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Safety in steep slope logging operations

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ABSTRACT

Partial results of a NIOSH-funded study for "Protecting the Logging Workforce: Development of Innovative Logging Techniques for a Safer Work Environment" by a team of researchers at Oregon State University are presented that review safety in steep slope logging. Comparisons are made for hazards and exposures of "conventional" and new technologies for steep slopes. Hazards of new technologies are identified. Safety assessments are addressed for forestry sectors internationally, for the firm and for workers. Important questions of technical feasibility, economic viability and environmental performance are raised. Ongoing research on operators using tethered and untethered systems are described. Results will help inform training and selecting operators. New Best Operating Practices and safety code regulations will result from the research. New technologies will reduce worker hazards and exposures for steep slope logging.

KEYWORDS
Logging; safety; slopes; yarding; felling

Introduction

The introduction to this special issue highlights safety issues in the logging industry and in forestry services. In the states of Oregon and Washington, efforts are underway to reduce fatalities on steep slopes in timber cutting with chainsaws and cable yarding. Figure 1 shows fatalities in Oregon and Washington for two time series for yarding and timber cutting. The data show timber cutting to be the most dangerous followed by cable yarding work on steep slopes.[1] Logging is often described as "difficult, dirty, dangerous, and declining."[2] The National Institutes of Occupational Safety and Health recognizes the hazards of logging and awarded Oregon State University a grant for "Protecting the Logging Workforce: Development of Innovative Logging Techniques for a Safer Work Environment"(1-U01-OH-010978–01). This paper describes the safety approach for the project.

New technologies

In the last few years, technologies developed in New Zealand for machines that employ wire rope tethers have allowed for large excavator-like forestry machines on steep slopes in the Pacific Northwest and British Columbia. The common version for tracked machines has a machine at the top of the slope equipped with one or two lines on computer-controlled winches attached to an operating machine secured by the tether and performing logging functions (felling or moving trees). Such felling machines can be heavy, approaching 40000 kg.[3] For more than 15 years, operations in the steep slopes of central Europe have employed winches on harvesters and forwarders (vehicles with wheels instead of tracks) to provide traction and stability assistance during harvesting. Other new technologies for cable logging such as using wireless video controlled grapples offer safety improvements to yarding crews working on steep slopes.

Adopting new technologies to improve safety is a systemic engineering approach involving several stakeholders with varying interests. Machines are not the most important part of the new technologies; it is the humans who control them and decide how to use them that are most significant. They are the human subjects of the research and require Institutional Review Board oversight. Operators

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Supplemental data for this article can be accessed here.

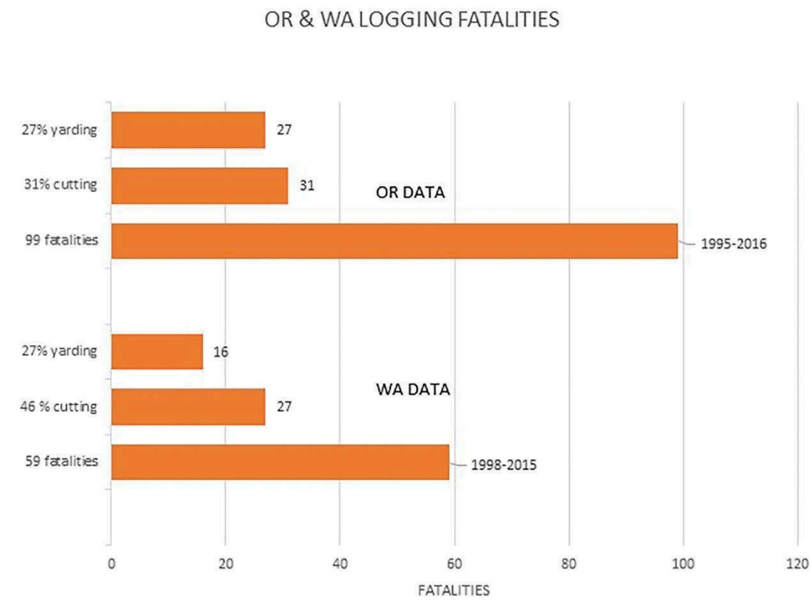

Figure 1. Oregon and Washington logging fatalities.

are critical to the safety success of the system. Operators are compared to workers in traditional cutting and yarding work on steep slopes. Contractors are the entrepreneurs who purchase the new machines and decide whether to replace traditional machines and work with operators in protected cabins. Forest landowners who offer their timber for harvest can select the new technologies for their harvest schedules mindful of the safety tradeoffs. Other individuals and groups are involved in the use of new safer technologies such as safety regulators, environmental regulators, system manufacturers, logging planners, and others.

