



CABLE YARDING IN EASTERN CANADA - 5 CASE STUDIES

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Abstract

Cable logging has been used in eastern Canada on a trial basis since the 1930's but has never met the success of ground-based systems. However, growing environmental pressure and a diminishing fiber supply have renewed interest in this harvesting method. Production data for four cable-logging systems studied in 1990 and for another system studied earlier are presented. Worker productivity was highest in "hot yarding" systems. Productivity is also maximized when yarding large volumes over short distances. Yarding large volumes over long distances was only slightly more productive than yarding small loads over long distances. The lowest cost per cubic metre was achieved with a self-propelled radio-controlled carriage. High mobility, low capital and operating costs and high worker productivity were found to be key factors.

Putnam 1945). This situation still prevails today, as demonstrated by the small number of systems in operation. In recent years however, concerns over a shrinking resource base and stricter environmental regulations have renewed interest in cable logging.

An earlier FERIC report (Courteau 1990) presented technical characteristics of the cable yarding equipment operational in eastern Canada. This report provides information on the potential productivity, harvesting cost and layout of the five systems studied to date by FERIC: the Ecologger, manufactured by Cypress Equipment in British Columbia; the Christie yarder, manufactured in the U.S.A.; the Smith Timbermaster, a Scottish machine; and two prototype machines: the Télérporteur from Quebec, and the Gabriel truck yarder from Newfoundland. (The glossary in Appendix 1 explains cable yarding terminology.)

Introduction

Cable logging has been tried since the 1930's in eastern Canada, but has never gained the acceptance of ground-based systems. Low productivity, high operating costs and poorly-adapted equipment have been cited as reasons (Heidersdorf 1978; McColl 1949;

Resource Overview

The potential areas for cable yarding on steep slopes in eastern Canada (see Figure 1) are found on:

- the Northern Peninsula and west coast of Newfoundland, and parts of Labrador;

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- Cape Breton Island, the South Atlantic region and north of the Minas Basin in Nova Scotia;
- the Southern Uplands, Upper Miramichi-Tobique and Restigouche regions of New Brunswick;
- the Gaspé region, all along the North Shore of the St-Lawrence River, around Lac St-Jean, and in the lower Temiscamingue regions of Quebec;
- around the eastern shores of Lake Huron and the northern shores of Lake Superior in Ontario.

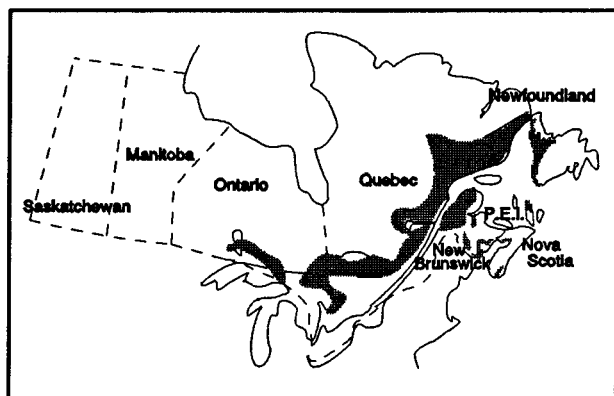


Figure 1. Potential areas for steep slopes logging in eastern Canada.

A survey of provincial forest inventories indicates an annual allowable cut of at least 1.4 million m^3 on eastern Canadian steep slopes (slopes $>40\%$). This volume is distributed approximately as follows: Quebec (1 180 000 m^3), Newfoundland (40 000 m^3), Nova Scotia (50 000 m^3), New Brunswick (60 000 m^3) and Ontario (40 000 m^3). The 1.4 million m^3 volume is a conservative estimate however, as inventories in the provinces of Ontario and New Brunswick do not always include steep-slope areas, and therefore provide only limited information. Furthermore, an additional volume could possibly be harvested by cable logging methods in areas where conventional equipment cannot freely manoeuvre such as in rocky areas, very broken terrain, sensitive sites, and selective thinnings.

Existing road networks provide access to many of the steep-slope stands, as these often make up the inaccessible portion of expired or active timber licenses. Their topographies vary from the rolling, rough terrain found in the Stephenville area in Newfoundland, to the steep escarpments found on Quebec's North Shore. For the most part, the areas are located in river valleys formed by glacial runoff during the last ice age. Their profiles are generally characterized by mostly concave slopes gradually flattened at the top and at the bottom, with distances rarely greater than 300 m.

Because of their glacial origins, soils on these slopes are well-drained sandy loams, and can sustain above average annual growth. This is typified in Nova Scotia's Cobequid and Quebec's Portneuf regions where average tree volumes on slopes are two to three times the provincial averages. However big these trees may be, they are often shallow-rooted, which makes their behaviour as guyline anchors unpredictable. The consequences are that careful planning is required to select anchors stumps, and even greater caution must be exercised when working near cables under tension.

Methodology

To determine the potential productivity, operating costs and effectiveness of cable yarding systems in eastern Canada, five different machines operating in Newfoundland, Nova Scotia, New Brunswick, and Quebec, were evaluated in an operational setting. Productivity was measured by intensive continuous time studies. Sample size was determined by the moving average method, with an acceptable error of $\pm 10\%$ on cycle times and a 95% confidence level. Stand parameters were measured through 10-m \times 25-m plots near the cut face. Load volumes were obtained from butt scales of each cycle, slope profiles from topographic survey lines, and distances were measured for each load by hip-chain.

Equipment and Operational Setups

The machines evaluated were an RMS Ecologger (Figure 2a) equipped with a gravity-fed Maki locking carriage; the Gabriel truck yarder (Figure 3a), a guyless

jammer-type highlead system hauling a skidding plate; a Christie yarder (Figure 4a) also running a gravity-fed Christie locking carriage (both the Ecologger and Christie are tower yarders); and the TLD Gauthier Téléransporteur (Figure 5a), another guyless system. The Téléransporteur is a self-propelled radio-controlled carriage which uses a single skyline cable, anchored by an excavator at the bottom of the slope and a skidder at the top.

