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Motor-manual forest fuel reduction treatment and silviculture operations:

A summary of productivity studies

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Forest fuel reductions treatments are conducted at a stand level in the wildland–urban interface to reduce the potential for catastrophic loss caused by wildfire. Given the considerable expense of conducting these fuel treatments, fuels managers want to better understand the productivity and cost of commonly applied fuel treatments in order to prescribe cost-effective treatment techniques. Due to the limited data available and the myriad combinations of fuel treatment options and equipment types used in a diverse range of ecosystems, cost projections for fuel treatments are difficult to forecast reliably.

This document provides background on and fundamental principles of productivity studies, and a summary of motor-manual productivity studies that have been conducted in timber silviculture operations, forest fuel reduction treatments, and other manual forestry operations.

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INTRODUCTION

Forest fuel treatments are conducted at a stand level in the wildland–urban interface to reduce the potential for catastrophic loss caused by wildfire. Given the considerable expense of conducting these fuel treatments, fuels managers want to better understand the productivity and cost of commonly applied fuel treatments in order to prescribe cost-effective treatment techniques. Due to the limited data available and the myriad combinations of fuel treatment options and equipment types used in a diverse range of ecosystems, cost projections for fuel treatments are difficult to forecast reliably.

Similar questions and concerns regarding cost and efficiency have been addressed in harvest operations in the forest sector. Forest harvest and silviculture operational staff have collaborated with forestry researchers to address these concerns by developing data collection programs, monitoring operations, and conducting productivity studies. FPInnovations Wildfire Operations group has applied these data collection methods and technologies in vegetation management to measure the productivity of equipment (primarily mulchers) that is used to conduct commonly applied treatment techniques in boreal and montane ecosites (Hvenegaard 2021).

To a lesser extent, productivity trials of motor-manual fuel treatments have been conducted to assess the performance of workers using hand tools (mechanical and manual). Rigorous productivity trials can be time-consuming; hence, the number of case studies and fuel treatment productivity data are limited.

OBJECTIVES

This document provides background on and fundamental principles of productivity studies of productivity studies. A literature search was done to compile a summary of motor-manual productivity studies that have been conducted in forest fuel reduction treatment operations, silviculture operations, and other motor-manual forestry operations.

BACKGROUND ON PRODUCTIVITY STUDIES

Measuring productivity

Why monitor operations? "You can't improve or manage what you do not measure" (Ryans, 2014, p. 4).

"The direct relationship between product output and time input is called productivity" (Magagnotti & Spinelli, 2012, p. 9) and can be expressed using different metrics depending on the outcome or product of an operation. Commonly applied product outputs in harvest operations are volume and weight. Productivity metrics are, therefore, expressed as volume/time or weight/time.

The most commonly applied product output for mechanical and motor-manual fuel treatments is area. Hence, area/time is the most prevalent productivity metric, since fuels practitioners are interested primarily in treating defined areas of forest, grassland, or other wildland fuels.

The following are common productivity measurements in mechanical treatments:

- Productive machine hours (PMH) = the time a machine is actively working at its primary function (e.g., mulching, felling trees). PMH excludes any time delay greater than 15 minutes.

- Scheduled machine hours (SMH) = the scheduled shift length. This is usually reported as monthly or yearly and is often used in machine costing formulas (Ryans, 2014). Most fuel treatment productivity studies have been conducted in winter, when the duration of the shift is variable and often dictated by weather. During winter productivity studies, the shift length is recorded as on-site arrival time until departure time.

- Machine utilization (%) = a measure of longer term machine efficiency, calculated as PMH/SMH.

These productivity measurements are also applied to motor-manual studies by substituting "worker" for "machine" in each of these terms. For example, in previous case studies, productive "worker hours" is the product of the number of workers and the number of productive hours worked.

Area/PMH or area/PWH are the most common metrics the Wildfire Operations group uses in assessing fuel treatment productivity. Area is the size of the treatment area in hectares. Given the small scale of fuel treatment operations relative to harvest operations, all fuel treatment productivity data were collected from short-term studies.