Conditions necessary for logging accidents

There are two conditions necessary for an accident. First, there must be hazards present that can impact workers. Second, there must be work practices, procedures, and operations that expose workers to the hazards. A simplified hierarchy of prevention follows: first, remove the hazards from workers; second, remove workers from the hazards; third, use administrative efforts of training and supervision; and finally, use personal protective equipment. The high accident rate for traditional timber cutting and cable yarding indicate that prevention is not working well. It is not practical to remove all the hazards from the worksite nor is it possible to take workers away from the hazardous tasks they perform. Administrative controls of training and supervision are used but accidents happen to well-trained and experienced workers for timber cutting and yarding work.

When safety improvement efforts are undertaken, it is impossible to show that the accident that did not happen was due to an improvement; i.e., cannot prove a negative. Epidemiological studies with large sample sizes or long terms of study are promising, but they are seldom available in logging studies. Rather, the new technologies use the engineering controls of removing the hazards from the worker, such as using a machine for work rather than walking on steep terrain. The new technologies remove the worker from the hazards by reducing the number of workers needed to accomplish the logging tasks. Hazards and their potential severity are different for the new technologies as well. Training and supervision (including "self-supervision"[4]) are vital to the safe implementation of new systems. Finally, there are major differences between personal protection of traditional logging systems and those afforded by a substantial, certified operator's cabin.

How are hazards and exposures identified for current and new approaches?

If the hazards and exposures are different for the approaches, what is needed to identify them for traditional and new systems? They can be identified "*a priori*" by a task analysis. "The Job Task Analysis (JTA) is the most widely accepted and nationally used process for determining valid job content and employment requirements.[5] A subject matter expert can perform the task analysis and verify it with incumbents as needed. The author has used task analyses in numerous designs for training loggers[6.] and has developed the format for this work as Task/Subtask; Knowledge; Skills; Abilities; Risks; Motivation. For the project, the author prepared Task Analyses for Walking in the Woods; Using a Chainsaw; Manual Timber Cutting; Machine Timber Cutting; Machine Travel on Slopes; and Rigging Tasks (choker setting, etc.). Risks and hazards for those tasks were identified.

Another approach to identifying hazards is to review the accidents that occur. Safety regulators in Oregon and Washington have logging accidents and fatalities reported to them, and they summarize them periodically.[7] Risks and hazards can be seen in the brief descriptions of the traditional logging systems. For the new technologies, the states and countries beginning to use them have collected accident and near miss reports for tethered logging that highlight the hazards (eg., WorkSafe New Zealand, 2016[8]). Best operating practices from forest landowners and manufacturers also provide risks and hazard identification.

Where competent accident analysis has been done, details of accidents provide sources for the hazards and work practices leading to the accidents. In forestry states like Oregon and Washington, logging accidents are investigated and documented in reports of the National Institute of Occupational Safety and Health (NIOSH) Fatality Assessment Control and Evaluation (FACE) reports.[9] Other forestry countries that have steep slope operations compile accident reports that help identify hazards and work practices (eg., WorkSafe New Zealand; WorksafeBC). Some organizations lack time and personnel for extensive accident investigations.[10] The research teams have served as experts in legal cases involving felling and yarding where resources permit detailed accident analysis to a high legal standard to identify the causes of accidents.

Questions of interest and results

With the hypothesis that new technologies may improve logger safety, there are a number of questions of interest.

Are new systems safer?