The project initially called for the study of a fifth machine, the Smith Timbermaster (Figure 6a); however, difficulties in obtaining a logging contract shut down this operation in 1990. Instead, unpublished productivity figures from a previous FERIC study are presented as background information.

Table 1 provides details on stand parameters for the systems studied in 1990, and Figures 2 to 6 describe the equipment, operational setup and average slope profiles for the sites observed during each study. A brief qualitative description is also provided for each operating site. Technical specifications of the machines are presented in Appendix 2.

RMS Ecologger

The RMS Ecologger was owned and operated by Fraser Inc. on their Kedgwick operation, 100 km north-east of Edmundston, New Brunswick. The yarder was secured by four guys, two of which were anchored behind the yarder on 19-year-old Clark 664 skidders, another was anchored by a stump 15 m downhill, and the fourth was tied to the log pile at roadside. A 1965 Caterpillar D6 tractor served as a mobile tailhold 300 m downslope. The yarder, which was set up on the access road, hauled pre-felled full trees uphill to roadside. The trees were then bunched, cleared from the landing, and piled by a 10-year-old Tree Farmer C7D skidder.

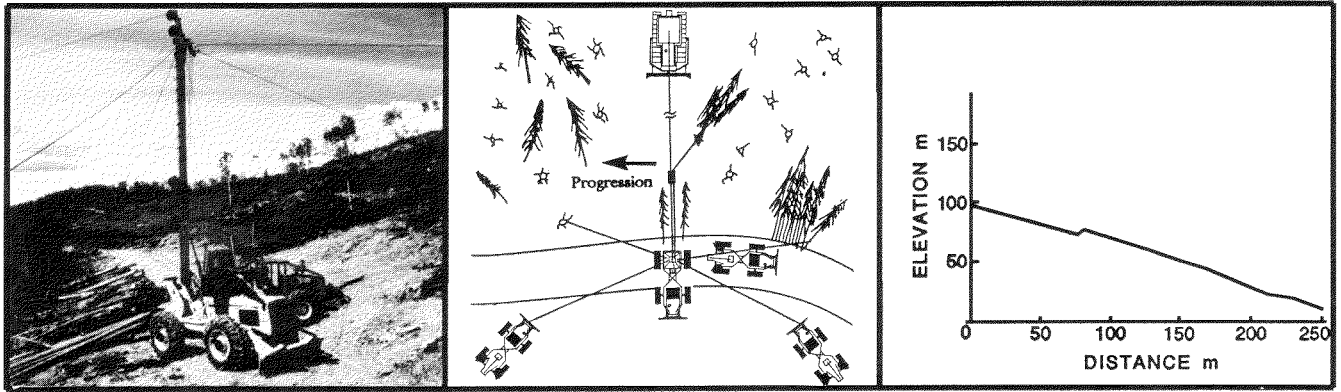
The study site was a clearcut on a concave slope over most of its width, except for a convex section obstructed by a slight hummock. Pre-choking was limited to the concave portions of the slope because returning choker sets would otherwise catch on brush along the hummock and fall off the carriage during out-haul.

Table 1. Stand parameters for the systems studied in 1990

Parameter	System			
	Ecologger	Gabriel Truck Yarder	Christie Yarder	Téléransporteur
Merchantable stems/ha	1130	280	860	700
Unmerchantable stems/ha	670	400	660	520
Species composition	Sb 60% Bf 20% Bw 20%	Bf 70% Bw 30%	By 50% Sw 30% Ms 20%	Bf 70% Bw 20% Sw 10%
% Blowdown	0	40	0	20
% Mortality	10	40	10	30
Average volume/tree, m ³ *	0.34 m ³	0.16 m ³	0.49 m ³	0.21 m ³
Average butt diameter, cm*	28	24	32	22
C.P.P.A. terrain index**	1.1.4. → 1.1.5.	3.3.1 → 3.4.4.	1.1.5.	1.4.5. → 1.5.5.

* Based on scale of harvested trees.

** Range of terrain conditions according to the Canadian Pulp and Paper Association terrain classification (Mellgren 1980).



2a: Machine in operation.

2b: Operational setup.

2c: Average slope profile.

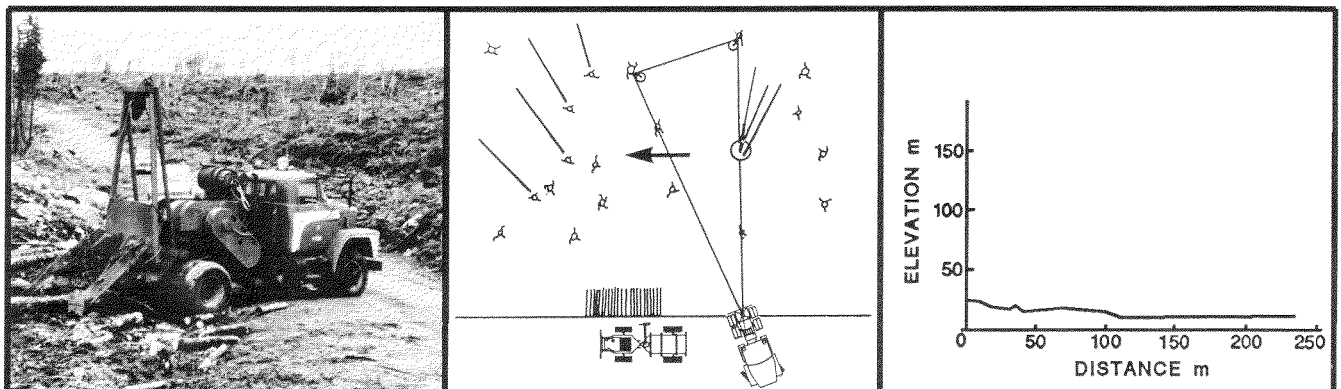
Figure 2. RMS Ecologger, New Brunswick (June, 1990).

The company crew consisted of four workers: an operator, a swing-skidder operator, and two chokersetters who also operated the bulldozer. The chokermen and the yarder operator used a horn for signalling. As the slope was gradually cleared of felled trees from top to bottom, the choker setters would signal to have the skyline lowered, then unlocked the carriage stop and slid it downhill to a new position. This process was repeated until the yarding road was cleared. The bulldozer was then repositioned 30 m across slope and the carriage stop returned to the top of the slope to start a new yarding road.

