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Steep Slope Skidding with the Tigercat 635D in Southeastern British Columbia

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V. Strimbu and A.J. MacDonald

British Columbia Ministry of Forests, Lands and Natural Resource Operations
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TABLE OF CONTENTS

List of Figures

List of Tables

Executive Summary

During the mountain pine beetle epidemic over the last decade, the lodgepole pines located on gentle terrain are being depleted. Steeper areas are currently being harvested to mitigate the midterm shortfall in timber supply. Cable harvesting has traditionally been used on steep slopes, but other ground-based systems are more economical. To understand better the options for innovative harvesting systems suitable for steep terrain, a one-week study was conducted in January 2014 in southeastern British Columbia. A Tigercat 635D six-wheeled skidder working on both steep and gentle slopes was evaluated for productivity, cost, and system characteristics as an alternative to cable yarding systems.

On slopes averaging 38%, the extraction cost was about $9.07/m^3 lower than the cost of cable yarding in similar stand conditions. More study of this type of skidder under various slope and felling conditions is needed. Furthermore, an exploration of different team configurations of skidder with loader-forwarders, combined with the option of building trails on very steep slopes, might help to identify the optimal ground-based alternative to cable yarding on steeper slopes.

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1 Introduction

Over the last decade the harvesting of timber killed by the mountain pine beetle has concentrated on fairly gentle terrain. As the supply of lodgepole pines becomes depleted on gentle terrain, a greater volume will be harvested on steeper areas to mitigate the midterm shortfall in timber supply. In recent years steep terrain has been avoided because of the higher cost of steep-slope operations. The traditional cable harvesting systems used on steep slopes are expensive, and alternative ground-based systems are economically attractive. Understanding the options for innovative ground-based harvesting systems that are suitable for steep slopes will help to limit the cost increases as steeper harvesting areas are developed. In January 2014 a one-week study was conducted of a Tigercat 635D six-wheeled skidder working on both steep and gentle slopes in southeastern British Columbia. Six-wheeled skidders such as the Tigercat 635 are reported to be more suitable for operating on steep terrain than conventional four-wheeled skidders.

2 Objectives

The objectives of this study were to evaluate the cost, productivity, and system characteristics and requirements of six-wheeled skidders operating on steep areas where cable systems are the traditional harvesting method.

3 Site, Stand, and Harvesting System

The study site on the east side of the Columbia Mountains was characterized by an average elevation of 1,910 m (see Figure 1). The stand was composed of 80% Engelmann spruce (Sp), 8% subalpine fir (Ba), and 12% lodgepole pine (Pl).

Figure 1 View of the study area.

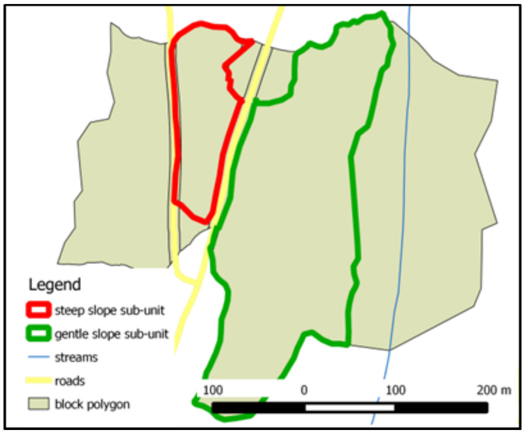

Figure 2 ***Study block and sub-unites.***

Overall site, stand, and sub-unit characteristics are presented in Table 1. Trees were felled mechanically, skidded, and then processed at the landing. The extraction equipment used in the study area was a Tigercat 635D skidder equipped with Olofsfors Eco-Tracks (see Figure 3) and having a 1.95 m² grapple holding area.

