SILVICULTURE

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EVALUATION OF THE LE CRABE FORESTRY DISC HARROW

Denis Cormier, F.E.*

Summary

The Le Crabe forestry disc harrow was field tested to determine both its productivity and potential applications under typical forestry conditions. Short-term evaluations and appraisal of the treatment results formed the basis for analyzing three different treatment patterns (single pass, double pass, checkerboard). The drawbar force required to pull the implement with 90-cm discs was measured on two different soil types.

Introduction

Harrowing is an intensive site preparation technique generally applied over 100% of the area to be treated. The purpose of a disc harrow in forestry is to mix organic matter evenly with the mineral soil and to chop and bury the competing vegetation. The quality of work accomplished by the Rome disc harrow, used in forestry for many years, varies with site conditions. Each row of discs is attached to the same axle, so results are less satisfactory on rough terrain. Since each disc on Le Crabe is independent, more uniform results should be obtained.

The Le Crabe forestry harrow is based on the design of a French machine introduced to Canada in 1985. Major modifications were made to prepare it for operational use under our forestry conditions. FERIC was involved in developing the prototype in 1987 (Cormier et al. 1987). The machine, commercially available since 1988, is manufactured and distributed by Équipements Denis Inc.

To date, the Le Crabe forestry harrow has been used mostly in Quebec to treat non-satisfactorily regenerated areas (backlog), with competing vegetation usually less than 3 metres high (Figure 1). The implement also has the capacity to do a more intensive treatment of recent cutovers harvested using the full-tree system. Because of the intensive site preparation done by the Le Crabe, it could also be considered for other applications, such as the preparation and maintenance of seed orchards. The smallest model, which has 60-cm discs, has been used on small, private woodlots.

Figure 1. The Le Crabe forestry disc harrow being used to treat a backlog site.

* Denis Cormier is a researcher, Silvicultural Operations, Eastern Division.
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FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
INSTITUT CANADIEN DE RECHERCHES EN GENIE FORESTIER
143 Place Frontenac, Pointe Claire, Québec, Canada H9R 4Z7, (514) 694-1140
201-2112 West Broadway, Vancouver, B.C., Canada V6K 2C8, (604) 732-3711

The objectives of this study were to: evaluate the productivity and potential applications of the Le Crabe harrow under typical forestry conditions; study how the treatment results were influenced by different patterns; and measure the drawbar force required to pull the harrow.

Description of the Implement

The Le Crabe forestry harrow is comprised of two rows of discs, with the back discs placed in the opposite direction to the ones in front. Each disc is attached to the frame by a separate rocker arm which allows independent vertical and lateral movement. Hydraulic cylinders attached to the arms apply uniform pressure to the discs (Figure 2). Two hydraulic accumulators allow the pressure to be adjusted depending on site conditions. Two other hydraulic cylinders attached to the wheels located on each side of the frame make it possible to raise the frame for towing the harrow over short distances (Figure 3).

Starting in 1990, two standard models of the Le Crabe forestry harrow will be available with eight, 70- or 90-cm discs. A summary of the characteristics of the new 70-cm model and of two older models is presented in Table 1. At the time of the study, only the older models equipped with 60- and 90-cm discs were available.

Table 1. Specifications of Le Crabe forestry harrow

	1990 model[1]	Older models	
Disc diameter (cm)	70	60	90
Frame width (m)	3.0	2.4	3.7
Number of discs	8	8	9-10
Approximate weight (kg)	5500	3000	8000

[1] The exact dimensions of the new 90-cm model have yet to be finalized.

The machine configuration used in the study was a harrow equipped with nine, 90-cm discs with a Caterpillar 528 cable skidder as the prime mover (Figure 1). This harrow treats a swath of about 4 metres. The skidder used had a net output of 130 kW, a three-speed powershift transmission and a weight of 14 040 kg.

Figure 2. The Le Crabe forestry harrow is equipped with hydraulic cylinders which provide constant pressure to two rows of independent rocker arms.

