Adverse Skidding Using a Tigercat 635E Assisted by a T-Winch 10.1

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Vladimir Strimbu, Researcher, Fibre Supply
Brian Boswell , Senior Researcher, Fibre Supply

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Abstract

This paper presents the productivity and utilization of a system comprising a skidder and an assisting self-propelled winch working on steep terrain. Environmental impact is also assessed for both conventional and winch-assisted skidding.

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Reviewers

Colin Koszman, Industry Advisor

Peter Dyson, Researcher, Fibre Supply

Dzhamal Amishev, Researcher, Fibre Supply

Jim Hunt, Research leader, Fibre Supply

Contact

Vladimir Strimbu
Researcher, Fibre Supply
(604) 222-5746
vladimr.strimbu@fpinnovations.ca

Table of contents

List of figures

List of tables

Introduction

The timber supply profile in western Canada is changing toward an increasing proportion of volume coming from steep slopes. Steep-slope harvesting often requires hand felling, and cable yarding or helicopter, but these are more expensive and hazardous compared to mechanized, ground-based harvesting systems. Winch-assist technologies are enabling harvesting of steep slopes by ground-based equipment. This technology shows potential for improving safety and increasing productivity compared to hand felling and cable yarding. Winch-assist systems have been used for many years in Europe, South America, and New Zealand. Many of these systems have recently been introduced for harvesting steep slopes in western Canada.

McGlynn Contracting, based in Grande Prairie, Alberta, is using a T-Winch 10.1 to assist a Tigercat 635E skidder. This report presents the results of two scenarios comparing the Tigercat's productivity and its associated soil disturbance. In the first scenario, the Tigercat was assisted by the T-Winch, and in the second it was unassisted. The utilization of the Tigercat was also assessed over a one-month period.

Objectives

The study objectives were to:

- Compare productivity of the Tigercat 635E skidder with and without assistance by a T-Winch.
- Measure soil disturbance caused by the Tigercat when assisted and unassisted.
- Document the T-Winch operating techniques, identifying advantages and disadvantages of the system.

Methodology

Detailed timing was used to determine the productive machine hours (PMH) of the skidder and the cycle time elements. The number of stems per load, skidding distance, and slope was recorded for each cycle. Detailed timing was conducted in one sample polygon for each scenario (Figures 1 and 2). A sample of the skidded stems was scaled at the roadside to calculate an average stem volume. The skidded volume was determined by multiplying the number of stems skidded by the average stem volume. The volume was divided by PMH to determine skidder productivity (m^3/PMH). Skidder productivity was standardized to account for the varying distances and slopes in the two scenarios. A multiple regression equation was generated for each scenario using the 167 productivity data points compiled through detailed timing. Next, a combined average skidding distance and average slope were calculated for the whole study area. Standardized productivities of both conventional skidding (CS) and winch-assisted skidding (WS) scenarios under average study conditions were then modelled.