Timber harvest operations

Productivity studies in timber harvest operations have been conducted for more than 50 years. At the inception of equipment productivity evaluations, there was a "growing need to be able to predict the expected productivity of logging machines when working under different environmental and operating conditions" (Aird et al., 1970, p.1). The Pulp and Paper Research Institute of Canada and the Forest Engineering Research Institute of Canada developed productivity evaluation methods and conducted extensive testing on harvesting machines performing different harvest operations.

Productivity studies are conducted to evaluate the cost and efficiency of equipment performing selected forest harvest operations. They are also conducted to evaluate how a modification to an operation can affect productivity and reduce operational costs.

Initially, short-term studies (1–2 weeks) were conducted on new harvesting equipment to describe the technical and operating characteristics of new machines and to estimate their potential productivity under measured operating and environmental conditions. Recognizing the limitations of the short-term studies, the Forest Engineering Research Institute of Canada developed long-term data collection methods that would evaluate machinery performance capabilities under a wider range of environmental conditions (Folkema, Giguere, & Heidersdorf, 1981).

The terminology and methods developed for these equipment evaluation programs form the basis of current productivity studies conducted by FPInnovations' Wildfire Operations group.

Manual silviculture operations

A productivity study is typically designed to evaluate how productivity can be affected by a change in an operational or environmental variable. Several productivity trials of motor-manual forest operations have been conducted in precommercial thinning and tree planting operations.

For example, Hedin's (1982) case studies of five independent thinning operations (manual and motor-manual) provide valuable insights into productivity of fuel-treatment techniques in various fuel environments.

Another approach to evaluating the productivity of fuel-treatment techniques uses a direct "side-by-side comparison'' to examine the effects of a change in an operational variable such as an innovation in treatment method or equipment. For example, Holmsen (1989) compared chain saws and clearing saws as the primary clearing tools in a motor-manual precommercial thinning operation. This paired study measured the effects of a change in a single operational variable (equipment type).

Modifying a work practice or prescription (Ewing & Lirette, 2001) in precommercial thinning operations is another way that changes in productivity can be evaluated through a change in an operational variable. Productivity trials were conducted to evaluate how varying mechanical interventions and block layouts would improve the productivity of manual thinning operations in high-density forest stands.

Productivity of tree planting operations has been studied to evaluate the effect of operational and environmental variables. Stjernberg (1991) compared productivity in mechanically prepared sites and unprepared ground, and found that planter productivity was higher in sites where disc trenching had been conducted.

The references identified above are examples of the various types of productivity trials that have been conducted to evaluate how different variables affect productivity. A more complete compilation of known productivity trials in silviculture operations is presented in Appendix A.

Forest fuel reduction treatment operations

Forest fuel treatments are conducted to address basic fuel-reduction principles (Agee & Skinner, 2005), which are essential to reducing fire intensity and the potential for crown fire. These treatments are carried out by means of a variety of mechanical and motor-manual techniques. Motor-manual treatments are conducted by workers using tools such as chain saws, clearing saws, and pole saws to reduce stem density, surface fuel loading, and ladder fuels. Motor-manual fuel treatments are, generally, successful in addressing these fuel-reduction principles (i.e., reducing surface fuel, increasing height to live crowns, reducing crown density, and retaining larger and healthier stems).

Key advantages of motor-manual treatments over mechanized treatments are that manual workers can be more selective in removing stems, and there is no chance of machine-caused stem damage. Another major advantage of motor-manual treatments is that workers using motorized tools can remove lower branches (ladder fuels) and put them in a burn pile.

Motor-manual productivity studies

FPInnovations conducted two motor-manual productivity trials in two different treatment units at Pelican Mountain FireSmart Fuel Management Research Site[1] (hereafter Pelican Mountain) during the winters of 2016/17 and 2017/18.

The prescription for these treatments were based on FireSmart[2] guidelines for thinning stems to a 3-m crown spacing and removing lower branches to a height of 2 m. However, in order to maintain average stem spacing throughout the plot, the textbook prescription was modified slightly because some areas of the stand were patchy, with dense clumps of stems in larger open areas. In these cases, some clusters of stems were thinned to a tighter spacing.