Table 1 ***Site and stand characteristics***

Study area parameter	Steep sub-unit	Gentle slope sub-unit
Average slope (%)	38	9
Maximum slope (%)	42	22
Maximum skidding distance (m)	145	250
Gross merchantable volume (m^3/ha)	380	456
Stand density (stems/ha)	595	617
Average stem size ($m^{3)}$	0.637	0.741

Figure 3 ***Tigercat 635D skidding downhill.***

4 Study Methods

The Tigercat 635D skidder was studied with a combination of detailed-timing and shift-level timing methods to provide measurements of turn size (average number of stems, volume, number of bunches), cycle time by distance, hookup, unhook, manoeuvring, decking times, delay times (over and under 10 minutes duration), productive machine hours (PMH) per day, and utilization. Additional data were collected for forwarding direction, average slope, time elements, and activities occurring occasionally. Payload volume was calculated by multiplying the number of stems delivered to the roadside with the calculated average stem size. Average stem size and species proportion were determined from stem-dimension measurements taken at the roadside and at the stump. Volumes were compiled with FPInnovations' cruise compilation spreadsheet for gross merchantable volume. Net volume was provided by the cooperating company from scale records at the mill. Machine costing was derived by FPInnovations' standard method based on market prices for ownership and operating costs.

For the shift-level study, a MultiDAT data logger was installed on the machine about one month before the beginning of the study and was removed at the end. Shift-level data were downloaded automatically every day and sent via satellite to the FPInnovations' FTP server. The main purpose of shift-level analysis was to measure overall productivity and utilization (i.e. percentage of the scheduled time when the machines are performing productive work). Detailed timing data were collected by researchers on site through direct observations totalling over nine hours of productive time. Simultaneously with the productivity study, a fuel-consumption study was conducted. Its results are presented in a separate report, but some results comparing operations on steep versus gentle slopes are included here.

5 Results

5.1 Shift-level Method

Shift-level data were collected over the complete skidding phase of the logging operation (about two weeks). A total productive time of 42.3 hours was spent skidding the whole block and extracting a gross volume of 2,384 m^3 to the landing, for an average productivity of 56.39 m^3/PMH. Machine utilization was measured at 88%. Assuming a machine cost of $139.25/SMH (scheduled machine hours) (see Appendix), the derived production cost was $2.79/$m^3$.

Productivity differences between the steep and gentle slopes were significant. Productivity was almost twice as high on the gentle sub-unit as on the steep one (65.6 m^3/PMH versus 33.9 m^3/PMH). Therefore, the cost of skidding on steep terrain was $2.26/$m^3$ higher than on gentle terrain. Table 2 shows shift-level method results by sub-block.

Table 2 Shift-level method-summary

Parameter	Steep area sub-unit	Gentle area sub-unit
Total PMH	12.3	30.0
Total volume skidded (m^3)	417.5	1,967.9
Skidding direction	downhill	downhill and adverse
Productivity—gross (m^3/PMH)	33.9	65.6
Cost ($/$m^3$)	4.67	2.41

On a net volume basis, production costs were \$7.27/m^3 for the steep area and \$3.75/m^3 for gentle slopes with a block average of \$4.37/m^3.

5.2 Detailed-timing Method

Detailed timing was conducted with a hand-held computer for about 9.4 operating hours over several days to measure the various components of the cycle. Summary results and time-element proportion for the sample are shown in Table 3 and Figure 5. Long delays (over 10 minutes) have not been included in the calculation of cycle time.

Table 3 Detailed timing—summary

Parameter	Steep	Gentle	Steep model (non-circular routing)
Sample size (hours)	8.62	2.00	8.62
Total stems moved	443	184	443
Stems/cycle—average	10.3	12.3	10.30
Average payload (m^3)	6.0	9.1	6.0
Average cycle time (min)	10.78	8.00	9.03
• travel empty	3.34	1.68	1.89
• loading	2.34	1.46	2.19
• travel loaded	1.01	1.58	1.01
• decking	1.65	0.63	1.50
• other	2.34	2.33	2.34
• operational delay	0.11	0.32	0.11
Productivity (m^3/PMH)	32.9	67.9	36.8
Production cost (\$/m^3)	4.82	2.33	4.31