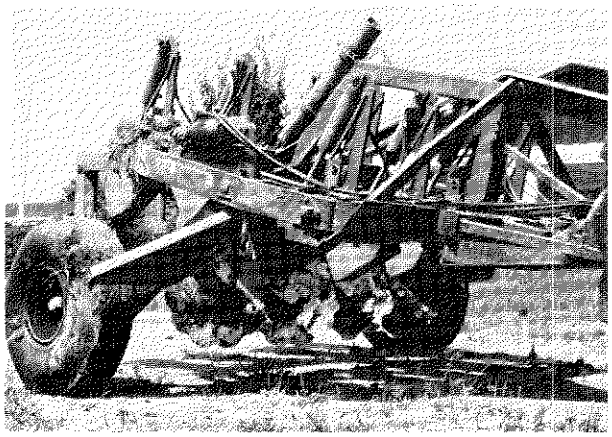

Figure 3. Moving the harrow over short distances is assisted by hydraulic cylinders attached to wheels which lift the frame.

Methods

The methods and parameters used to evaluate the pretreatment site conditions were similar to those described by Sutherland (1986), except for using 100-m^2 circular plots and 20-m line intersects for the slash measurement.

A drawbar pull test was done during the short-term study. The methods used for the tests, designed to measure the horizontal force required to pull the implement, are described in an internal report prepared by FERIC (Cormier and Levesque 1990). Also, a second drawbar pull test was done independently in the Beauce region of Quebec.

Site Description

A fairly homogeneous site of about 13 ha near Despinassy, northeast of Amos in the Abitibi-Temiscamingue region of northwestern Quebec, was chosen for the evaluation of the Le Crabe forestry harrow in July 1989. REXFOR was responsible for putting the site back into production, after it had been full-tree harvested five years before. The aim of the treatment was to temporarily eliminate competing vegetation and to get a uniform mixture of the clay mineral soil with the humus so as to favour the growth of the planted seedlings and to prevent frost heaving. Another aim was to evaluate the operational feasibility of the checkerboard scarification pattern.

Three operational treatment patterns were studied on this site (Figure 4). Two-thirds of the site was completely treated using a concentric pattern. A second concentric pass was then carried out on a section of this area where the ground-bearing capacity had not been reduced too much by the first pass. The remaining third of the site was scarified using a checkerboard pattern consisting of a partial double-pass treatment (a space of 2 m between two successive passes of 4-m wide each).

Table 2 gives a brief description of the site conditions at the time of the evaluation. The clay texture of the soil constituted the limiting site factor in this region, creating moderate to poor soil strength conditions depending on the level of soil moisture. Because of the delay following harvest, there was only a small amount of slash on the site, but the dense brush often surpassed 12 000 stems/ha.

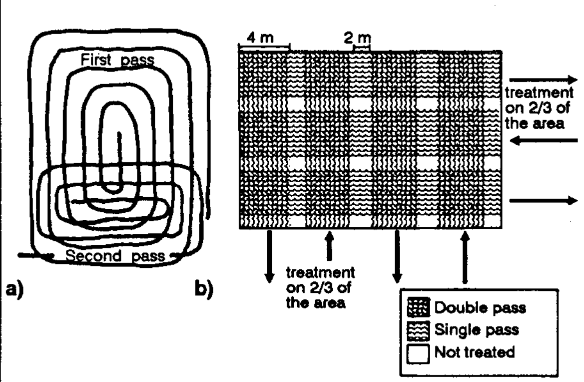

Figure 4. Operational patterns:
a) full coverage single- and double-pass treatments using concentric patterns;
b) partial coverage double-pass treatment using checkboard pattern.

Table 2. Site description summary

	Mean	Range
Stumps		
- density (no./ha)	490	100-1600
- diameter (cm)	22	10-40
- height (cm)	23	10-62
Brush		
- density (no./ha)	12 180	0-27 450
- height (m)	1.8	1.5-3.0
Slash		
- height (cm)	7	0-68
- volume (m^3/ha)	34	9-76
Humus depth (cm)	8	2-22
Stoniness (%)	< 5	0-20
Slope (%)	1	0-6
CPPA site classification[1]	3(4).1.1	

[1] Terrain classification using the following criteria: soil strength, roughness and slope, on an increasing scale of difficulty from 1 to 5 (Mellgren 1980).