Gabriel Truck Yarder

The Gabriel truck yarder is a prototype, designed and fabricated by Mr. Mike Gabriel of Stephenville, Newfoundland. The machine was observed on Abitibi-Price Inc.'s Cold Brook timber license, 40 km northeast of Stephenville. Pre-felled and delimbed tree lengths were yarded to roadside then manually bucked into pulpwood and sawlogs.

The yarder consisted of a 1976 Ecologger drumset mounted on a 1969 Dodge truck. Haul-in and haul-back lines were used to run a skid pan and chokers over the logging site. The two lines met at the skid pan and

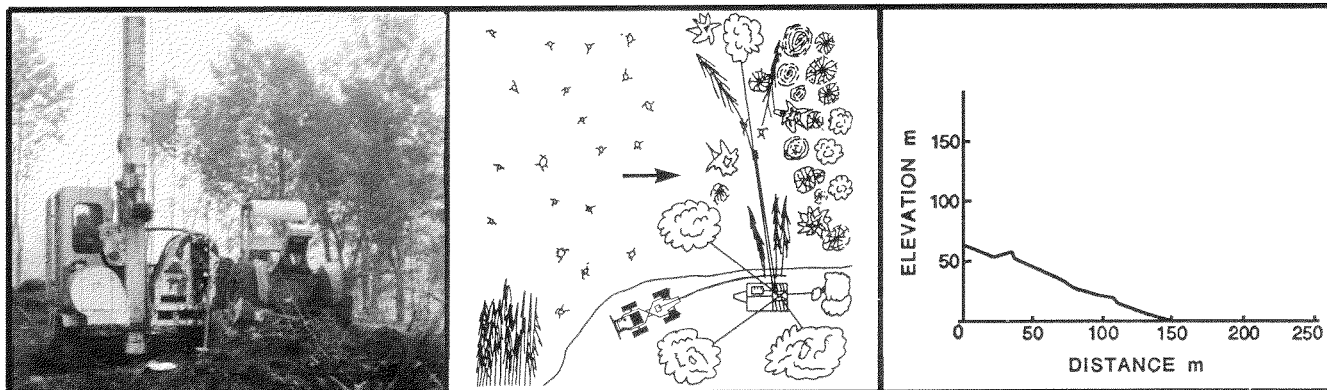


3a: Machine in operation.

3b: Operational setup.

3c: Average slope profile.

Figure 3. Gabriel truck yarder, Newfoundland (June, 1990).



4a: Machine in operation.

4b: Operational setup.

4c: Average slope profile.

Figure 4. Christie yarder, Nova Scotia (July, 1990).

were joined by a butt rigging flying four chokers. The haul-back line was fed through a tail block, and a secondary block provided the bight for lateral skidding.

The study site was a clearcut and was set on relatively flat, but very broken terrain, interspersed with rocky knolls. No pre-choking was done during the study.

The contractor crew consisted of a yarder operator and a chokerman who communicated by radio. The yarder operator also unhooked trees at the landing. The chokerman's job was very physically demanding since he had to pull slack on the complete butt rigging and choker set at every turn. At long yarding distances, the task was further complicated by the weight and friction of the entire length of the haul-in cable. For example, at 150 m from the yarder, an effort comparable to pulling a small car was required, while at 200 m the line set was almost impossible to move.

Christie Yarder

The Christie yarder was owned by Scott Worldwide Inc., in Nova Scotia and operated by a local contractor, Robert Hunt & Sons, in the Brookfield timber license, 25 km from Parrsboro. This tower yarder was guyed by four cables, all anchored to residual mature maples, and was set up on its own landing 40 m from the access road.

This was a "hot-yarding" operation in which full trees were felled, yarded uphill, then cleared and piled by a

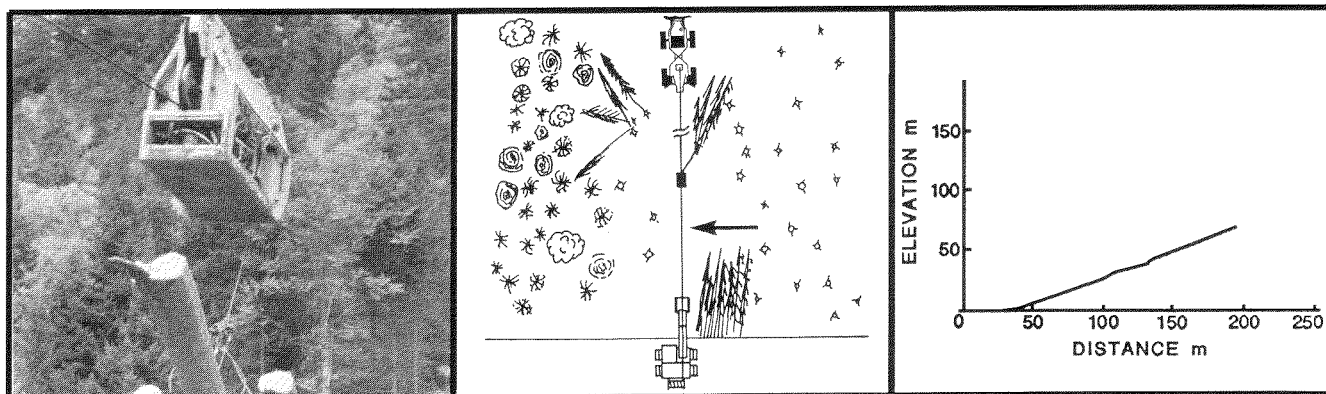
15-year-old Clark 664 swing skidder. The logging site was clearcut, and was located on a slightly convex, steep escarpment. The high quality of the timber gave priority to sawlog production.

The crew consisted of a yarder operator who also unhooked loads and doubled as the skidder operator, a faller-chokerman, and an apprentice (the yarder operator's son) who did not affect productivity. The tailholds for the skyline consisted of large, standing trees. As the operation progressed, the carriage stop was moved down the skyline and upon reaching the tailhold, the skyline was extended downslope and anchored to the next large tree.