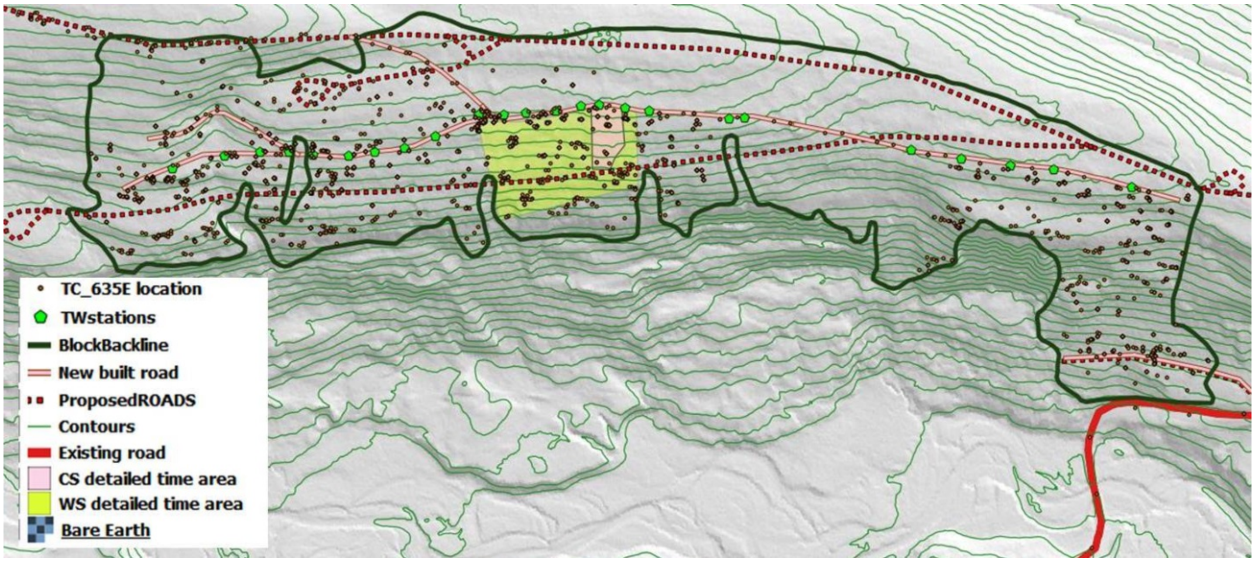

Figure 1. Overall block map and detailed time study polygons.

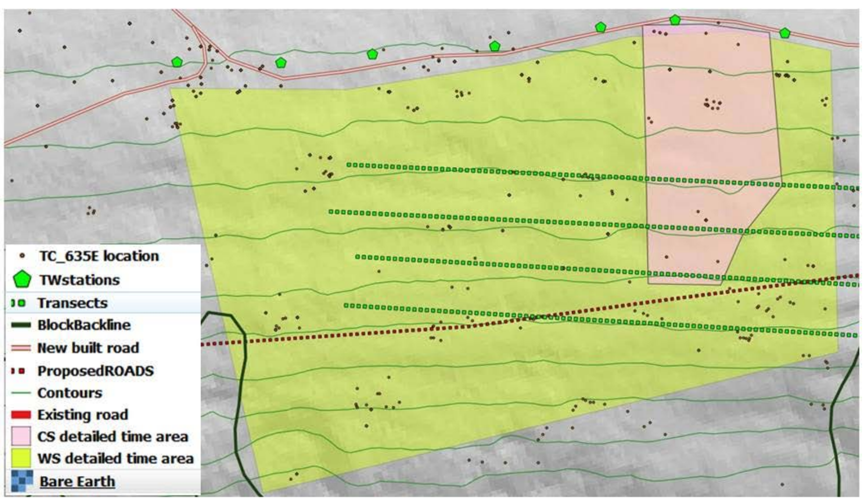

Figure 2. Zoomed-in block map showing detailed time polygons, site disturbance assessment transects and the T-winch set up locations.

MultiDAT units with GPS receivers were installed in the T-Winch and the Tigercat to determine machine utilization (Figure 3). In addition to detailed timing, a shift-level study was conducted to calculate the productivity of the WS system. PMH recorded from August 4th to September 3rd by MultiDAT onboard recorders and merchantable volume at the scale point were used.

Figure 3. MultiDAT data logger installed in the Tigercat cab.

A site disturbance methodology, unique to this study, was developed based on B.C.'s Forest Practices Code (B.C. Ministry of Forests, 2001) and the U.S. Department of Agriculture's Forest Soil Disturbance Monitoring Protocol (Page-Dumroese, Abbott, & Rice, 2009). The Forest Practices Code soil disturbance categories were used, but a minimum size of countable disturbed areas was not considered; therefore, all disturbances were recorded, regardless of size. A survey point was defined as a 15 cm diameter circular area around the end of researcher's toe (the definition used in the Forest Soil Disturbance Monitoring Protocol). Four transect lines were established perpendicular to the main skidding direction, spaced 20 m apart (Figures 1 and 2). Survey points were established along each transect, at 5 m intervals, and site disturbance was assessed. One hundred seventy-three assessment points were completed in the WS treatment and 39 in the CS.

Site, equipment, and operating method

The 63.9 ha cutblock was approximately 2 km long and varied in width from 200 to 400 m. A flat ridge marked the upper boundary of the cutblock, and a creek delineated the bottom boundary (Figure 4).