The question of whether the new systems are safer for the entire forestry sector in Oregon and Washington cannot be answered from accident data, as the systems are too new and too few (starting in 6/2016) to provide a time series. However, New Zealand has used these steep slope systems longer, and it shows some trends. Figure 2 shows data for the New Zealand forestry sector, demonstrating a reduction in accidents as the steep slope technology was introduced. This finding prompted Northwest forest land managers to see if the technology had merit. One manager of forest lands in New Zealand described the alternative to using tethered logging machines:

> It should be noted that from 2013 to September 2016, which represents a period of time when NZ has gone from 2 tethered systems to 40+ there have been 19 deaths in NZ Forestry, 9 of these have been workers struck by trees being felled and 5 struck by trees being broken (sic, yarding) out that is 74% of death related to tree falling or breaking out. (Rowan Struthers, personal communication, 10-10-2016)

Safetree New Zealand identifies a steep slope risk assessment form.[11] Data collection on use of steep slope logging is underway in all countries using the technologies.

In Oregon, employers using steep slope technologies on slopes over 50% (~27°) need a variance from current regulations to operate unless the manufacturer states the machine is suitable for slopes greater than 50%.[12] Our research cooperators comprise 8 of the 19 firms using steep slope technologies. Such small firms may keep time series records of accidents, but the population is too small to capture the events that are few in number.

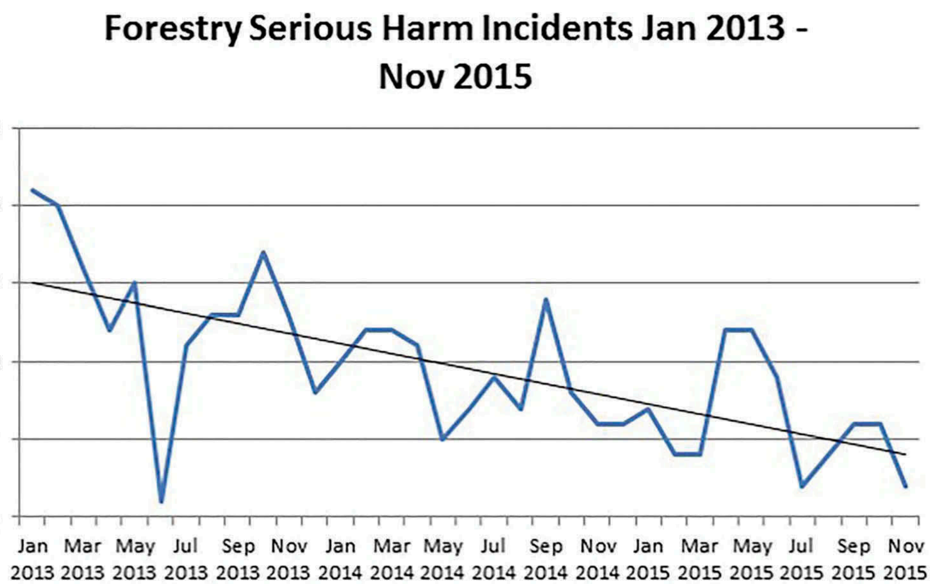

Figure 2. New Zealand accident during introduction of tethered logging (Worksafe New Zealand, 20,017).

Reduction in hazards for new technologies

What our research can show for traditional and new technologies is the difference in the hazards and worker exposure as well as the reduction in workers exposed to the hazards. The hazards of the work were identified by the task analysis and other methods described earlier. The exposure of workers is evaluated by a Behavioral Observation Scale (BOS) checklist as our researchers observe the operations.[13] The BOS is a snapshot of the operation using an estimate of exposure to the hazards of the work. A BOS for the steep slope felling operation could include traveling, overhead, frontal, maintenance and chainshot hazards; stability, rocking and sharp movements; temperature and noise; line failure; and machine handling. The BOS checklist includes time estimates that are non-linear (e.g., rarely to frequently), and the scale may be adjusted by researchers during observation. Supplemental Appendix A illustrates the BOS instrument.

Table 1 shows a partial comparison of the hazard exposure for the tree felling with traditional hand felling and using a felling machine for selected tasks. A review and comparison shows the new technology is projected to virtually remove most of the dangerous hazards found in traditional hand felling on steep slopes, such as slips, falls, etc.; struck by overhead hazards; and struck by objects while cross cutting. However, new technologies using large, heavy equipment on steep slopes have deadly hazards for machine rollover and chainshot hazards. The frequency is so low for these hazards that the new technologies are much safer. Similar differences can be seen comparing traditional cable yarding with use of grapple yarding of tree piles bunched on steep slopes. Thus, new technologies reduce the hazards workers face on the job.