TLD Gauthier Télétransporteur

The TLD Gauthier Télétransporteur, a prototype radio-controlled self-propelled carriage, was operated in Université Laval's Montmorency experimental forest, 65 km north of Quebec City. The operation was run by Mr. Daniel Gauthier, a logging contractor and the inventor of the machine. The skyline was anchored by a 1974 John Deere 540 skidder at the top of the slope and a 1972 model 450 Massey Ferguson excavator at the bottom.

This was a "hot-yarding" clearcut operation. Full trees were felled, skidded downhill, and then decked in front of the excavator. When the pile grew too high, the skyline was loosened and the excavator moved a few metres along the roadside. The cutover was conse-



5a: Machine in operation.

5b: Operational setup.

5c: Average slope profile.

Figure 5. Téléransporteur, Quebec (September, 1990).

quently wedge-shaped from bottom to top. The operating conditions ranged from difficult to very difficult especially towards the top of the slope where a blowdown had occurred on a rockfall. The crew consisted of two men: a chaser-carriage operator and a faller-chokerman.

In this system, both crew members can control the carriage. However, if the chaser controls the carriage, it is more efficient for two reasons: the faller uses the time in which the carriage travels to and from the landing to cut the next load of trees; and the faller must continually move uphill to cut or choke the next load, which leaves little energy or patience to spare for the extra task of removing the radio from its carrying case, removing gloves, pushing control buttons, and then putting everything away until the next load.

Smith Timbermaster Trials (1984 - 1985)

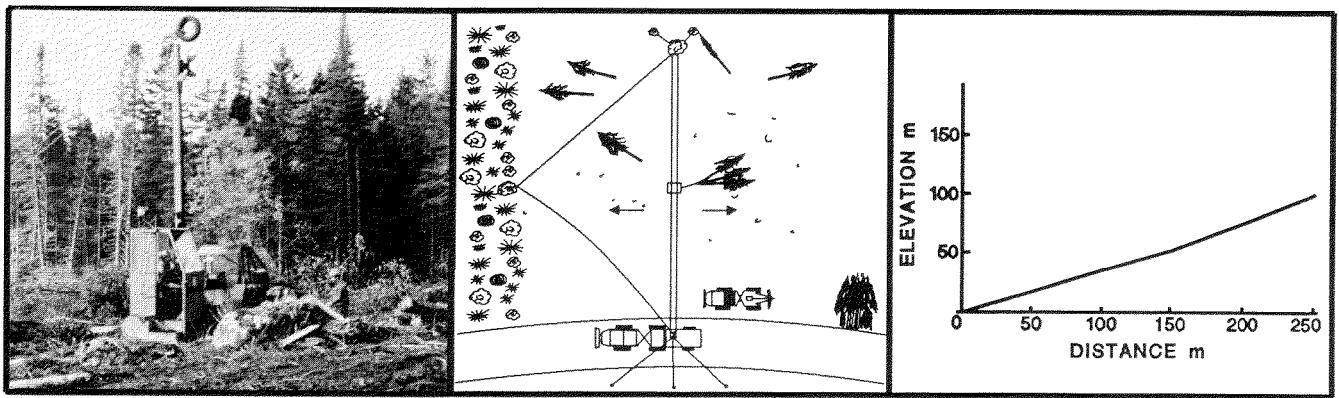
The Smith Timbermaster is a trailer-mounted tower yarder which runs a load-locking carriage on a standing skyline by means of haul-in and haul-back lines. The machine is manufactured in Scotland, and was imported by Highlands Contracting Ltd. in Gander, Newfoundland. There were no Timbermasters operating in eastern Canada during 1990.

Productivity results (Table 2) were obtained during trials run on Rexfor Inc.'s timber limits in Hauterive (1984) and Matane (1985), Quebec, in which two Smith

Timbermasters were operated in parallel. The machines were used on clearcut operations on fairly uniform slopes to yard pre-felled full trees downhill. In both trials, the company crew consisted of four men: a yarder operator, a swing-skidder operator, and two chokermen who generally pre-choked their loads. The swing skidder (Clark grapple skidder) was shared between the two machines. Both yarders were towed by used Timberjack 230 skidders and powered via a PTO therefrom.

Table 2. Smith Timbermaster trial summary (1984-85)

Parameter	Year of study	
	1984	1985
Yarding direction	Downhill	Downhill
Number of cycles	246	122
Average cycle time, min	7.5	5.0
Average volume/tree, m ³	0.28	0.54
Average number of trees/load	3.6	2.2
Average volume/load, m ³	1.0	1.2
Average distance, m	150	70
Average slope, %	51	42
Productivity, m ³ /PMH	8.2	15.0



6a: Machine in operation.

6b: Operational setup.

6c: Average slope profile.

Figure 6. Smith Timbermaster, Quebec (1984-1985).

The yarders were anchored by three guys attached to stumps or occasionally boulders, and the tail block for the skyline was set in a guyed standing tree. In 1984, the yarders were set up at roadside, which limited the manoeuvring and decking area and caused operational delays. In the 1985 trials, the crew was more experienced, and both yarders were set up on purpose-built landings, which consequently reduced delays and increased productivity.

Timing Results

The detailed timing results for each system are presented in Table 3. Differences in the number of timing elements stem from differences in design and mode of operation between the systems.

System Productivity

Figure 7 shows the influence of distance and load size on hourly productivity for each system, while Figure 8 illustrates the effect of average piece size on overall hourly productivity. These curves were developed by running regressions through the timing and volume data. Regression equations and error coefficients are available upon request.

Delay Summary

The complexity of cable logging systems makes them prone to various operational delays. Most notable are yarding road changes, moving carriage stops in gravity-fed systems, moving tail spars, and overcoming hang-ups. Delays are also sometimes inherent to certain systems because of their specific design or configuration. Such was the case with the gravity-fed systems in which carriages were repeatedly slammed into a stop at each outhaul. Resulting damage to internal mechanisms on the Ecologger carriage, and a bent cable guide on the Christie yarder carriage caused major delays during the study. A new and untried radio-control system was the source of several minor delays in the Télétransporteur operation, while tailhold failures caused by small shallow-rooted trees slowed the Gabriel truck yarder. In the latter system, the skid pan and butt-rigging assembly were also responsible for lost time, as they frequently became entangled during outhaul. The Timbermaster operation was slowed by interference from the swing skidder, and by unhooking delays which occurred when chokers released under tension sprang back up and over the mainline or skyline. In such cases, the choker set was freed by climbing the yarder tower or loosening the skyline and lowering the carriage to bring the suspended choker within the chaser's grasp.