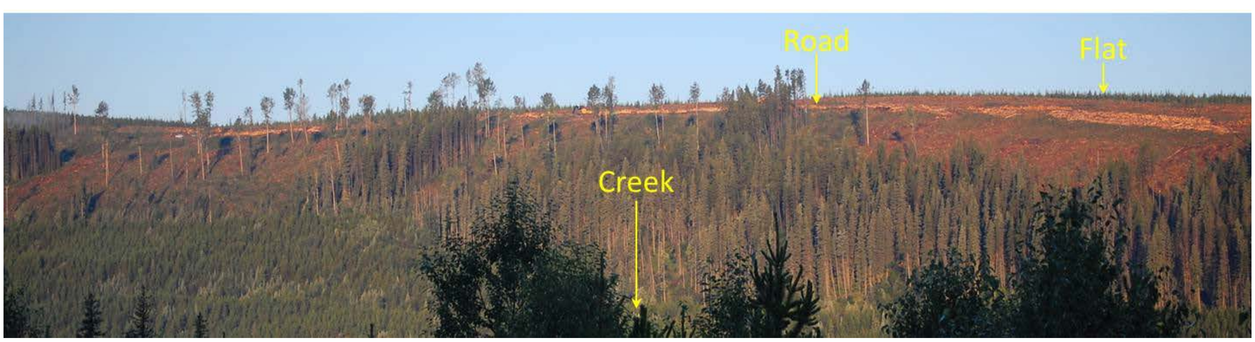

Figure 4. View of the cutblock, showing the main in-block road along the slope breaking line.

The steep area starts at the edge of the plateau and becomes steeper along the creek. The main road was built on the top of the plateau (Figures 1 and 4). In the study area, the slope averaged 26% across a benched profile, with pitches of up to 61%. The average elevation was 1250 m; the substrate constitution was heavy clay soil, which significantly limited the operation or caused it to shut down during wet conditions. The stand was mainly lodgepole pine and spruce, with a total merchantable volume of 19 478 m^3, according to the scale, with an average volume of 304.8 m^3/ha. Based on researchers' measurements, the average piece size would yield 0.442 m^3 in merchantable volume.

Trees were felled by a Tigercat 870L feller buncher and skidded to the roadside by a Tigercat 635E skidder (Figure 5). At the roadside, the trees were processed by either an Eltec FH277L, equipped with a Southstar QS600 processing head, or a Hyundai HX330, equipped with a Southstar QS630 processing head. A Caterpillar 568LL log loader equipped with a heel-boom grapple acted as a decking machine for the skidder (Figure 6). Once a turn was landed at the roadside, the log loader decked the skidded logs, allowing the skidder to immediately leave for another turn.

Figure 5. Adverse skidding of the Tigercat 635E.

Figure 6. Caterpillar 568LL log loader assisting the Tigercat 635E skidder at the roadside.

On steep terrain, the skidder was assisted by a T-Winch 10.1. The T-Winch is a remotely operated, tracked machine that provides traction assistance to harvesting machines through a single-cable winch system (Figure 7).

Figure 7. T-Winch 10.1 set above the main road.

The T-Winch can be controlled remotely using a handheld control box that allows tension adjustment and machine movement (Figure 8). T-Winch specifications are listed in Table 1. Further information and specifications can be found at www.ecoforst.at/ .

Figure 8. Skidder operator remote control (*left*) and the additional control module (orange box) (*right*).

Table 1. T-Winch specifications

Technical specification	
Weight (kg)	7050–7800
Engine power (kW)	107
Fuel tank (L)	280
Maximum winch pulling force (tonnes)	8.0
Maximum winch speed (km/h)	4.0
Rope diameter (mm)	18.5
Rope length (m)	500

The skidder working pattern always skids loads front-forward uphill and reverses empty downhill. The T-Winch cable attaches to the front of the skidder, below the dozer blade (Figure 9), and the winch automatically keeps the cable tension at a pre-set value. When the skidder drags a load uphill, the tension is changed to a higher value to help traction, and when the skidder backs down empty, the cable is released from the winch at a lower tension value.

Figure 9. T-Winch cable attached to the skidder body. The wire rope was attached through a double-chain system using a wedged socket and shackles.

The contractor has used a 30-tonne excavator with a boom-attached block that enables a cable to run from the T-Winch to the Tigercat skidder (Figure 10). This system provides an additional anchor support to the T-Winch and reduces the time required when changing the skidding corridor, but the contractor did not use this system during the study.