Table 1. Hazard comparison for manual and mechanized cutting.

Manual Cutting	Mechanized Cutting
Hazards of walking in the wood	Tipovers/Rollovers
Slips	
Trips	
Falls	
Heat/Cold	
Knees/Back	
Chainsaw hazards	Maintenance hazards
Kickback	
Cuts	
Noise	
Eye/face injuries	
White fingers	
Widowmakers	Whole body vibration
Snags	Neck/shoulder
Falling & rolling	Cumulative
Logs/trees	
Tension	
Wood	
Fatigue induced injuries	Overhead/frontal hazards
	Chainshot hazards

Reduction in workers exposed to hazards

The productivity of the new technologies of steep slope logging also reduces the number of workers exposed to the hazardous tasks in felling and yarding. Each of our cooperating contractors estimated the area or volume of timber they would be harvesting using the machines versus traditional systems. Cutter years are estimated from the annual timber volume estimates provided by study contractors and landowners that will be cut with tethered felling machines. Estimated timber volume is used to estimate the cutter years needed to manually fell that volume. Average productivity of machine cutting is estimated by cooperators and production estimates to be four times that of a hand faller. The cutter years for the Oregon variance hourly use is estimated similarly with cutter hours divided by estimated yearly hours for a cutter.

Contractors have generally good information on the future operations they have in their schedule. In addition, the cooperating forest landowners estimate the area or volume they would be harvesting using new technologies. This larger estimate is from planning data and would require contractors not included in our study, but the landowners' intention is to use the new technologies rather than traditional systems. Table 2 summarizes the reduction in workers needed and exposed to any hazards. Data for the shift to grapple yarding technologies are just coming available, so the table only refers to felling and shovel logging applications of the contractors and landowners.

The use of new technologies dramatically reduces the number of workers exposed to the most dangerous task of tree felling. Cooperators gave their estimates for use of new technologies in either volume or area harvested. Table 2 shows estimates of the cutter years saved with differing populations and differing projection bases. Our sample contractors would save 13 cutter years if they cut their annual projections, and the landowners in our study would save 41 cutter years using the tethered technologies for projected harvests with new technologies. Another estimate of cutter years saved is from the 23 contractors using the Oregon OSHA variance reporting scheme (through 12/31/2018), which showed 23,135 machine hours worked without incident. This translates into 67 cutter years saved. At these levels of savings, it is likely that cutter fatalities and serious injuries were avoided, but longer-term data are needed. These estimates are for tethered logging technologies and do not represent the full safety benefits of machine cutting versus hand cutting.

Table 2. cutter years saved using new technologies in Oregon.

Population	Volume basis	Cutter years saved
Study contractors	Annual projections	13
Oregon contractors	Annual projections	23
Study landowners	Annual projections	41
Contractors with OR variances	Hours worked 6/2016–12/31/2018	
No injuries	23,135	
Comparable cutter hours	92,540	67

*Cutter Years are estimated from the annual timber volume estimates provided by study contractors and landowners that will be cut with tethered felling machines. Estimated timber volume is used to estimate the cutter years needed to manually fell that volume. The cutter years for the Oregon variance hourly use is estimated similarly with cutter hours divided by an estimated yearly hours for a cutter.

Do new systems bring new hazards?

One would expect new systems to bring different hazards to workers. The task analysis for the maintenance of steep slope machines indicates that at times operators would need to perform maintenance and repair tasks on steep slopes near 80% (~38 °). Machines are not specifically designed to be repaired on such steep slopes, so operators will need safe operating procedures for repairs. Also, if repairs are not possible, operators may need to exit the machine and climb up the slopes to the tethering machine and make adjustments/repairs. In difficult situations, additional steep slope machines may be needed to help extract the failed machine.