Unit 1 at Pelican Mountain was designed to compare the cost-effectiveness of two different fuel treatments conducted to achieve the same fuel treatment prescription. A fuel removal treatment (motor-manual) was applied in the south half of Unit 1; a fuel displacement treatment (semi-mechanized) was applied in the north half. Productivity of each treatment was evaluated independently of the other. A key difference between these two treatments is that a motor-manual treatment removes residue (stems and branches) by piling and burning, whereas

[1] For more information about the Pelican Mountain FireSmart Fuel Management Research Site, see the Canadian Wildland Fire & Smoke Newsletter.
[2] https://firesmartcanada.ca/wp-content/uploads/2022/01/FireSmart-Protecting-Your-Community.pdf

a semi-mechanized treatment displaces debris to the surface layer, where it is mulched and incorporated into the surface fuel layer.

The motor-manual treatment achieved complete removal of the understorey component, while the overstorey density was reduced from 2334 to 1228 stems/ha. Live crown base height increased to 3.5 m. This motor-manual treatment was conducted in three phases that employed a varying number of workers. Taking this variation in worker numbers into account, the overall productivity rate for this treatment in Unit 1 was calculated at 0.0051 ha/worker hour (Hvenegaard & Hsieh, 2017a).

Semi-mechanized silviculture operations (St. Amour, 2007) use machines to remove the bulk of unwanted stems and create pathways for workers. This makes it more efficient for workers equipped with motorized tools to remove additional stems and perform other work required to meet the prescription.

Hvenegaard & Hsieh (2017b) assessed the productivity of the semi-mechanized operation in Unit 1, in which a small mulcher removed the bulk of stems to create better access for crews to selectively remove unwanted stems and remove lower branches on stems. The treatment removed all the understorey and reduced overstorey density from 1278 to 568 stems/ha. Post-treatment live crown base height was 3.5 m. Machine productivity was calculated at 0.08 ha/PMH, and overall workforce commitment was 72 worker hours over the 4 days of treatment work.

Cost analysis

The motor-manual fuel treatment in Unit 1 (south half) was administered through Alberta Agriculture and Forestry, and was conducted by seasonal staff retained to work on winter fuel treatment projects. The overall cost of the entire motor-manual fuel treatment through all three treatment segments was $18 976. For the 1.5-ha treated area, the cost was $12 650/ha. This cost is mid-range on the spectrum of manual treatment costs reported by Canadian wildfire management agencies (Hvenegaard, 2012).

At the time of this survey, the average cost of motor manual fuel treatments reported by agencies ranged from $7 360 to 22 300. Several environmental and operational variables impact fuel treatment costs and productivity trials should attempt to note factors that influence productivity on that treatment project. For example, environmental factors would include stand density, steep slope, ground cover (snow) or cold temperatures. Operational considerations will include travel distances and equipment types.

The semi-mechanized fuel treatment in Unit 1 (north half) was administered through a contractor who hired local workers and subcontracted the mulchers with operators. The total cost of the treatment, including equipment, fuel, personnel, management, and administration, was $27 962. For the treated area of 1.8 ha, the cost was $15 534/ha.

Productivity of larger crews

Crew size varies in motor-manual fuel treatments. In Alberta, eight-person contract firefighting crews are common. Planning and budgeting of motor-manual fuel treatments could be

improved with good data for eight-person crew productivity. The most reliable productivity data would be from case studies; however, there is a lack of case study data. Unit 1 results were extrapolated to provide a coarse estimate of potential productivity for an eight-person crew. Based on the overall productivity of 0.0051 ha/worker hour in Unit 1 (Pelican Mountain), an eight-person crew working 8 hours per day could treat 0.33 ha/day. In a 5-day work week (40 h), the crew could treat 1.63 ha.