Figure 10. Excavator assistance for T-Winch. (Photo courtesy of McGlynn contracting.)

The wood bunched on the plateau was skidded without winch assistance. On the slope, the typical work pattern was adverse skidding, with the T-Winch assisting the skidder (WS). For comparison, a small area on the slope was conventionally adverse-skidded without winch assistance (CS). The T-Winch 10.1 was always installed on the main road facing down the slope during the study. The total length of the winch rope was about 265 m.

Results

Productivity comparison

The standardized CS and WS productivity was very similar, at 80.6 m^3/PMH and 81.3 m^3/PMH, respectively, when the skidding distance was 75 m and the slope was 17% (the average study conditions) (Table 2).

Table 2. CS and WS working parameters and standardized productivity

Skidding system	Average skidding distance (m)[a]	Slope (%)	Average load (m^3)	Cycle time (min)		Speed (km/h)		Standardized productivity[a] (m^3/PMH)
				Total	Road change (min/cycle)	Empty	Loaded	
CS	59	15	4.6	3.4	0	3.6	2.2	80.6
WS	90	19	5.7	4.6	1.1	4.9	3	81.3

[a] Standardized for average study conditions: Skidding distance (75 m) and slope (17%)

However, at a 100 m skidding distance and 30% slope, the standardized productivity for WS was much higher, at 69.4 m^3/PMH, than CS, at 40.9 m^3/PMH.

Even though the slope was steeper in the WS system, the average load was 24% larger than in the CS system. This is explained by the fact that winch assistance provided extra power and traction, which allowed larger adverse skidding loads. Despite the steeper terrain, the average speed was also higher in the WS system. The average time to change roads or reset the T-Winch was 21.6 minutes per setting, for a frequency of one change or reset every 87 minutes, or once every 19 cycles. The time to change roads shown in Table 2 was prorated at 1.1 minutes per cycle. The average distance between two T-Winch settings was 42 m. On steeper terrain, that distance decreases due to the limited side-hill manoeuvering capability of the skidder, which limits the lateral reach of the system.

The detailed timing results are presented in Table 3, and the work cycle and cycle time elements are summarized in Figure 11.

Table 3. Detailed timing summary

Description	CS	WS
Sample size (PMH)	1.5	8.7
Total cycles (no.)	27	112
Total trees (no.)	278	1421
Total volume (m^3)	122.8	627.5
Productivity		
Cycles/PMH	17.8	12.9
Trees/PMH	185	163
m^3/PMH	81.9	72.1

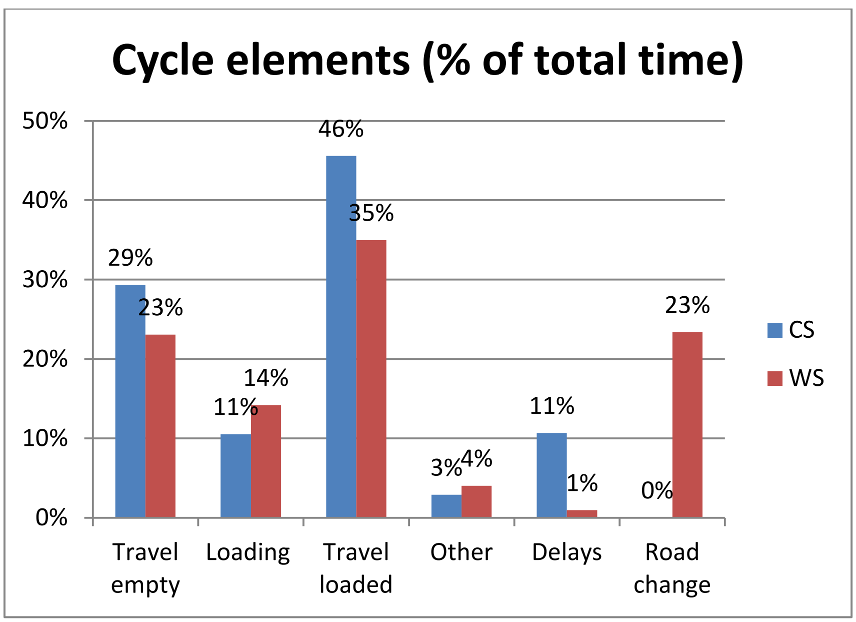

Figure 11. Work cycle elements by skidding system.

