longer term. The work patterns indicated high incidences of short passes, manoeuvring, and slower vehicle speeds, which are indicative of broken terrain and more confined treatment areas probably more suited to a smaller machine. A double trenching pattern was also observed from time to time, where a treatment is done twice to improve quality. With a utilization rate of 70% applied, estimated machine costs were $154/PMH or $85/ha at Site 2 and averaged $140/ha over the longer term. These are based on the cost of used equipment and do not reflect the actual costs incurred by the contractor.[2]

Post-treatment assessment

The post-treatment survey assessed the disc trenching quality (Table 4). Weyerhaeuser prescribed disc trenching to create a raised microsite with higher soil temperatures, improved drainage, and reduced grass competition. The preferred planting locations are at positions 6 or 7 of the trench berm (Figure 2).

Table 3. Summary of productivities for long-term blocks

	Block[a]	Treated area (ha)	Avg. speed (m/min)	Productive time (PMH[b])	Productivity (ha/PMH)	Scheduled machine hours (SMH = PMH + delays[c])	Utilization % (PMH/SMH)
Weyerhaeuser	1	65.3	28.9	64.9	1.0	82.9	78
Tolko	2	28.7	29.4	23.1	1.2	88.7	74
	3	25.2	31.1	22.8	1.1		
	4	1.9	26.7	2.6	0.7		
	5	19.6	28.8	17.3	1.0		
Total		140.8	29.0	130.7	1.1	171.6	76

[a] Blocks are classified as areas with the same timber mark. There were identified patches of varying sizes within each block that the machine treated.

[b] PMH is total productive time including delays less than 15 min.

[c] Delays do not include machine travel to and from the treatment start point within the block and on roads.

Table 4. Description of trenches

Study area	Trench dimensions							
	Spacing		Width[a]		Depth		Exposed mineral soil	
	Average (m)	Range (m)	Average (cm)	Range (cm)	Average (cm)	Range (cm)	Average (cm)	Range (cm)
Site 1	2.3	1.9–2.7	120	80–180	13	5–25	20	10–40
Site 2	2.2	1.7–2.8	120	80–150	17	10–30	20	10–40

[a] Width of trench is entire width of disturbed area including berm.

[2] PMH costs are based on used equipment: $60,000 for the clambunk carrier and an estimated $30,000 including modifications for two 2-row disc trenchers, and the machine working 10 h/day, seven months per year. About 17% of the costs are from ownership charges while the remaining portion comes from operating expenses (labour and machine).

Trench spacing was assessed by locating the pre-harvest plot centre and relocating it to the centre of the exposed mineral soil (EMS) in the closest trench. The distance between the centres of two adjacent trenches on either side of the plot centre was measured. Ideal trench spacing was 2.7 m, but the measured spacing varied from 1.9 m to 2.8 m. Tighter spacing of the top two trenches was common if machine passes were closer than intended, or if the machine worked across even the slightest of slopes. The top two trenches had a tendency to be shallower and closer to one another. This contributed to the average overall spacing between trenches of 2.3 m on Site 1.

In the post-treatment surveys, plantable spots were selected based on Weyerhaeuser's criteria. The target planting density at this site was 1200 stems/ha, with an ideal inter-tree spacing at 3.1 m along the trenches.[3] The minimum inter-tree spacing was 1.6 m. The microsite opportunities were assessed by starting at the plot centre from which 3.1 m was measured along the trench. If an acceptable microsite was found, an acceptable spot was recorded and measurement commenced from that location until the edge of the plot was reached. If the microsite was inadequate, spacing was adjusted backward until an acceptable site was encountered to a minimum of 1.6 m from the first. If no microsite was available within the spacing guidelines, a non-plantable spot was recorded with a reason noted. Table 5 summarizes the plantable spots survey.

The number of plantable spots at Sites 1 and 2 were slightly above target by 6% and 10%, respectively. This is attributable to the relative spacing of the trenches to one another, even though the inter-tree spacing along the trench was adjusted. In some plots, there were four trenches 2.2 m apart (or closer) or areas where trenches were not continuous, but there was plenty of elevated mineral soil exposure, especially at Site 2, where there was more disturbance from the machine turning around. A thin duff layer and favourable ground and slash conditions in both blocks allowed for maximum mineral soil exposure by the trenching implement and allowed the machine to create continuous trenches over the majority of the study areas.

Table 5. Plantable spots

Study area	Plantable spots						
	Acceptable microsites per plot ($100\ m^2$)			Unacceptable microsites per plot ($100\ m^2$)			Total available opportunities
	Average (target)	Range	Per hectare	Average	Reason	Per hectare	Per hectare
Site 1	13 (12)	12–14	1210	1.3	debris, mulch or rock	75	1285
Site 2	13 (12)	12–14	1250	1.4	debris, mulch or rock	70	1320

[3] A two-row disc trenching machine with ideal 2.7-m spacing between rows and an inter-tree spacing of 2.1 m would result in 1200 stems/ha. The inter-tree spacing was increased to 3.1 m for any blocks where this machine worked.

Discussion

Short-term productivities of the four-row trencher were comparable to the advertised production numbers (1.8 ha/h) of a Bräcke T26 twin working in what Bräcke refers to as medium ground. Bräcke T26 twins are four-row machines that are not yet sold in Canada, but are the only manufactured four-row machines being produced. The machine worked well in the short-term study areas, which were clear of debris and had few obstacles to affect machine trafficability. Passes were long and consistent in both study blocks and allowed for a reliable comparison to evaluate the effect of block size on the productivity. More frequent turn-arounds and manoeuvres reduced productivity by 0.3 ha/PMH (17%) when operating the machine in the smaller area under the same ground conditions.

Average long-term productivity (1.1 ha/PMH) for the four-row trencher was lower than the short-term productivity and compared more to that of a skidder- or forwarder-mounted two-row machine. The GPS tracks during the long-term study showed many instances of patterns that are indicative of scarifying in broken terrain and in more confined areas. To achieve the target number of plantable spots in those conditions, techniques such as double-trenching and additional turning and manoeuvring of the machine were required, which reduced productivity. FPInnovations, through its studies in eastern Canada, found that forwarding machines have a productive disadvantage in blocks less than 2 ha in size and in discontinuous ground, which was confirmed in this study.

This four-row disc trencher is an operating prototype with planned upgrades to its hydraulic capacity and structural integrity. Combined, these improvements could enhance the operational speed of the machine, as well as augment the disc spacing for a wider treatment pass, which in turn will improve the machine's productivity. If the operating speed could be increased from a current average of 30 m/min to 50 m/min, productivity could rise from 1.1 ha/h to 1.8 ha/h. Ideally, for contractors who own several types of site preparation machines, matching the machine to the topography and block size will also maximize productivity and lower costs. Operationally this is not always possible, especially if the blocks are not in close proximity to one another and significant lowbedding is required.

Implementation

The four-row disc trencher in this report is a specialized machine and is also a working prototype. In the current state of development, this machine is well adapted to large, gently sloped blocks with few obstacles, which will allow it to achieve good quality for a very low operating cost. As site conditions become more difficult, it forces the machine to be run in first gear, which significantly reduces travel speed and productivity. Small sites with broken terrain, or sites with standing residual trees, are not suitable for a large machine.

Improvements, most of which are already known by the contractor, need to address uneven quality from the outside discs, as well as hydraulic improvements which allow for second gear travel and quicker turning ability.

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