Another motor-manual treatment was conducted in Unit 5 at Pelican Mountain in December 2017 by applying the same treatment prescription. Productivity (unpublished) of a six-person crew was evaluated, and trial results indicated that productivity averaged 0.0087 ha/worker hour. This is similar to the productivity of the four-person crew in Unit 1 (0.008 ha/worker hour), in their first four workdays in similar conditions (mild weather and minimal snow cover). This would translate to a daily rate of 0.55 ha/day for an eight-person crew for 8 hours of on-site treatment work. It should be noted that actual on-site treatment work hours were approximately 5.5 hours/day. Extrapolation to 8 hours of treatment work per day assumes crews could maintain the same working pace.

Both documented motor-manual productivity trials were conducted in winter, with limited daylight hours. The shorter workday was also a consequence of longer travel distance. With longer days and shorter travel distance, the utilization rate (efficiency) of a crew will be increased.

EVOLVING DATA COLLECTION METHODS

In the initial productivity study at Pelican Mountain, a rigorous data collection method was employed, with two researchers on-site for 4 days in early December 2016. During this time frame, data collection included daily measurement of the processed area and the operational time. The specific tasks conducted daily included:

- recording times – travel, on-site, and start/stop for breaks or delays;
- determining the number of productive worker hours for the day;
- recording a GPS track of the area processed for the day; and
- detailed timing of specific work activities.

Conducting this daily routine allowed researchers to evaluate the data collection processes and identify sources of error, inefficiencies, and redundancies. For example, a GPS track recorded at the end of the day needed to be flagged to establish the start point for the next day's work; otherwise, this would have provided questionable data since a portion of the entire area may not have been completely treated, with all debris piled and burned. It was decided that recording a daily GPS track did not provide value in the overall productivity output since the area of the entire treated area could be tracked and measured at the completion of the treatment operations.

One exception to this would be if there was an obvious change in stand characteristics such as density or species and there was a need to compare productivity in these distinct fuel environments.

Additionally, it was decided that a measure of daily productivity was not important. An overall measure for the entire project area was deemed to be a more representative metric for measuring productivity. With these observations noted, adjustments to the data collection process were made, and the crew supervisor collected relevant basic data for the continued treatment of the plot. Recorded data were later processed by FPInnovations researchers.

This "hands-off" data collection process was formalized for use in Unit 5 at Pelican Mountain in December 2017. FPInnovations researchers provided a user-friendly data collection sheet to the crew leader so they could collect daily productivity data, including start/stop times for different operations and breaks throughout the day. After a minimal amount of training, the crew leader completed the daily data sheets and submitted them to FPInnovations. Manual entry and compilation of the data in a spreadsheet yielded basic productivity data as hectares/productive worker hour.

This streamlined approach to productivity assessment using a modified data collection sheet is proposed as an alternative to rigorous and expensive data collection protocols. Fuels managers will be able to collect data that are more relevant to local fuel environments and will be able to evaluate productivity specific to local crews, which may have different skill sets, experience, or equipment types.

This approach is presented in a separate FPInnovations publication, which includes guidelines to support field supervisors in simplified data collection in motor-manual forest fuel reduction treatments.

DISCUSSION

Other productivity and costing frameworks

Wildfire management agencies, with assistance from forestry contractors, have been conducting motor-manual forest fuel reduction treatments in Canada for more than 30 years. During this time, planners and supervisors have developed methods for assessing the cost of a fuel treatment and the productivity of crews performing the treatment activities.

For example, during the development of the Slave Lake Mulch Research Area, FPInnovations worked closely with Alberta Agriculture and Forestry and Mistik Environmental to identify commonly applied fuel treatment techniques in the most dominant forest fuel environments in that area. Productivity data for previous mechanical fuel treatment work were shared by outlining essential productivity variables and outputs: treatment strategy, production days, equipment on-site, and productivity per machine day. Comments in the worksheets described site characteristics, treatment tactics, and environmental factors that may have influenced productivity.

The productivity data presented in these worksheets provided practical guidance on estimating costs of future projects with similar operational and environmental conditions. Almost certainly, similar unpublished assessments of motor-manual treatment productivity have been conducted as a decision support tool in appropriately estimating treatment cost and resourcing.

Scales of rigour in data collection

At a very coarse scale, treatment cost/area is easily calculated using administrative records of treatment cost and area treated. This metric is sometimes used as rough indicator of productivity. These data are generally specific to a certain geographic area; therefore, comparisons to fuel treatments in other areas is more of an “apples to oranges” comparison.