When productivity points, calculated through detailed timing, are plotted against the two main variables (i.e., slope and distance), clear trends are noticeable (Figure 12). At about 70 m skidding distance, productivity was similar in both systems. For shorter skidding distances, the WS system was less productive mainly due to the time taken for resetting the T-Winch. At a longer distance, longer cycle times were observed, and the proportion of road change time per cycle decreased. This factor, combined with longer skidding distances into steeper terrain, was a disadvantage in the CS system, resulting in the WS system being more productive than the CS system when the skidding distance was longer than 70 m.

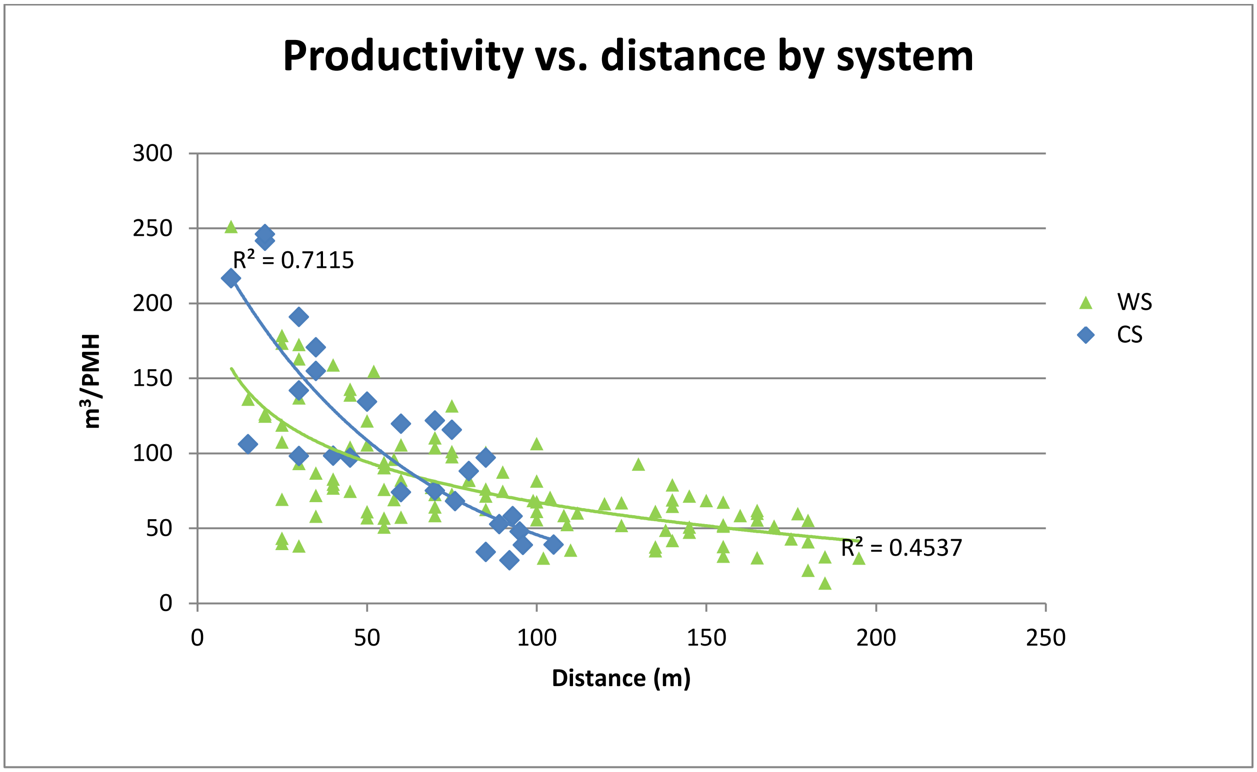

Figure 12. Productivity plotted against distance by skidding system.

Figure 13 shows that productivity was sensitive to slope in both skidding systems. As expected, CS productivity was more sensitive to high slopes than WS productivity. The equivalence point was around 18%; above this slope value, WS productivity became progressively higher than CS productivity.

