Improving Cable Thinning System Productivity by Modifying Felling Phase Operations

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ABSTRACT

Two methods of felling were tested in a thinning operation to determine if Scandinavian techniques in manual felling could be applied successfully in combination with a cable yarder for thinning in young stands of western hemlock and Douglas-fir. The study results suggest that manual felling productivity was much lower using the Scandinavian techniques, although subsequent yarding productivity was improved by more than 170% when compared with yarding production after conventional felling operations. Cost estimates developed during the study suggest that productivity improvements in the yarding phase reduced the cost of processed logs delivered to roadside by more than $2.50 per ton for the Scandinavian system.

Keywords: *Manual felling, Scandinavian methods, stand damage, production, costs.*

INTRODUCTION

Recent large reductions in the amount of timber available from federal lands, combined with a more active market for wood products, has focused more attention on commercial thinning by forest land managers in the northwestern United States [9]. Terrain conditions in this region require that a significant portion of the stands selected for commercial thinning be treated using manual felling and cable harvest methods.

Commercial thinning with cable systems is typically a marginal operation, due to low productivity and high labor costs [6, 8]. Studies also show that yarding productivity for these systems could be greatly increased by pre-bunching logs prior to yarding [5, 7].

This study examines conventional felling operations relative to a set of felling procedures developed in Scandinavia that emphasize precision felling and pre-bunching by the faller. The primary study objective is to quantify how this modified felling system affects felling productivity relative to conventional methods used in the Northwest United States. The study also examines the effect of this modified "Scandinavian" system on subsequent operations, specifically the yarding phase, to quantify the effect of these operations on yarding productivity.

Background

Two different methods of manual timber felling were evaluated in cable commercial thinning operations; they are referred to as North American and Scandinavian style felling practices throughout the rest of this paper. The objective was to identify whether Scandinavian methods, which were developed for use in ground-based forwarder operations on gentle slopes and which involved pre-bunching of logs by the faller, could be applied to a steep slope thinning operation using a small cable yarder for timber extraction in a practical and cost effective manner.

Conventional felling was performed by a North American faller whose experience had previously emphasized clear-cut harvests, although he had been felling in thinning operations for over a year. The faller used equipment typical of fallers in the Pacific Northwest, a large chain saw with a 80 cm (32 in) bar to fell timber and a set of wedges to direct felling. Timber was felled towards the corridor in a herringbone pattern meant to assist yarding. The faller would typically fell several trees into the same opening in the stand and then limb the felled timber on three sides of the bole.

The alternative method of felling was performed by a Swedish faller who was trained in silviculturally based tree selection, and who had extensive experience – over 20 years – in felling, tree selection, and log preparation. Timber was felled and processed using a commonly manufactured chain saw equipped with a 40 cm (16 in) bar. The Scandinavian faller also used a tool called a felling iron and a pair

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of log hooks to process the stems. The felling iron aids in directing the fall of trees and releasing hung trees, while the log hooks are used to move felled logs into bunches for subsequent yarding.

The Scandinavian faller also felled in a herringbone pattern, but trees were typically felled and processed individually before the processed logs were moved into bunches for yarding. Delimbing was performed to a higher standard than that conducted by the North American faller because of the need to move the felled logs. Additional time was spent removing slash from the corridor area to improve working conditions, both for the faller and the yarding crew.

The logging contractor set preferred log lengths at approximately 10 m (33 ft) for both fallers. Corridors were laid out by the contractor prior to any falling. Each faller was responsible for creating adequate corridors for later yarding operations. Yarding of both areas was performed using a small yarder rigged for operation as a running skyline using a mechanical slackpulling carriage capable of lateral yarding to distances of 33 m (100 ft) [1]. No landings were used and all yarding was to roadside. Pre-setting of chokers was not conducted during yarding operations. The four-person crew consisted of a yarding engineer, a loader operator, a rigging slinger, and a hooktender/chokersetter.

Loading and other landing operations were performed by a medium-capacity hydraulic knuckleboom loader. All operations, including the falling, yarding, and loading, were conducted during the Spring and Summer months.

Study Area

The study area was located near Forks, Washington, on the Olympic Peninsula in the western hemlock and Pacific silver fir series [4]. Two stands of 35 to 37 year-old naturally regenerated second growth timber on similar slopes were selected for the study (Figure 1). The predominant species in the stand was western hemlock (*Tsuga heterophylla*), with a scattering of Pacific silver fir (*Abies amabilis*), Sitka spruce (*Picea sitchensis*), red alder (*Alnus rubra*), and Douglas-fir (*Pseudotsuga menziesii*).