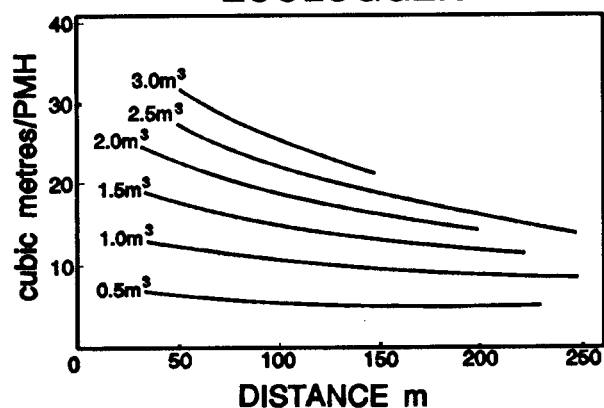
Table 3. Time study results

SYSTEM																
Parameter	Ecologger			Gabriel Truck Yarder			Christie Yarder			Télétransporteur			Timbermaster (1984 & 1985 studies)			
Sample size (cycles)	162			95			151			119			368			
Study duration	15.00 h			9.12 h			15.74 h			15.35 h			40.34 h			
Activities	yarding only			yarding only			felling and yarding			felling and yarding			yarding only			
Yarding direction	uphill			uphill and downhill			uphill			downhill			downhill			
TIMING RESULTS (minutes)																
	avg	S.D.*	%	avg	S.D.	%	avg	S.D.	%	avg	S.D.	%	avg	S.D.	%	
Outhaul	0.41	0.22	7	0.87	0.32	15	0.26	0.10	4	0.87	0.43	11	0.39	0.38	6	
Walk mainline (winch out)	0.90	0.51	16	1.34	0.71	23	0.82	0.53	13	0.88	0.29	11	1.75	0.80	27	
Choke	0.48	0.54	9	0.89	0.66	15	0.41	0.41	7	1.79	1.17	23	1.12	0.60	17	
Clear line	0.25	0.22	5	0.20	0.17	4	0.23	0.14	4	0.06	0.12	1	----	----	----	
Winch in	----	----	----	----	----	----	----	----	----	1.11	0.43	15	----	----	----	
Inhaul	1.11	0.58	20	1.15	0.50	20	1.28	0.43	20	0.88	0.52	11	0.59	0.62	9	
Deck	0.34	0.20	6	----	----	----	----	----	----	----	----	----	0.12	0.06	2	
Unhook	0.61	0.44	11	0.62	0.33	11	0.81	0.61	13	0.93	0.53	12	1.57	0.70	24	
Delay	1.46	2.51	27	0.69	1.88	12	2.45	3.39	39	1.22	2.91	16	0.98	2.25	15	
Cycle time	5.56	3.29	100	5.76	2.90	100	6.26	3.83	100	7.74	4.33	100	6.52	3.08	100	
YARDING CONDITIONS																
	avg	max.	min.	avg	max.	min.	avg	max.	min.	avg	max.	min.	avg.	max.	min.	
Stems / load	2.9	7	1	2.2	5	1	1.3	3	1	3.9	7	1	3.06	6	1	
Volume / load, m ³	0.97	2.98	0.1	0.35	1.17	0.05	0.63	1.83	0.05	0.83	2.95	0.08	1.08	2.41	0.14	
Distance, m	127	277	20	99	236	10	80	145	33	104	260	20	124	241	10	
Slope, %	37%	53%	15%	22%	46%	2%	51%	101%	8%	46%	86%	3%	47%	67%	27%	
PRODUCTIVITY																
Trees / PMH	33			23			12			30			24			
m ³ / PMH	10.6			3.7			6.0			6.5			9.8			
m ³ / worker-hour	2.6			1.8			3.0**			3.2**			2.8			