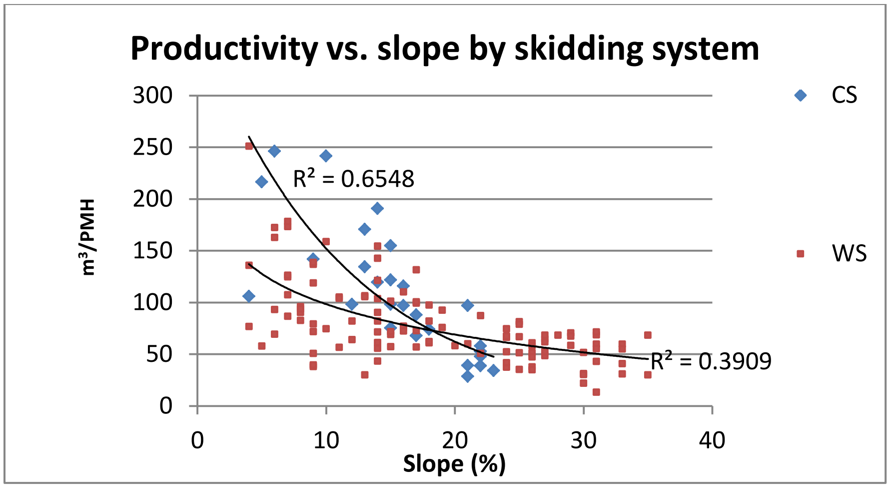

Figure 13. Productivity plotted against slope by skidding system.

The combined skidder utilization in both CS and WS systems over the one month time period was 76%. Skidder utilization on flat terrain (CS) was 79%, while on steep terrain (WS) utilization was 71%. This difference could be explained mainly by long idling intervals during T-Winch setting during each road change. Except for a cable break, which occurred once over the week-long detailed time study, no other mechanical delays specific to the WS system were identified. For one cable repair, the delay time recorded was 34 minutes.

The WS system's productivity calculated through the shift-level study was 73.6 m^3/PMH while working on an average slope of 33% and at an average skidding distance of 86 m. The detailed timing–based model applied to the same working conditions generates a productivity value of 73.8 m^3/PMH.

Site disturbance

All disturbed areas, including very small ones, were counted, which resulted in a disturbance proportion higher than if the method in B.C.'s Forest Practices Code had been used. The disturbance levels were not calculated to assess compliance with prescribed limits, but rather to compare the WS and CS systems. Counted disturbance in the CS area was 8.4% higher than in the WS area (Table 4). Comparing the lower limits, after applying calculated confidence intervals, the difference was 6.0%. The average slope of the disturbance survey area was 26%, which is similar to the average slope of the whole block.

Table 4. Disturbance by skidding system[a]

	CS	WS
C/T (%)	33.3	24.9
CI (%)	6.6	4.2
Lower limit (%)	26.7	20.7

[a] C, Counted disturbance; CI, Confidence interval; T, Total points surveyed

Over half of the disturbance in the CS area was gouges (54%), whereas gouges accounted for less than 23% in the WS area (Table 5). No noticeable trails (dispersed compaction) were recorded in the CS area.

Table 5. Disturbance type (as a percentage of total counted disturbance)

Disturbance category	CS	WS
Gouges (%)	54	23
Scalps (%)	8	26
Ruts (%)	38	26
Trails (%)	0	25

Road density analysis

One potential significant impact of the WS system on overall logging cost is that fewer roads are needed than with traditional cable yarding. Assessing savings on road construction would be a useful objective for future work. In Figure 1, the two main roads planned to be built (3.4 km long) are marked by dotted red lines. One single road 2.4 km long was built instead (pink line), placed somewhere between the two planned road locations. The WS system required 36% less road length to be built. The potential of increasing road spacing is even higher on sites with longer average skidding distances, since the maximum skidding length in the study block was about 230 m, while the standard rope length is 500 m.