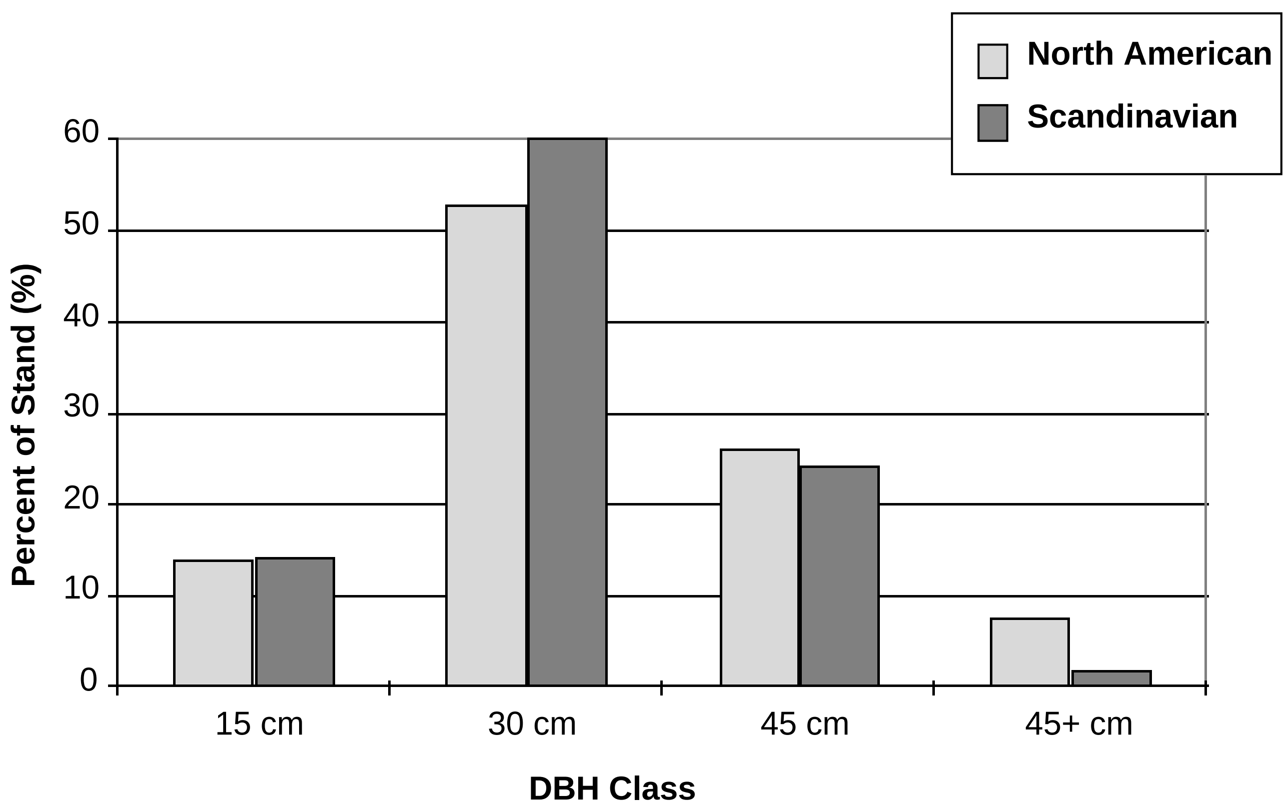

Figure 1. Comparison of stand conditions prior to thinning.

The area harvested using the North American felling system was on a northern aspect and had numerous "Wolf Trees" that were heavily infected with mistletoe. Average DBH in this stand was 31.3 cm (12.3 in), while stocking averaged 1085 stems per ha (440 stems per acre). The Scandinavian felling area was on an eastern aspect with similar stand conditions. Mean stand diameter was 29.9 cm (11.8 in) and stocking averaged 1485 stems per ha (601 stems per acre). Slopes in both areas ranged from 10 to 85% and were concave in profile, making them ideal for cable yarding operations.

The stand was treated using a spacing regime that required a 5.2 m (17 ft) spacing between leave trees. The expected number of trees remaining in the stand was anticipated to range between 360 and 400 stems per ha (146 to 161 stems per acre). Removals were not based on species preference, but emphasized form and dominance within the stand. Poorly formed, overtopped trees were preferred for removal.

METHODS

Data collected for this study fell into three distinct groups: stand damage, felling operations, and yarding operations. Stand damage data consisted mainly of observations from sample plots established prior to the start of operations that were revisited after yarding was completed to evaluate individual stem damage levels. Felling and yarding observations were used mainly to identify differences in system operation and productivity.