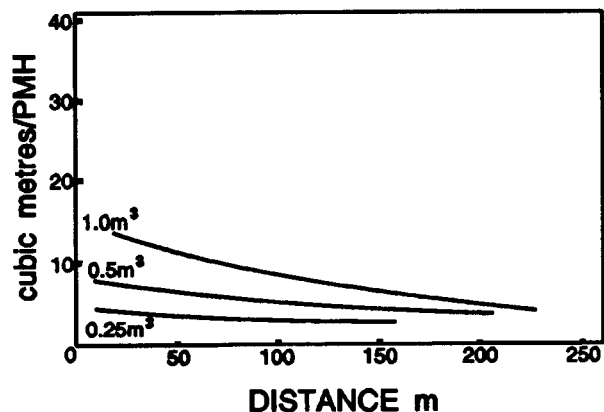
* S.D. = Standard deviation

** Includes felling.

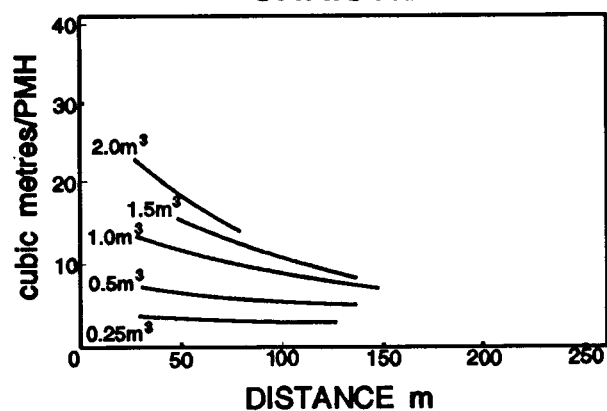
ECOLOGGER



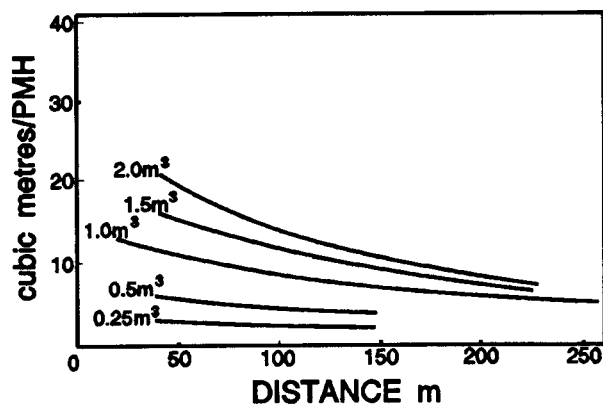
GABRIEL



CHRISTIE



TELETRANSPORTEUR



TIMBERMASTER

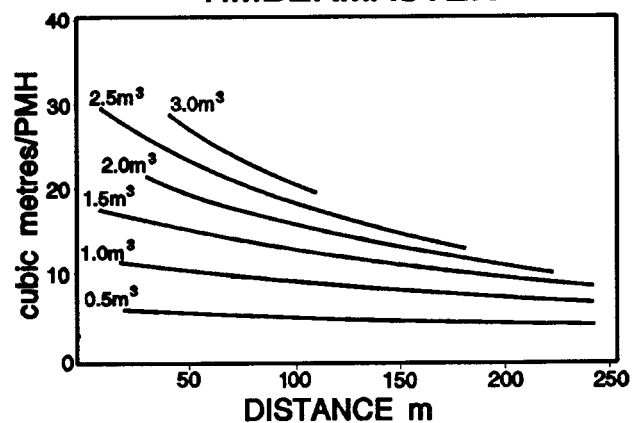


Figure 7. Effect of distance and load size on productivity

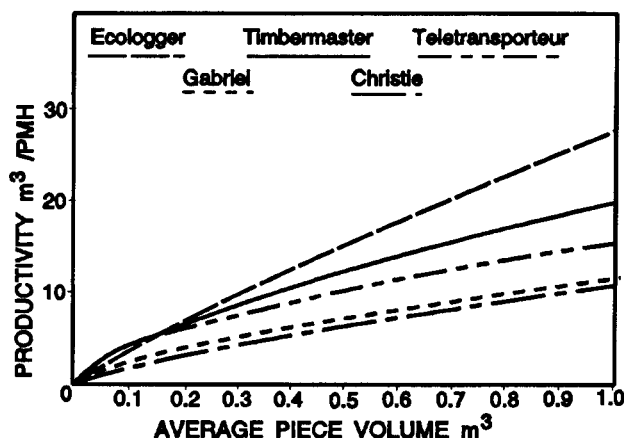


Figure 8. Effect of average piece size on overall productivity

Direct Costs Analysis

The *direct* owning and operating costs of the systems as studied were analyzed according to the Canadian Pulp and Paper Association's McNally revised costing method (Rickards et al. 1983). To compare the systems on the same basis, all indirect costs (supervision, road construction, ancillary support) were *omitted*, and operating cost inputs such as wages and fuel costs were normalized. Capital costs for the yarders are based on 1990 prices, or estimates thereof, while realistic used-equipment estimates were input for the support machines. The reader is cautioned that the costs presented are based on short-term studies and are specific to the operations as studied. As such, they should only be used elsewhere with due caution.

Details and results are given in Table 4.

Discussion

The **productivity curves** developed for different load volumes and distances (Figure 7) provide valuable insight as to the potential of the systems. An important

trend shown is that as yarding distance increases, productivity levels out, independently of the load volume. Thus, attempting to yard large loads over long distances does little to increase productivity, whereas substantial gains in productivity are achieved by yarding large volumes over short distances. This is because an increase in load size corresponds to an increase in the probability of "hang-up" delays. The problem worsens with increased distance, since lift is inversely proportional to the distance from the yarder. Load size should therefore be reduced on long hauls, and maximized on short hauls. This should not only maintain productivity, but should also limit equipment wear and tear by reducing the risk of shock loading caused by hang-ups.

Combined felling and yarding costs per cubic metre were calculated using the productivity figures observed during the study and the *normalized* owning and operating cost for each system. The highest cost came from the Christie yarder at \$27.92/m³, while the lowest was with the Télétransporteur at \$20.69/m³. Wood harvested with the Gabriel truck yarder cost \$27.79/m³, the Smith Timbermaster came in at \$21.20/m³, while the Ecologger produced wood for \$26.20/m³. The reader is cautioned that these costs should *not* be used for comparisons because of differences in site and operating conditions, crew experience, and system configuration between the respective operations. Instead, the costs are presented *solely* as an indication of the order-of-magnitude production costs under the given operating conditions, the suitability of the systems to these conditions, and the economics of using *new* yarders for such operations. It is interesting to note that although the Gabriel truck yarder is the most affordable system per hour, difficult site conditions and its physically-demanding mode of operation gave it the lowest productivity and the second highest wood costs.

Per-worker productivity, defined here as the hourly productivity divided by the size of the crew, was highest with the Télétransporteur (3.2 m³/PMH), and the Christie yarder (3.0 m³/PMH), both "hot-yarding" operations. Productivity increases of 5% to 15% have been reported in the past for cable systems where "hot-yarding" was practised (Putnam et al. 1984). A possible explanation for this is that although the faller must do two jobs at once, choking the trees is much easier because the location of ground obstacles and felled trees is already known. In comparison, a choker-man working on a pre-felled site must often crawl over tops and branches to reach the next tree, and can seldom see ground obstacles through the thick mat of residues.