Discussion

Although the T-Winch is a relatively light (7 tonnes) and small piece of equipment, most of the time it was able to provide enough pulling power and speed for the 22-tonne Tigercat 635E skidder. Since the average slope was moderate over the whole area, the stability of the T-Winch was adequate without a need to anchor it to stumps, trees, a deadman, or any piece of equipment. This significantly reduced road change time. On steeper terrain, or when a heavier piece of equipment is to be assisted, the pulley excavator would help the T-Winch to remain stable. At higher slopes, lateral stability is also challenged, when a large skidder offset occurs or when the skidder operator uses stumps as “corner blocks” to help widen the lateral reach. Serving as a heavier anchoring point, the excavator allows a longer distance between two corridors due to a larger offset angle allowance for the skidder. The higher position of the pulley also keeps the cable elevated, resulting in a longer cable lifespan. Cable bending around the pulley angle is typically +/– 90°, so an optimal ratio of sheave diameter to cable diameter should be considered. FPInnovations’ guide on winch cable integrity (Boswell & Field, 2017) recommends a minimum ratio of 16:1 for a rope operating around sheaves. Another good cable use practice would be to place a brow log under the line to reduce cable rubbing against the ground. By using the pulley excavator, the average road change time of 21.6 minutes required to relocate the T-Winch can be reduced to 2 to 4 minutes.[1] However, the cost of adding an extra machine to the system should be considered.

The productivity of WS was slightly higher than CS at the average study slope (17%). Using a pulley excavator, on steeper terrain, where road changes are more frequent and conventional adverse skidding speed and payload drops dramatically, WS productivity is expected to be double that of CS, or even more. On very steep or broken terrain, adverse skidding without using winch-assist systems is not feasible. The alternative system in most cases would be cable yarding.

While skidding uphill on deep snow, WS productivity was about double that of CS.[2] Winch assistance on flat, soft ground significantly improved productivity and reduced soil disturbance. On soft terrain, steep or flat, a lighter skidder would perform better than the Tigercat 635E. Moreover, shutdown time due to weather disturbance was reduced, as winch assistance had the advantage of keeping equipment working while conventional equipment had to stop. Fuel consumption and skidder life improves significantly with winch assistance (less than half the fuel was burned in WS compared to CS[2]).

In terms of site disturbance, it should be noted that the survey transects were laid out on a block section steeper (26% on average) than the area used for the productivity calculation (17% average slope) (Figure 2). The overall visual impression of the entire block (not including roads and landings) was of a low to medium site disturbance (Figures 14 and 15).

[1] Contractor observations
[2] Contractor and operator observations

Figure 14. Gouge, CS area.

Figure 15. Overview of a WS section.

Conclusion

Standardized productivity values of CS and WS systems, for 17% slope and 75 m average skid, were 80.6 m^3/PMH and 81.3 m^3/PMH, respectively. The modelled productivity of the CS system on 30% slope and 100 m average distance was 40.9 m^3/PMH, which amounts to 59% of the WS system's productivity (69.4 m^3/PMH). For average block conditions (33% slope and 86 m average skid),[3] the WS system's productivity calculated in the shift-level study was 73.8 m^3/PMH. Higher WS productivity on steep terrain resulted from higher speed on adverse slope and larger payload. On steeper terrain, WS productivity could potentially double when a pulley-carrying excavator is included in the system, by reducing road change time and providing a more stable anchor.

The WS system is also more effective on soft ground, minimizing the impact on the ground while making sensitive sites more accessible. On flat terrain and gentle slopes, with adequate terrain strength, the WS system is less productive than CS. Site disturbance caused by the WS system was 26% lower than CS disturbance on steep terrain.

The WS system had an overall lower fuel intensity, caused less wear, and promoted a longer life for the skidder than the CS system. The use of the T-Winch in this particular study saved 1.1 km of road construction. Adequate block layout and road engineering with optimal WS use in mind could potentially reduce road construction efforts by half compared to the required road network for a conventional cable yarding system.

Further work needs to be done to assess overall skidding cost ($/$m^3$) of the WS system, potential cost savings due to fewer roads being built, and the system's fuel intensity compared to the typical CS system.

For useful links, see [steepslopeinitiative.fpinnovations.ca/.](steepslopeinitiative.fpinnovations.ca/)

[3] The average slope and skidding distance of the block section where the T-Winch was used

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Head Office

Pointe-Claire
570 Saint-Jean Blvd.
Pointe-Claire, QC
Canada H9R 3J9
T (514) 630-4100

Vancouver
2665 East Mall
Vancouver, BC
Canada V6T 1Z4
T (604) 224-3221

Québec
1055, rue du P.E.P.S.
Québec, QC
Canada G1V 4C7
T (418) 659-2647