Observations - Stand Damage

Prior to felling, both areas were thoroughly surveyed using 0.01 ha sample plots set at 50 m intervals. Collected data included tree counts and measurements of the tree diameter at breast height (DBH). Plots were revisited post-harvest to measure the damage level sustained by the residual stands under the different felling methods.

Observations of damage fell into three severity classes – small, medium, and large, and at four different levels on the tree – root/stump, low, intermediate, and high (Table 1). Selection of the severity categories and the level of individual damage scars divides the damage into regions of different susceptibility relative to infection and impact on the merchantable value of the tree itself [10, 3, 8]. Damage was measured in a cumulative manner, such that multiple medium and small scars were classed as a single large damage scar for individual trees.

Observations - Felling

Observation of the felling operation consisted of two different methods of time and motion study. The initial study involved detailed observations of the individual felling cycle for each system to determine average felling and processing times when felling and processing trees of different diameters. Collected data included the time spent felling, limbing, and bucking individual trees and the associated stem DBH.

Table 1: Classification scheme for quantifying bole damage in the two stands under study.

Parameter	Classification
Scar Size:	
small	scars to the cambium ≤ 40 cm^2 (6 in^2),
medium	scars to the cambium > 40 cm^2 (6 in^2) and ≤ 200 cm^2 (31 in^2)
large	scars to the cambium ≥ 200 cm^2 (31 in^2)
Location of Scar on Tree:	
root/stump	location <30 cm (~1 ft) from groundline.
low	location ≥30 cm (~1 ft) and <1.5 m (~5 ft) from groundline.
intermediate	location ≥1.5 m (~5 ft) and <3.0 m (~10 ft) from groundline.
high	location ≥3.0 m (~10 ft) from groundline.

This initial time study was followed by a series of five-minute-long periodic observations, during which the time spent by the fallers performing different actions was observed. This second study did not focus on individual actions, but instead concentrated on the proportion of time spent performing each felling function. Approximately 100 periodic observations were made during falling operations.

Observed felling functions included felling merchantable trees, felling non-merchantable trees, processing felled logs, releasing trees that became hung during felling, planning the fall of timber and walking between trees, maintenance on saws, clearing brush, moving logs for yarding, staking the corridor, and "other" to cover actions not adequately included in any of the other categories. Break time was also observed for both fallers in the five minute periodic study but was excluded from subsequent analysis, since it was considered dependent on the personality and habits of the individual faller, and not a feature of the felling system.

Observations - Yarding

Detailed time and motion studies were made of yarding under each felling system. The observed yarding elements consisted of carriage outhaul, lateral outhaul, choker setting, lateral inhaul, adjustment of the carriage and turn to deal with hang-ups encountered during inhaul, inhaul of the turn up the corridor, and unhook/deck at the landing. During subsequent analysis, the adjust carriage component of the cycle was grouped with lateral inhaul times as a component of the lateral yarding time. A delay/other category was also timed and observed, which covered delays not covered by the main headings. The causes of these delay times were also recorded where possible to facilitate further analysis. In addition to the yarding cycle times, yarding distances and the number of pieces yarded per turn were also recorded. In all cases, three chokers were used per cycle, although this did not limit the number of logs yarded to three. In some cases, as discussed in the subsequent section, "bonus" logs were acquired by wrapping two or more logs with the choker cable.

Analysis - Economics

The falling rate for the North American faller was assumed to equal $4.80 per ton of production. The rate for the Scandinavian faller was based on this rate and increased proportionally on a per ton basis to provide a similar level of daily income to the faller.

The yarding rate for this operation using the North American faller was set at $22.00 per ton delivered to the landing. Hourly wages for the yarding crew were assumed to be constant between the two systems. Other machine costs such as fuel consumption might be expected to rise due to increased payloads, although the contractor did not believe that consumption had increased. Based on these comments, the operating costs for yarding were also assumed to be constant between the two systems. Fixed costs such as lease payments on equipment were also assumed to be constant. Therefore, the only variables that had a significant effect on total logging costs were the production and subsequent rate differences for falling and yarding.

RESULTS AND DISCUSSION

Stand Damage

Total damage observed under the two felling systems was not significantly different at an alpha level of 0.05. At the most detailed level of sampling detail, where any damage reaching the cambium was counted, both systems achieved statistically the same level of damage. The Scandinavian system resulted in 21.7% of the residual trees being damaged, while the North American system resulted in 20.0% of the residual trees being damaged (Table 2, Figure 2).