Results

Productivity

The percent of time actually spent scarifying was similar for the three operational treatment patterns, varying between 75 and 78% (Table 3). During the first pass, low soil strength was the main obstacle which hindered the movement of the prime mover. Frequently, the harrow had to be winched across a wet spot after being disconnected using the quick-release hitch. This also accounted for the high percentage of scarification done while winching. Repairs to the radiator cap were responsible for almost all of the delay time which occurred during the second pass. Compared to the concentric passes during the complete double coverage, the checkerboard pattern demanded more manoeuvering time. The length of the passes in the block treated using the checkerboard pattern varied from 50 to 300 m, with an average of 170 m.

The production rate during the first pass was almost 1 ha/PMH. As might be expected, the productivity of the double-pass pattern was about half that for a single pass. The checkerboard pattern, representing an overall coverage of 133% of the area, would normally have resulted in a 25% reduction in productivity compared to a single pass. However, the skidder was able to sustain a speed 27% higher, with a production rate of 0.89 ha/PMH, because of the drier soil in this part of the cutover.

Table 3. Time distribution and operational summary

	Single pass	Double pass	Checker-board
Scarification (%)			
- forward	64.5	73.1	70.1
- winching	13.5	2.1	6.3
Obstacles (%)			
- prime mover	15.0	2.4	2.0
- harrow	1.5	0.0	0.2
Manoeuver (%)	3.3	3.9	13.1
Travel (%)	0.2	5.2	1.6
Delay (%)	2.0	13.3	6.7
Total (%)	100	100	100
PMH[1]	8.80	1.99	4.69
Area (ha)	8.69	1.94	4.17
Productivity (ha/PMH)	0.99	0.49[2]	0.89
Working width (m)	4.02	4.06	5.91
Average speed[3] (m/min)	52	53	66

[1] PMH = Productive Machine Hours (which include delays of < 15 minutes).

[2] Productivity of a double-pass treatment.

[3] Speed = $\frac{10\,000\ m^2/ha}{\text{working width (m)}}$ /scarification time (min/ha)

Drawbar Pull

An average horizontal force of 64 kN was needed to pull the harrow, with peak forces up to 125 kN, during the first pass on the clay soil at Amos (Table 4). The narrower range of readings obtained during the second pass were due to a smaller sample size. Another field trial was carried out using the same machine configuration on a recently-harvested loamy site at St. Georges de Beauce in southern Quebec. Both sites were classified as being CPPA roughness class 2. The lower force required to pull the harrow in the Beauce region appeared to be caused by a shallower penetration of the discs in the soil. Three factors could have contributed to impede deeper penetration of the discs: the physical soil characteristics, a stoniness index of 43%, and a greater amount of slash coverage. The peak forces were very similar for both sites.

Table 4. Drawbar pull measurements

	Amos		Beauce
	First pass	Second pass	
Mean (kN)	64	63	52
- range[1] (kN)	56-80	61-65	48-56
Peak force[2]			
- mean (kN)	90	83	86
- range (kN)	68-125	77-90	68-110

[1] Range of the means measured over a distance of 20 metres. (sampling varied between 5 and 20 plots).
[2] Maximum values observed over a 20-metre distance.

Treatment Quality

As shown in Table 5, discing is a very intensive site preparation method in that 79% to 94% of the soil was disturbed. The double-pass pattern created the most disturbance, while the checkerboard pattern left more areas undisturbed. The checkerboard pattern best met the treatment objective; namely, to mix the mineral soil uniformly with the organic matter. The second pass in the double concentric pattern resulted in an increase of only about 9% in the amount of mineral soil mixed with organic matter.

Table 6 shows that the differences in terms of plantability were small. All three operational patterns produced good plantability results. However, the double pass was more consistent in creating good planting microsites.

Table 5. Soil disturbance

Type of disturbance	Gross disturbance (%)[1]		
	Single pass	Double pass	Checker-board
Mineral soil exposed	28.0	25.0	14.5
Mixture (mineral/organic)	13.9	22.4	35.8
Other disturbances	39.5	46.2	28.8
Total disturbance	81.4	93.6	79.1

[1] Percent of the total area disturbed by the treatment.