Table 4. Direct cost analysis (for additional technical specifications see Appendix 2)

Parameter	SYSTEM				
	Ecologger	Gabriel Truck Yarder	Christie Yarder	Télétransporteur	Timbermaster
Machine life, years	20	10	10	5	10
Scheduled machine hours, h/yr	1 100	1 100	1 100	1 100	1 100
Purchase price, \$	175 000	80 000	90 000	77 000	80 000
Salvage value, \$	17 500	8 000	9 000	7 700	8 000
Insurance cost, \$/yr	5 250	2 400	2 700	2 310	2 400
Interest rate, %	16	16	16	16	16
Utilization, %	60	70	60	70	50
Repair and maintenance, \$/life	\$175 000	80 000	90 000	77 000	80 000
Fuel consumption, L/PMH	8.4	7.4	1.3 *	6.3	5.0
Fuel price, \$/L	0.55 (diesel)	0.65 (gasoline)	0.55 (diesel)	0.55 (diesel)	0.55 (diesel)
Lubricants, \$/PMH	1.85	0.18	4.26 *	0.55	0.19
Cable cost, \$/cable	2 000	2 000	2 000	2 000	2 000
Cable life, h	2 200	2 200	2 200	2 200	2 200
Number of cables	2	2	2	1	3
Machine operator wage, \$/h	19.50	19.50	19.50	19.50	19.50
Assistant wage, \$/h	17.55	17.55	17.55	17.55	17.55
Number of assistants	3	1	1	1	2
Yarder cost/PMH, \$	196.52	94.51	114.45	109.81	164.83
Support equipment cost					
Skidders, \$/PMH	49.81	N/A **	49.81	5.87 ***	43.76
Bulldozers, \$/PMH	6.34	N/A	N/A	N/A	N/A
Excavators, \$/PMH	N/A	N/A	N/A	15.51	N/A
Chain saws, \$/PMH	included in felling cost	included in felling cost	3.31	3.31	N/A
Total equipment cost/PMH, \$	252.67	94.51	167.57	134.50	208.59
Total cost per PMH, \$	252.67 + felling cost **** 94.51 + felling cost		166.06 (felling included)	134.50 (felling included)	208.59 + felling cost

* Contractor's estimate.

** N/A = not applicable.

*** Cost for unmanned used skidder used solely as an anchor.

**** Felling cost projected at \$2.25/m³ where applicable.

Productivity is also a function of a machine's design and inherent capabilities. This relationship is illustrated in Figure 8 which shows the effect of average piece size on overall productivity. A more powerful machine like the Ecologger can make substantial gains in productivity as average piece size increases. The fact that the Ecologger was under-utilized by hauling "small" trees partly explains its high cost per cubic metre during the study. Although less powerful, the Timbermaster and the Télérporteur combined high lift with downhill skidding, and thus could also achieve a sizeable increase in productivity with increasing piece size. The Gabriel and Christie yarders had less power and lift, and did not achieve comparable gains in productivity as piece size increased.

Crew size also affects the economics of cable logging. Two-person crews have been found to be optimal for small-wood cable logging (Olsen 1981). The reasons cited are that as extra persons are added to a crew, it becomes increasingly difficult to achieve proportional economies in cycle times, which results in a higher final cost. Large crews were responsible for the high cost per cubic metre in the Ecologger and Smith Timbermaster operations, although these systems achieved the best productivities.

Because cable logging is physically more demanding than conventional logging, safety and crew motivation are prime concerns. **Safety is particularly important** as workers must work on slopes in close proximity to moving cables and logs. Equipment-related injuries can be minimized however, by maintaining proper communications between crew members. Another safety concern is strain-related injuries, of which there is a great risk in a system such as the Gabriel truck yarder, where both the chokerman and the operator perform physically-demanding tasks. The chokerman must pull slack from the haul-in cable at every turn while the operator must often lift the skid pan to unhook the load. These tasks present risks of muscle injuries.

Mechanical reliability was not a major problem with any of the systems studied. The Ecologger experienced drum brake and carriage lock problems, while the Christie yarder experienced cable guide roller problems which caused the carriage to fall off the skyline. In both cases, causes of carriage problems were probably operator-related, as they always allowed the carriages to hit the stop at maximum speed, regardless of slope or distance. The Timbermaster suffered mostly from cable-related repairs resulting from the operators' use of excessive force during breakout. The

Télérporteur, which is a prototype, suffered from remote-control problems caused by under-designed circuitry and overloaded transistors. The Gabriel truck yarder, also a prototype, had one major repair resulting from broken splines on the drumset's main shaft.

Anchoring is an important factor for systems operating in eastern Canada, as large stumps are rare and soils are often shallow. A system which utilizes guylines can therefore be at a disadvantage, especially if frequent moves are necessary. The time required to set up and take down these systems can consume precious operating hours. The Gabriel truck yarder and the Télérporteur (both unguyed) thus provide advantages in situations where proper anchoring cannot be found or where frequent moves are necessary.

Planning is probably the single most important aspect of cable logging operations. It is not enough to simply trace cutblock boundaries and identify riparian strips. The cable logging planner must know the site's topography well enough to locate deflection lines that maximize lift, must plan landings, identify potential anchor trees, know the direction of prevailing winds, and most of all, must know the crew and the equipment (Garrison 1976). Deficiencies in planning were observed during the study and one of particular interest was the failure to recognize the direction of prevailing winds in one operation. Although hardly perceptible, most of the trees in the cutblock leaned to one side. Because the logging operation also progressed in the same direction as the lean, most of the cut trees fell back into the standing timber. This caused many tops to break off when the stems were extricated from the remaining stand. Another case-in-point is the Timbermaster operation where productivity rose from 8.2 m³/PMH to 15.0 m³/PMH between 1984 and 1985. Although the increase was partly due to greater piece size and shorter distances, better planning (purpose-built landings) contributed greatly to this productivity gain.

A positive aspect which was noticeable for all the systems observed was their **limited site disturbance**. Unlike conventional ground-based systems, no tire ruts were made on the logging sites, and only negligible scalping of the humus layer. This was especially true of the Télérporteur which requires high lift to operate. Although the Ecologger and Christie machines skid uphill and consequently develop less lift, their site disturbance was still much lower than that caused by ground-based systems.