A difference was observed when the smallest scars were removed from consideration as damage (Table 2). Under these conditions, damage levels fell to 14.1% of the residual stand for the North American faller and 5.8% for the Scandinavian faller. The difference in damage levels between the two systems is further increased when the medium sized scars were removed from the analysis. This resulted in damage levels of 9.4% for the North American faller and 2.9% for the Scandinavian. At this point, the cumulative area of damage scars on an individual tree approximated the size or severity deemed by the landowner to be significant.

Damage for both systems was concentrated in the lower bole and root area, with an average of 42.1% of the damage scars occurring in the lower 4.5% of the trees in the stand (based on an estimated average

Table 2: Summary of severity and location of damage to residual trees.

Severity of Damage

Felling System	*Damage Level (as a % of Residual Trees)* **Small** **≤40 cm²**	**Medium** **>40 cm²**	**Large** **≥200 cm²**	**Total**
North American	5.9	4.7	9.4	20.0
Scandinavian	15.9	2.9	2.9	21.7

Location of Damage

Felling System	*Position of Damage (as a % of observed scars)* **Stump**	**Low**	**Intermediate**	**High**
North American	36.1	16.7	27.8	19.4**
Scandinavian	52.4**	9.5	38.1	0

** At alpha = 0.05, a significant difference was detected.

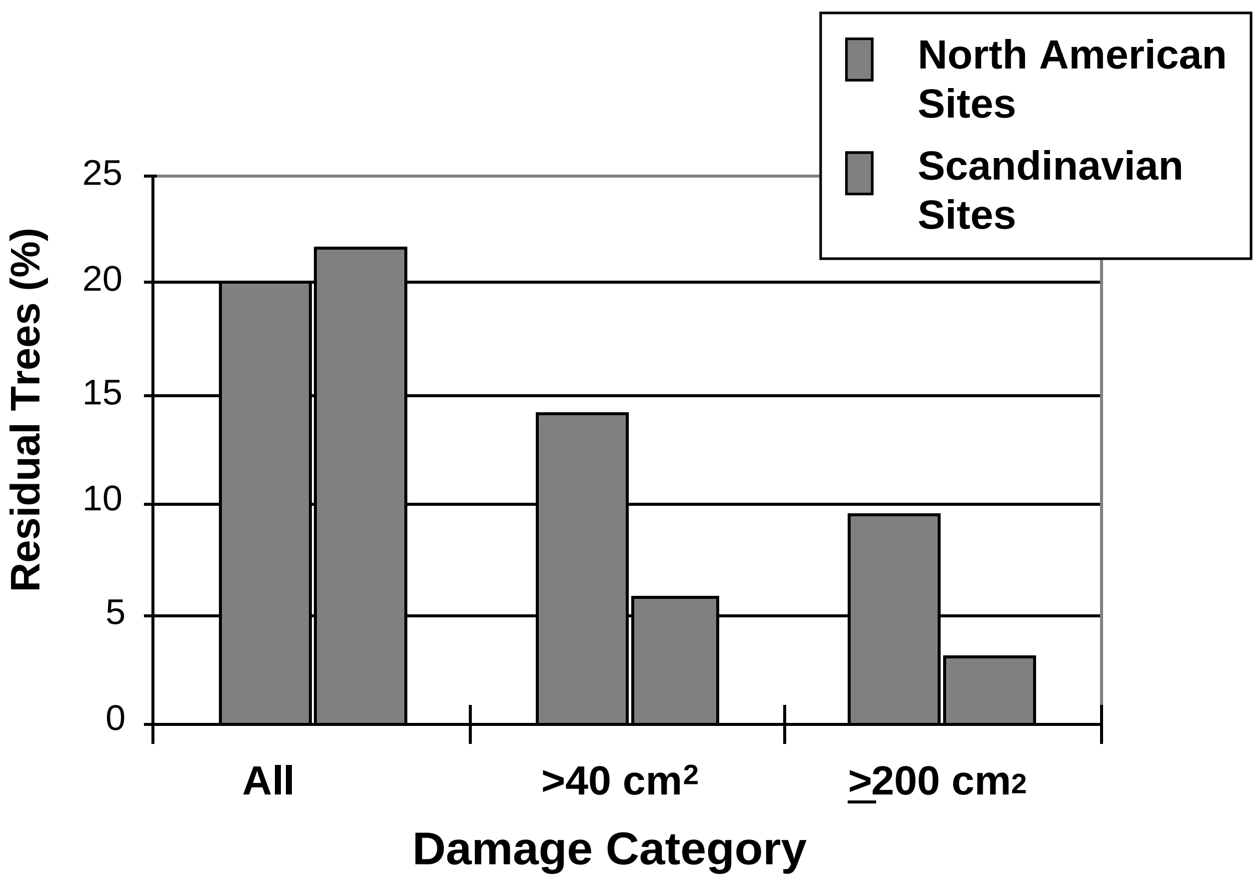

Figure 2. Thinning damage from the studied systems.