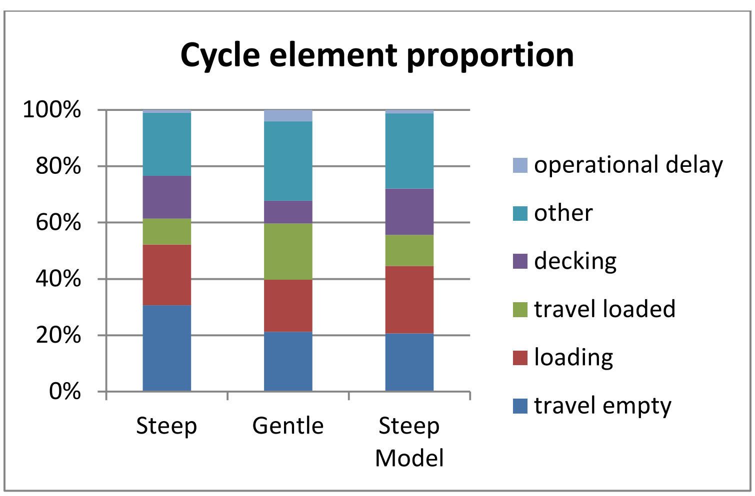

Figure 4 Operational time elements—proportions in an average cycle.

Different work patterns were employed by the operator on each area (see Figure 5). On gentle slopes, skidding was done in a common skidding pattern (i.e. skidder backs up empty, loads, and travels loaded on same trail). Within the steep sub-unit most of the cycles had a circular route, partly because of the slope but mainly because of the deep snow. (I.e., the skidder travelled from the landing uphill—forward or reversing—using a haul road located around the felled area and then, from the top, travelled downhill across the cut block, stopping to load one or several bunches and continuing loaded downhill to the landing.)

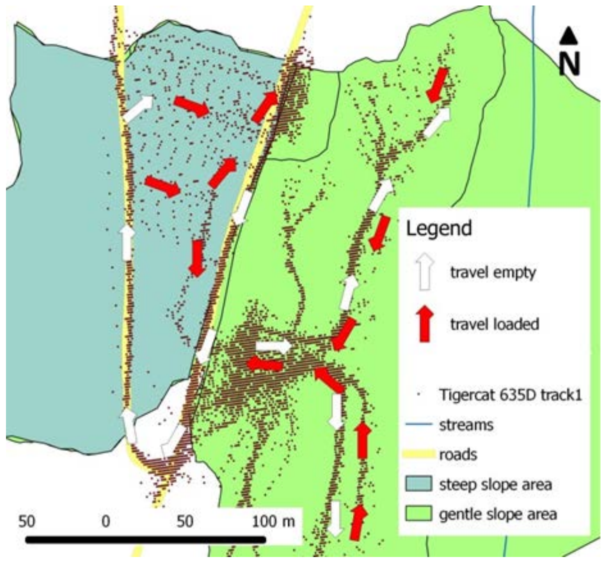

Figure 5 Machine GPS tracks in the steep and gentle slope areas.

Despite a shorter skidding distance in the steep sub-block, the total cycle time was longer (10.78 min versus 8.00 min). The largest time element for steep cycles was the time spent travelling empty time because of the circular route caused by the skidder's inability to back up across the felled area on a steep slope covered with granular snow. Loading time was also longer than in the gentle sub-unit, again because of the deep snow. The snow made it very difficult to back up a couple metres to position the grapple and grasp a bunch; and the skidder's tracks and wheels dug through the snow, gaining almost no traction. Decking also took longer in the steep area because of the smaller space for landing and the limited accessibility (see Figure 6).

Figure 6 While decking stems to the road side the skidder is actually blocking the truck road.

Productivity calculated from the detailed timing results was 32.9 m^3/PMH on steep slopes and 67.9 m^3/PMH on gentle slopes, which is quite consistent with the shift-level results.

Table 3 contains a column where the steep slope results were modelled for a non-circular route. The assumption was that on dry ground or shallow snow, the skidder would be able to travel empty uphill by backing up across the cut block, as is the common work pattern for skidding. On the basis of the model, along with the fact that the skidder would not have to manoeuvre at the loading point to turn around, the travel-empty time element measured during the study would decrease by 43% and the total cycle time by 11%. Productivity would increase to 36.8 m^3/PMH, and the cost would fall to \$4.31/m^3.

It was noticed that bunch size (i.e. the number of trees per bunch) affected the total cycle time, but the size of the effect was not measured by the study. Small bunches, which would necessitate numerous stops to make a full load, might lower skidder productivity, especially when difficult conditions hamper the grapple-arch-skidder, thus resulting in longer stops for loading. However, the size of a bunch is limited by the productivity of the feller-buncher; therefore, an optimal balance should be determined.