Table 5. Comparative advantages and disadvantages

Parameter	SYSTEM				
	Ecologger	Gabriel Truck Yarder	Christie Yarder	Télétransporteur	Smith Timbermaster
Purchase price	High	Low	Moderate	Moderate	Moderate
Labour requirement	High	Moderate	Low	Low	High
Labour intensity	Moderate	High	Moderate	Moderate - High	Moderate
Mobility	Moderate - Low	High	Low	High	Low
Operating cost	High	Low	Moderate	Low	High
Power output	High	Moderate	Moderate	Low	Moderate
Fuel consumption	High	High	Low	Moderate	Moderate - Low
Decking capacity	Moderate	Limited	Moderate	Good	Moderate
Comments	Expensive to operate, high power output.	Very affordable, but low productivity because highly labour intensive.	Very efficient, low fuel consumption. Sometimes insufficient power.	Also good for thinning work, efficient and mobile. Low power and limited to downhill logging.	Very productive once set up. Good speed and power. High labour costs.

The comparative advantages and disadvantages of the systems studied are presented in Table 5. The authors' qualitative comparison is based on eight parameters which influence operational efficiency and harvesting costs.

Conclusions

This study has demonstrated that cable logging systems currently operating in eastern Canada show their highest potential productivity when hauling large volumes over short distances. More importantly, it was also shown that as distances increase, the law of diminishing returns sets in, offsetting possible gains in overall productivity from increases in load volume.

An economic analysis has indicated that *in the conditions encountered* during the studies, *direct* production

costs ranged from \$20.69/m³ to \$27.79/m³. Although it has a low owning and operating cost, the Gabriel truck yarder had low productivity and a high cost per cubic metre, while the Télétransporteur had the lowest cost per cubic metre. This analysis reflected the suitability of the systems to their operating environments and the economics involved if new yarders are used.

Profitable cable logging operations can be carried out in eastern Canada if they are properly planned, conducted with systems that are mobile, and adapted to the operating environment. While direct logging costs will generally prove somewhat higher than for ground-based systems, economic advantages may be realized through the potential for harvesting higher-value timber located closer to the mills, and through environmental benefits. "Hot-yarding" has been shown to be an effective way to harvest steep slopes, providing that the crew is well trained and motivated.

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Appendix 1

Glossary of Cable Logging Terms

Bight: the middle part of a slack rope or a loop or bend in a rope. A rope under tension will spring back towards the bight area.

Butt rigging: a system of swivels and clevises which connect the haulback and main lines (haul-in) and to which chokers are fastened.

Carriage: a load carrying device from which logs are suspended. The carriage rides up and down the skyline on sheaves during its operation.

Carriage stop: a device which locks in a fixed position and stops the progression of a carriage along the skyline.

Chaser: a person who unhooks chokers from logs or trees at the landing.

Deflection: the vertical distance between the chord of a skyline and itself. This distance usually measured at midspan of the skyline.

Guyline: a wire rope used to brace or steady a structure.

Gravity-fed carriage: a carriage which depends on the force of gravity for downhill travel or outhaul.

Haul back line: a wire rope used to pull back the main line with carriage or butt rigging to the yarding site for the next load.

Haul-in line: see main line.

Highlead system: a cable yarding system which provides lift through lead blocks suspended on a tower or spar.

Hot-yarding: a cable logging operation in which the trees are sequentially felled and yarded during the same work cycle.

Jammer: a lightweight ground-lead yarder usually mounted on a truck with a spar and boom.

Lateral yarding: any movement of logs towards the center of the yarding road or cableway.

Main line: the cable used to haul logs to the landing. (Also called haul-in line in eastern Canada).

Skyline: a cableway stretched between two points and used as a track for a block or carriage.

Spar: a tree or mast used to support rigging for one of the cables used in a yarding operation.

Standing skyline: a fixed skyline not running during yarding operations.

Swing skidder: a skidder used to move logs or trees away from a landing to a distant pile or deck.

Tail block: a block at the back of the yarding area or on the spar which is used to guide the haulback line.

Yarding road: the path followed by a load of logs or trees skidded or yarded by a cable system.

Appendix 2

Equipment Specifications¹

SYSTEM	Christie	Ecologger	Gabriel	Smith Timbermaster	Télétransporteur
GENERAL					
Operating range	~ 250 m	~ 300 m	~ 350 m	~ 450 m	~ 200 m
Crew size	2	4	2	3½	2
Carrier	Trailer mounted	Tree Farmer C7	Truck mounted	Trailer mounted	---
Gross weight	5 000 kg	14 100 kg	N/A	N/A	1 020 kg
Powerplant	57 kW	97 kW	N/A	60 kW (PTO)	21 kW
Development	Commercial	Commercial	Prototype	Commercial	Prototype
TOWER					
Height	9 m	12.8 m	4 m	7.3 m	5 m
Guylines	3	4	0 (outriggers)	3	0 (excavator)
Tail spar	tree or stump	tree or stump	stump	tree	skidder
CABLE SIZES					
Skyline	16 mm	19 mm or 22 mm	---	13 mm	19 mm
Haul-in	14 mm	19 mm	19 mm	9 mm	10 mm **
Haul-back	11 mm	14 mm	14 mm	9 mm	---
Guylines	14 mm	19 mm	---	13 mm	---
OPERATING SPEEDS					
Haul-in	6.6 m/s	5 m/s	5 m/s	6.3 m/s	1.2→2.0 m/s *
Haul-back	6.6 m/s	5 m/s	5 m/s	4.2 m/s	2.0 m/s *
MAXIMUM LINE PULLS					
Skyline	10 000 kg	19 000 kg	---	N/A	5 600 kg
Haul-in	9 000 kg	13 600 kg	13 600 kg	2 000 kg	2 700 kg **
Haul-back	9 000 kg	13 600 kg	13 600 kg	N/A	N/A
Load capacity	N/A	N/A	N/A	1 500 kg	2 700 kg
CARRIAGE					
Make	Christie	Christie	---	Smith	Télétransporteur
Weight	200 kg	N/A	---	N/A	1 020 kg
Power	---	---	---	---	21 kW
SUPPORT EQUIPMENT					
Type	Skidder	Skidder	---	Skidder	Excavator and skidder
Remote controls	None	Yes, partly	None	None	Yes, fully

¹ These specifications are for systems as they are currently being used in eastern Canadian operations. Specifications may have changed for more recent models of the commercially-available machines and the reader is asked to contact the manufacturer to obtain this information.

N/A Not available.

* Carriage drive.

** Carriage winch.