tree height of 27 m or 90 ft). There was a significantly higher proportion (alpha = 0.05) of the damage occurring on the roots and in the stump area for the Scandinavian faller, with all of the large damage scars for the Scandinavian system occurring on large surface roots and root buttresses typical of the hemlock in the stand (Table 2). Both felling systems produced similar levels of damage in the lower and intermediate bole area, which constitutes much of the first merchantable log. No damage was observed for the Scandinavian faller in the high range. It should be pointed out that under both systems, rub trees in the corridor were used by the yarding crew and removed as part of the harvest.

Felling

When analyzed individually, the proportion of total time spent by each faller performing principle felling functions – specifically felling, limbing/bucking and planning – was not significantly different at an alpha level of 0.05 (Table 3). However, the North American faller required an average of 1.87 minutes to complete a cycle, while the Scandinavian faller required an average of 4.48 minutes to complete a cycle.

Analysis of the felling cycle times for the two fallers indicated a significant difference (alpha = 0.05) in the mean cycle times (Table 4). A large portion of the cycle time difference is due to the time spent by the Scandinavian faller either performing tasks that the North American faller did not (e.g., moving logs and staking the corridor following felling), or performing the same tasks to a higher standard.

For example, the North American faller typically limbed only three sides of the felled tree, while the Scandinavian faller limbed on all four sides and took care to remove branches flush to the bole to allow the logs to be moved and pre-bunched. The planning and walking phase of the felling cycle was also more time consuming for the Scandinavian faller (0.67 min. vs. 0.36 min. for the North American faller), because of the increased planning required when manipulating logs after felling and because of the faller's background in training situations, which emphasize proper technique rather than production as a priority.

Table 3: Summary of detailed timing results for felling operations.

	Scandinavian Faller		North American Faller		
Felling Cycle Element	Mean (min/cycle)	Percent Cycle (%)	Mean (min/cycle)	Percent Cycle (%)	Differ. (min/cycle)
Plan/Walk	0.67	14.9	0.37	20.1	0.30
Clear Brush	0.30	6.7	0.03	1.6	0.27
Fight Hang-up	0.15	3.3	0.20	10.9	-0.05
Clean Butt	0.07	1.6	0.02	1.1	0.05
Stake Corridors[1]	0.03	0.7	0.0	0.0[1]	0.03
Maintenance	0.30	6.7	0.08	4.3	0.22
Other	0.03	0.7	0.07	3.8	-0.04
Fell Merch. Tree	0.68	15.2	0.42	22.8	0.26
Fell Non-merch Tree	0.10	2.2	0.07	3.8	0.03
Limb and Buck	1.47	32.8	0.58	31.5	0.89
Move Logs[2]	0.68	15.2	0.0	0.0[2]	0.68
Total Cycle	**4.48**	100.0	**1.84**[3]	100.0	**2.64**

[1] Stake Corridors element refers to the staking of the yarding corridors with stakes and flagging prior to yarding. This element did not occur for the North American faller.

[2] Move Logs element refers to the process of creating small bunches of logs by sliding single logs together manually after felling and processing. This element did not occur for the North American faller.

[3] At alpha = 0.05, a significant difference was detected.

Table 4: Felling and yarding productivity summaries for Scandinavian and North American fallers.

Felling Productivity	Mean (pcs/hr)	Std. Dev. (pcs/hr)	Tree Size (tons/tree)	No. of Obs.
Scandinavian	13.49	1.0	0.45	62
North American	32.44	3.11	0.48	67

	Yarding Distance (meters)			
Yarding Productivity	**0 - 60**	**60 - 120**	**120 - 180**	**180 - 240**
Scandinavian				
Mean Cycle Time (min/cycle)	3.9	4.8	5.3	6.0 **
Std. Deviation (min/cycle)	1.1	1.0	0.8	0.9
Mean Productivity				
(In pieces/cycle)	4.4**	6.1**	6.6**	6.6**
(In pieces/hour)	67.7	76.3	74.7	66.0
No. of Observations	56	74	58	52
North American				
Mean Cycle Time (min/cycle)	3.5	4.1**	5.2	6.4
Std. Deviation (min/cycle)	1.1	1.0	1.0	1.1
Mean Productivity				
(In pieces/cycle)	3.4	3.1	4.2	4.9
(In pieces/hour)	58.8	45.0	48.7	46.1
No. of Observation	47	47	51	71

** At alpha = 0.05, a significant difference was detected.

The cycle time differences were also a factor in defining the observed differences in productivity for the two fallers. The Scandinavian faller produced 13.49 logs per productive hour, while the North American faller produced 32.44 logs per productive hour.