5.3 Fuel Consumption Study

Although not a main focus of this particular report, some information obtained from our fuel measurements are presented here since they may affect the operating costs of the Tigercat 635D on steep slopes.
We found that the overall hourly fuel consumption on the steep block was 7.3% higher than on gentle slopes. That 2.2 litre/hour difference may add \$0.04 to \$0.09 i to the cost per m^3 .

6 Other Observations

On steep slopes, the bunching phase, particularly bunch orientation and size, has a significant effect on skidding productivity. Poor communication between the felling team and the extracting team can be a problem, especially when a different contractor operates each phase. Care should be taken to build and orient the bunches to minimize the loading time and facilitate the extraction to the landing.

On very steep terrain, the reach of the arch and grapple are very important; because of the more limited mobility, especially in deep, sugar-like snow. It is also difficult on steep terrain to double-bunch; therefore in many cases, bunches were skipped and left for the next trip.

Uphill skidding is not feasible on steep slopes when the ground is covered with deep granular snow. A solution might be to build skid trails and to use short-distance loader forwarding to feed these skidder main trails. However, the additional cost of a six-wheeled machine would not be justified since the trails would also be accessible to four-wheeled machines.

An operator’s turn-around station with full rear-facing drive control, which is a feature of the Tigercat 635D skidder, makes it possible not only to reduce the total cycle time but also to employ safer work patterns. At the loading point, to grab bunches on steep slopes, the skidder operator does not have to turn the machine around if the skidder is able to back up for long distances.

7 Conclusions

One of the objectives of this study was to assess this skidder type as a ground-based alternative to cable yarding systems. It is clear that under the study conditions in this particular cut block, skidding costs significantly less ($4.67/m^3) than cable yarding ($13.74/m^3 on average for a grapple/choker yarder extracting bunched wood of a similar size class). Not included in the comparison is the extra cost for the loader commonly used to deck for the yarder. Therefore, it is clear that the skidder was more cost-effective in these conditions. Moreover, since the $9.07/m^3 difference does not take into account any variables that were not measured during this study (e.g. extra road building for yarders, the shortage of qualified workers for cable yarding, the greater versatility of skidders compared to yarders), the actual difference might be significantly greater in most cases. Steeper slopes could possibly be harvested with this machine in combination with a loader-forwarder for part of the forwarding phase, where bunches might possibly be consolidated to a prepared skid trail.

The data in this report will be incorporated into FPInnovations' productivity database. Finally, further work is necessary to study the use of this type of skidder in dry conditions, with a more typical work pattern, and under various slope and felling conditions. A side-by-side study comparing different combinations of skidder and loader-forwarders with traditional cable yarding systems would also be of interest. Beyond that, a study comparing the performance of six-wheeled and four-wheeled skidders would allow block areas to be allocated among machines more efficiently.

Appendix

Machine costs	
Model carrier	**Tigercat 635D**
Attachments	1.9 m^2 grapple
	Eco-Tracks
New or used	New
Year of costing	2013
INPUT COST	
Expected machine life (years)	6
Scheduled machine hours/yr	2 433
Total purchase price ($)	425 000
Salvage value ($)	106 250
Licence ($/yr)	
Insurance ($/yr)	7,956
Interest rate (%)	5.0
Utilization (%)	88
Lifetime repair & maintenance ($)	330,402
Fuel consumption (L/PMH)	30.0
Fuel ($/L)	1.20
Oil and lubricants ($/PMH)	3.6
Wages and benefits ($/SMH)	43.30
FIXED COST	
Annual capital cost ($)	66,421
Yearly other costs ($)	7,956
Yearly total ($)	74,377
Costs per PMH ($)	34.74
Costs per SMH ($)	30.57
VARIABLE COST	
Yearly costs ($)	159,070
Costs per PMH ($)	74.3
Costs per SMH ($)	65.38
LABOUR COST	
Yearly costs ($)	105,349
Costs per PMH ($)	38.1
Costs per SMH ($)	43.3
PROFITS AND RISKS	
Percentage of profit/risk	0
TOTAL COST	
Grand total per year ($)	338,795
Grand total per PMH ($)	158.24
Grand total per SMH ($)	139.25