The most severe hazard for operators is a tipover or rollover of a machine on steep slopes. This might occur from failure of the tether line(s) or failure of the slope itself with the machine in a compromised position. The machines are equipped with ISO (International Standards Organization 8082:1994) approved Rollover Protection (ROPS) cabins, but it is unknown if such protections can protect the operator from multiple rollovers on steep slopes. Tipovers have occurred without injury to the operator, but fortunately in the United States, no rollovers have occurred with tethered steep slope equipment. Fatal rollovers have occurred on slopes with untethered machines of various configurations.[14] Operator training, specific operating guidance, machine and system maintenance, machine safeguards and warnings, and operator vigilance will all be needed to prevent tipovers and rollovers.

Research is underway studying the effects on the operators from working on steep slopes and considering the stress on the operators, the whole-body vibration, and the fatigue from tethering versus untethered operations (Bozicevic, Tom, OROSHA. personal communication, 11/7/2016). Data are still being collected on these measures. Cumulative trauma of machine operators is well-known in Scandinavia but is little studied in North America.[15] It will be necessary to conduct an analysis of the potential and actual errors of machine operators, as described by Peters and Peters,[16]·as related to training and fatigue. As the population of operators increases, our research will use questionnaires and interviews to further assess impacts.

Are new systems feasible and economically viable?

We have conducted field research to develop and verify models of machine operability that provide fundamental basis for feasible operations that are beyond the scope of this paper.[17] Studies of economic viability of tracked, wheeled, and grapple operations are underway as well.[18]

What are training requirements?

New technologies require re-thinking the training requirements of operators. Our study should help provide some guidance on operator training needs. It is likely that operator skills on moderate slopes without use of a tether will carry over to tethered machine operations. However, new circumstances on steep slopes require new operator knowledge and skills unique to the terrain, timber, and machines. At present, the only guidance in use is a requirement for some specified time and observed proficiency on an untethered machine. For the harvester/forwarder wheeled machines, the Scandinavian manufacturers have developed simulators for training operators that include steep slope operations with over 150 tasks covered (Tuomo Moilanen, Ponsse, personal communication, April 13, 2018). In Oregon and Washington, operators of tracked felling machines are not familiar with simulator training, like in Europe, as they are not available from manufacturers or others.

Are new systems environmentally acceptable?

The question of whether steep slope tethered operations are environmentally acceptable is beyond the scope of the NIOSH-funded research, but some of our feasibility analyses contribute to understanding the soil-machine interface. Soil moisture, machine traction, and type of operation contribute to the questions. Machine cutting and grapple yarding are currently done in a satisfactory fashion for forest landowners and regulators on slopes that do not require a tethered machine. In some operations using tethered machines on steep slopes, it is difficult to see where the machine has operated. Tethered machines have the potential to mitigate soil impacts in post-harvest operations and can provide slash treatments not possible with hand cutting and yarding operations.

Conclusions

Our research shows distinct differences between conventional logging systems and new technologies for steep slope harvesting. There is a reduction in exposure to hazards and a reduction in workers exposed to the most serious work in logging– felling and working on cable operations on steep slopes. While new systems bring new hazards, workers are in protected cabins rather than on the terrain. Questions remain on economic viability, environmental impacts, and operator training and safer operations. Use of the new systems continues to expand in the Pacific Northwest and western Canada.

Continuing research

Our project is continuing with measurements on individual operators using non-tethered and tethered operations, using different machines, and at differing times in the operators' experience. We are measuring operators' vital conditions of:

- heart rate;
- galvanic skin response;
- temperature; and
- whole-body vibration.

We have eye-tracking glasses on the operators and a camera showing the inside of the cab and operating views. Operators have been interviewed for fatigue and measured their typical sleep period. Demographic data of age, experience, height, weight, prior injuries and complaints, and wage/hours basis are available. Our research on grapple yarding technologies is now underway. We are hopeful that our research will help inform development of safety guidance and regulations, experience and training needs of operators, machine designs, and planning and management of steep slope operations.

Future research

With new and developing steep slope logging technologies as well as novel measurements such as eye-tracking glasses, research is first needed to understand the technologies and measurements. Our descriptive research opens new questions that designed research can address such as different operator restraints; different operator stations and control monitoring; monitoring safety differences and increased risks for timber cutting in areas too difficult for new technologies;[19] critical terrain/soil/machine interactions; and longer-term impacts on machine operators. Our research team looks forward to research that can improve safety in the most dangerous occupation of logging.

Disclosure statement

No potential conflict of interest was reported by the authors.

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