Yarding

Observations of 259 complete cycles were made for yarding in the Scandinavian felling area, while 216 complete cycles were observed for the North American faller. Results showed that the mean yarding cycle times for both systems were the same (alpha = 0.05) over the first 180 m (600 ft) of the yarding corridors. Yarding cycle times in the 180 to 240 m (600 to 800 ft) yarding segment were significantly lower (alpha = 0.05) for the Scandinavian felling method when compared with the North American method.

As expected, yarding cycle times increased with increasing yarding distance (Figure 3). Comparison of individual yarding elements indicated that both lateral outhaul and choke times tended to be significantly lower for the Scandinavian system. This was probably due to the additional time spent by the Scandinavian faller in brushing out the corridor and clearing away debris. Chokersetters could find the logs that they wished to choke more easily, and travel by the chokersetters was less impeded by brush during lateral outhaul.

While mean yarding cycle times were largely the same, the average number of pieces yarded per turn was significantly higher (alpha = 0.05) for the Scandinavian faller at all distances (Table 4, Figure 4). Pieces yarded per turn for the Scandinavian area ranged from 140 to 223% greater than the number yarded by the same yarding crew under the North American system. The increase in pieces yarded per turn combined with the yarding cycle times translates to an average 72.5% increase in yarding productivity measured in pieces per productive machine hour.

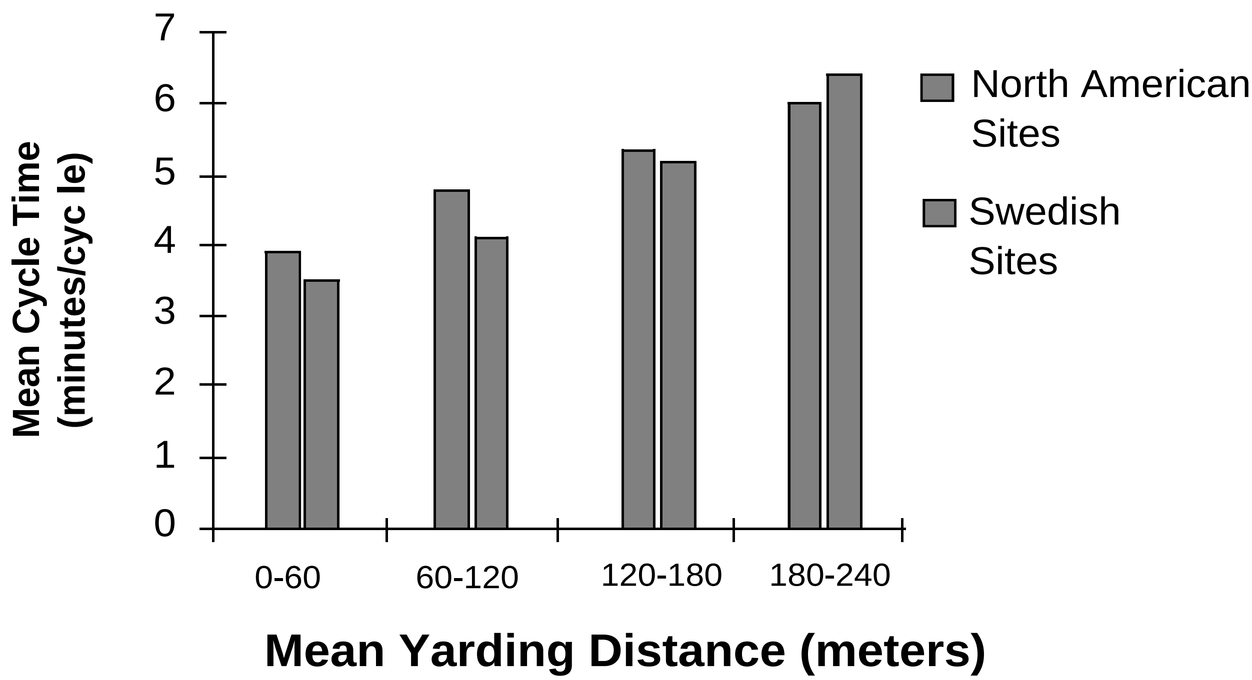

Figure 3. Comparison of yarding cycle times for two felling systems.