A more representative productivity metric for motor-manual treatment operations uses the overall area treated divided by the number worker hours (area/time). Start and stop times for workers and the number of workers can be used to calculate productive worker hours.

Capturing such precise productive worker hours is generally not attempted for each crew member in a motor-manual treatment operation that involves larger crews. Generally, the same times for productive hours and rest breaks are applied to all crew members in the same crew. However, it is important to record the number of crew members on each working day. On-site data collection can record delays as mechanical or personal.

“Apples to apples” comparisons

Because many environmental and operational variables change from one fuel treatment operation to another, it is challenging to conduct comparative productivity trials to measure the effect of manipulating one independent variable. Many trials may be required to achieve a high level of confidence in the productivity data.

Productivity trials have been conducted during motor-manual fuel treatments in fairly consistent site conditions at Pelican Mountain. The treatment area was in even-aged black spruce (Picea mariana) on sites with similar ground conditions during winter.

To collect the most reliable productivity data, an optimum methodology would have the same crew conduct the same treatment technique (operational variables) in treatment units of similar size and stand characteristics under the same weather conditions (environmental variables).

To study the effect of a change in an independent variable (e.g., fuel treatment intensity), a forest stand with consistent attributes (species, stand age and density, topography) would be subdivided into several subunits of similar size. With variations in the independent variable applied in the subunits, productivity in each subunit would be measured. Further data collection in productivity studies can include an inventory of fuel attributes and stand characteristics in each subunit.

Other productivity trials have been conducted during other fuel reduction treatments in varied fuel environments. These studies have used an opportunistic approach to collect data as fuel treatments are prescribed. The downside of this approach is a lack of consistency in several variables (fuel environment, machinery type, and fuel treatment technique). Given these differences in environmental and operational variables, it is difficult to merge data from many dissimilar projects to produce reliable universal productivity curves.

Forest stand and fuel inventory

In most of the productivity trials conducted by FPInnovations, the fuel treatment site had been sampled by the Alberta Wildland Fuels Inventory Program crews using established data collection methods.[3] The data collected were used to quantify forest stand attributes. These sampling initiatives and quantified stand attributes were invaluable in establishing similar trial sites in comparative productivity studies. Detailed sampling of forest fuels is time-consuming and not always practical for most project managers and field supervisors. However, a general description of site characteristics is useful in assigning a fuel environment (or ecosite) category that can be used to group similar sites as part of the data analysis process.

KNOWLEDGE GAPS AND CHALLENGES

The primary target in the literature search was productivity trials in motor-manual forest fuel reduction treatment operations; a secondary priority was assigned to harvest operations and silviculture operations that employ similar tools or methods as those used in the fuel reduction treatment operations.

The author acknowledges that these forestry-related operations are conducted on a global scale and that productivity trials have been conducted by other forestry research groups. With this in mind, this summary report is not intended to be an exhaustive literature search, and as such, is not a complete compilation of all forestry-related productivity trials.

Reports in Appendix A that are readily available include a hyperlink to the report. Other reports are available, upon request, from FPInnovations.

Application of productivity data

At a local level, a fuels manager can use an informal data collection process to better understand and assess resource requirements for treatment operations commonly applied in that area. When the same treatment technique is consistently applied in a similar fuel environment using the same crew configuration, a fuels manager can develop a solid data set to determine reliable productivity metrics. They can apply a standard productivity rate (ha/PWH) to more reliably estimate the amount of productive working time that would be required for future treatment projects.

A project planner can use this estimate of working time to determine the number of working days required and factor in other considerations such as travel time (driving and walking), length of work day, and season to determine the projected cost for the treatment unit.

At a regional or national scale, fuels managers will benefit from a larger productivity data set for motor-manual fuel treatments. To optimize value from a shared data set, it is critical to standardize inputs to the data collection form. Fuel treatment technique and forest stand type are inputs that can be classified in several ways; therefore, commonly accepted terminology should be developed to ensure valid data entry. The Canadian Wildfire Fuel Management

[3] Alberta Wildland Fuels Inventory Program Crew Information Manual 2014

Knowledge Base[4] has developed terminology for treatment tactics that can be applied in this data collection process.