Table 6. Plantability

Microsite quality	Plantability (%)[1]		
	Single pass	Double pass	Checker-board
Good	65	78	70
Passable	26	16	21
Total	91	94	91

[1] Plantability based on a tree spacing of 2 m × 2 m (2500 microsites/ha).

Discussion

The number of passes required to disc a site will depend on both the treatment intensity desired and the site conditions. A single pass will often be sufficent on sites with a thin layer of organic matter or on poorly-drained soils. Under these conditions, a single pass would prevent a mixture with too high a mineral soil content, or the development of standing water. Where site conditions permit, a double pass would ensure more uniform mixing of mineral soil and organic matter. It would also result in better chopping and burying of the competing vegetation. Double-pass treatments should be used only during the dry season if the soils are fine textured.

According to the results obtained, the second pass increased the degree of soil disturbance by only 12%, the amount of mixing by 9%, and the plantability by 3%. However, good quality microsites increased by 13%. Since the differences observed between the single and double passes are not very great, the second pass would be easier to justify if it could be shown that it significantly reduces frost heaving and tending costs resulting from the regrowth of competing vegetation.

This study was not designed to determine the optimal layout between the first and second passes. However, it would seem preferable to conduct the second pass perpendicular rather than parallel to the first. The successive perpendicular passes of the checkerboard pattern seem to have mixed the mineral soil and organic matter better than the sometimes parallel and sometimes perpendicular concentric patterns of the complete double pass. A study carried out by the Quebec Ministère de l'Énergie et des Ressources (Caron 1986) again showed that the mixing of mineral soil and organic matter obtained during a perpendicular double pass was more uniform. On some sites, however, it may be difficult to keep the second pass perpendicular because of slope, rough terrain, or the shape of the block. The value of a second pass should be questioned if it must be conducted parallel to the first.

The checkerboard pattern is interesting from an operational point of view, since it provides the benefits of perpendicular passes, but reduces the area treated by 67%. However, the reaction of the competing vegetation following this treatment remains to be seen.

Based on the normal direct costs for the type of prime mover required, and a purchase price of about $65 000 for the harrow, the operating cost for the equipment studied is approximately $130/PMH, using the standard costing procedure outlined by Rickards and Savage (1983). Assuming a production rate of 1 ha/PMH per complete pass, the theoretical treatment cost of a single-pass, a double-pass and a checkerboard treatment pattern are about $130, $260 and $175 per ha, respectively.

FERIC had previously carried out field trials using a pre-production model of the Le Crabe forestry harrow equipped with 60-cm discs (Cormier et al. 1987). This harrow was not as aggressive because of the small diameter of the discs and its light weight. During the trial, only 41% of the area was disturbed after the first pass and 55% after the second. Compared to the larger models, the smaller harrow is much more sensitive to the quantity of slash on the site, and its narrower width will also reduce productivity. The smaller harrow requires less drawbar power, but the treatment intensity is less.

Because of its weight and the way that it works the soil, the 90-cm Le Crabe forestry harrow studied has a high drawbar pull requirement, necessitating a powerful prime mover. The horizontal force needed to move the harrow will vary with field conditions. Moreover, because the drawbar pull required will increase with slope, the use of a wheeled prime mover would be restricted in steep terrain.

Conclusion

The 90-cm Le Crabe forestry disc harrow performed well during the evaluation. The system of independent rocker arms with hydraulic cylinders allows each disc to easily negotiate obstacles such as rocks and stumps. Because of the intensive site preparation treatment, the power needed to pull the harrow is high and will vary according to the site conditions.

When using this equipment, the principal objective is to mix the mineral soil uniformly with organic matter. Treatment results will vary according to the number and relative positioning of the passes, as well as with the model of harrow used. From an operational viewpoint, the checkerboard pattern is preferable to the complete double pass. It provides the advantages of perpendicular passes, while reducing the treated area by 67%. However, the response of the competing vegetation to this scarification method must be studied.

Starting in 1990, a new model of the Le Crabe forestry disc harrow with eight, 70- or 90-cm discs will be marketed by Équipements Denis Inc. Further studies will be required to evaluate the performance of this new harrow under varying conditions.

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