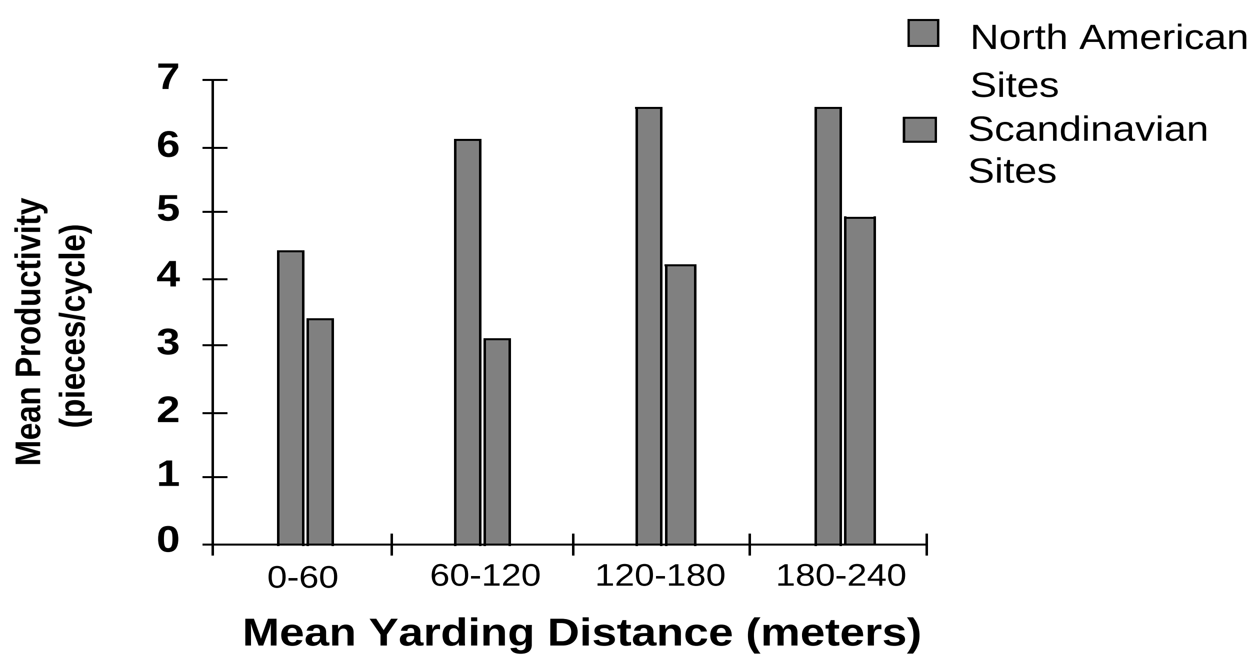

Figure 4. Comparison of yarding productivity for two felling systems.

Economics

Analysis shows that both the North American and the Scandinavian fallers removed a range of trees that did not significantly differ. The mean DBH of trees removed by the North American faller was 21.91 cm, while the mean DBH of trees removed by the Scandinavian faller was 20.92 cm. Tree heights, calculated from measurements taken from the residual stand post-harvest indicate that tree heights for the two areas were not statistically different (alpha = 0.05). Therefore, for the purposes of economic analysis, it was assumed that the average piece size or log extracted during the harvest was the same for both felling methods and areas.

By assuming that the harvested piece size was the same in both areas, the ratio of harvest costs between the two systems can be approximated by the ratio of pieces produced per productive hour by both the fallers and the yarding crew. Based on this relationship, felling costs for the Scandinavian faller were estimated to be 240% greater than the costs for the North American faller.

Felling costs were generated using the contract rate typically provided to the North American faller. Logs processed by the North American faller had an average cost of $4.80 per ton. Based on the difference in production for the two systems, logs processed by the Scandinavian faller were estimated to cost approximately $11.52 per ton. This represents an additional expense of $6.72 per ton in felling costs for logs processed by the Scandinavian faller.

Yarding productivity for logs processed using the Scandinavian system ranged from 1.38 times that for the North American over the 0 to 60 m (0 to 200 ft) yarding distance to 2.08 times as much over the 60 to 120 m (200 to 400 ft) yarding distance. The average yarding productivity for yarding logs processed with the Scandinavian system over the entire range of yarding distances was 172.5% of the yarding productivity for the North American system. Average yarding costs for the sites treated by the North American faller, again based on typical yarding contract rates, were about $22.00 per ton. Due to increases in yarding productivity, costs for yarding the sites treated by the Scandinavian faller ranged from $15.94 per ton over the 0 to 60 m (0-200 ft) distance to $10.58 per ton over the 60 to 120 m (200 to 400 ft) distance. These differences were thought to occur because of the higher level of processing and pre-bunching done by the Scandinavian faller.

Generally, yarding costs were estimated to average $12.75 per ton for the Scandinavian sites. Based on the average productivity and yarding costs for the Scandinavian system, this represents a reduction in yarding costs of $9.25 per ton. The total direct effect on logging costs when using the Scandinavian felling methods was a cost reduction of $2.53 per ton for processed logs delivered to roadside. A summary of the phase level costs is provided in Figure 5.

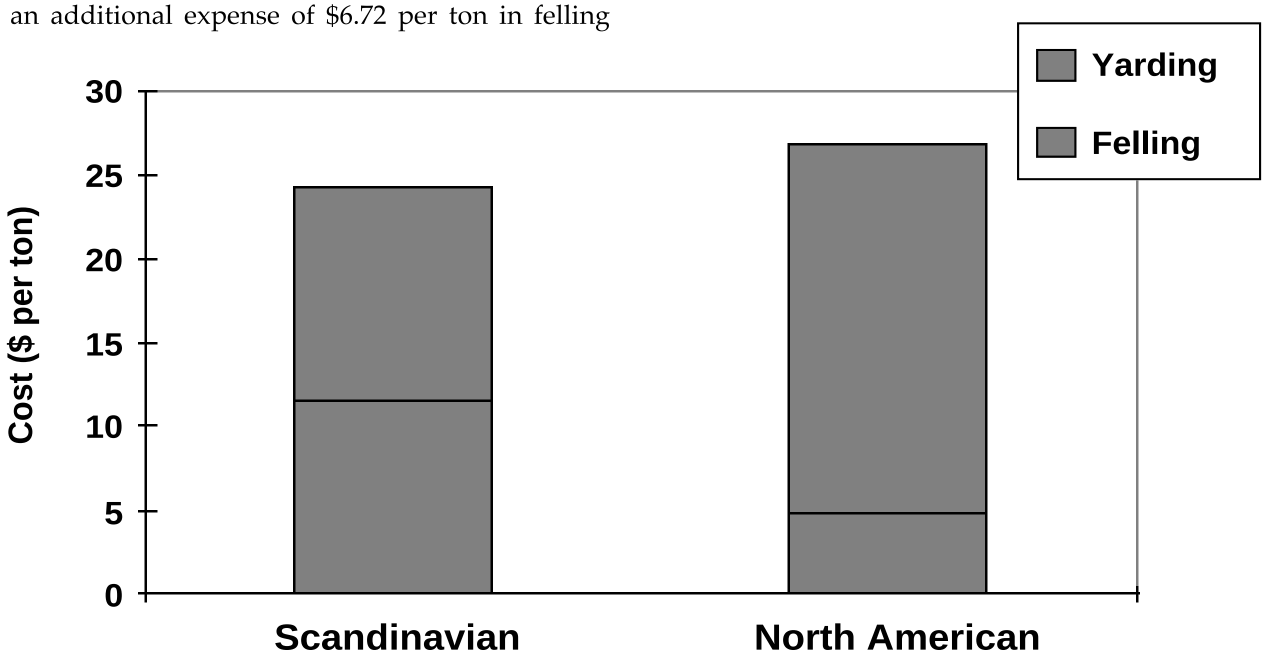

Figure 5. Cost of harvesting by phase.

Thus, while the felling cost associated with the Scandinavian methods examined in this study were substantially higher than those achieved by the North American faller, the use of the Scandinavian system resulted in substantial improvements in the yarding costs that offset the increased felling costs by approximately $2.53 per ton.

ADDITIONAL OBSERVATIONS

Additional savings might be realized under the Scandinavian felling method in loader and landing operations, and through improved landing conditions resulting from the reduction in logging debris at roadside. In cable yarding operations, either in clearcuts or in commercial thinning, removal of yarding debris from landing areas can represent a significant cost to either the operator or the land manager. This portion of the operation however, was not subject to detailed analysis and no conclusions can be drawn at this time.

CONCLUSIONS

Based solely on the economic criteria from this case study, justification exists to implement the Scandinavian felling methods, or at least the standards to which the Scandinavian faller processed and positioned – or bunched – the logs for yarding. Although conditions for the Scandinavian faller were not optimum, yarding productivity increased and costs were substantially reduced in the area where this system was used. This, combined with lower stand damage levels and the potential for improved landing conditions, suggests that land managers and contractors should consider implementing these methods into their felling practices.

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