Innovations in equipment and treatment techniques

The key advantages of using the chain saw for motor-manual treatments are its versatility and availability, and its familiarity of use among wildfire personnel. The chain saw operator is able to remove unwanted stems and limb residual stems with the same tool. Because chain saws are standard issue for fire operations, they and their parts are readily available for fuel treatment operations. Certified and experienced chain saw operators are trained in basic sharpening and maintenance of the chain saw.

Even though there are obvious benefits of using the chain saw, opportunities exist to increase efficiency, reduce fatigue, and increase productivity. Productivity studies in precommercial thinning operations (Hedin, 1982; Holmsen, 1989) suggest that the use of clearing saws may be more appropriate in dense forest stands on flat terrain. However, on steep terrain or in areas of thick slash and windfall, operators who used clearing saws had difficulty moving through the forest stand, and productivity was lower than that of operators who used chain saws.

For fuel treatment prescriptions that specify limbing to a height greater than 2 m, alternative tools such as manual or mechanical pole saws are required. Other variations in fuel treatment prescription might include a reduced crown spacing or surface debris management process such as prescribed burning.

These variations in fuel treatment prescription and equipment types require modifications to work routines. Observing fuel treatment operations and recording productivity data are important in evaluating the effect of a change in treatment technique or innovations in equipment.

CONCLUSION

The cost of forest fuel reduction treatments is a relevant consideration for fuels managers, and contractors have used various methods to determine the cost of treatment operations. Productivity trials have been introduced as a standardized approach to evaluate the cost of motor-manual operations and develop a data set that can be used to project fuel treatment costs.

A review of documented harvest and silviculture productivity trials has been essential to developing sound data collection methods to evaluate productivity of motor-manual fuel treatments. Although growing a viable data set is a challenge, continuing productivity trials with a consistent data collection approach across a larger landscape will provide benefit to fuels managers in planning future fuel treatments.

[4] https://wildfire.fpinnovations.ca/Research/ProjectPage.aspx?ProjectNo=204

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APPENDIX A: SUMMARY OF MOTOR-MANUAL PRODUCTIVITY STUDIES

Wildland fuels mitigation

Title	**Productivity of a motor-manual forest fuel reduction treatment: a case study in Central Alberta**
Authors	Hvenegaard, S. and Hsieh, R.
Date	2017
Data collection methodology	Worker productivity, pre-and post-treatment stand characterization
Keywords	Motor-manual productivity, forest fuel reduction treatment, chain saw
Ecosystems	Boreal forests
Abstract or relevant findings	
Forest-fuel reduction treatments have been applied extensively in Canada's wildland–urban interface to mitigate the risk of wildfire to communities and other values. Motor-manual fuel treatments are labour intensive and time-consuming. In the winter of 2016/17, FPInnovations documented the productivity of a fuel treatment conducted by workers using chain saws and hand tools to apply prescribed fuel reduction guidelines in a dense black spruce forest stand. The results and observations from this study will help forest fuels managers plan and budget for motor-manual fuel treatments and develop operational best practices.	

Title	**Productivity of a semi-mechanized forest-fuel reduction treatment: a case study in Central Alberta**
Authors	Hvenegaard, S. and Hsieh, R.
Date	2017
Data collection methodology	Worker productivity, pre- and post-treatment stand characterization
Keywords	Motor-manual productivity, forest fuel reduction treatment, semi-mechanized operations, mulching
Ecosystems	Boreal forests
Abstract or relevant findings	
The productivities of equipment and personnel engaged in harvesting and silviculture operations have been well documented over the last three decades; however, there has been relatively minimal documentation of productivity in forest fuel-treatment operations. In February 2017, FPInnovations conducted a study at the Pelican Mountain FireSmart Research Site in central Alberta to document productivity of a semi-mechanized forest fuel treatment. The treatment involved a Rayco C130 mulcher, and workers who thinned the forest stand and moved and piled debris. Observations and results from this study will contribute to an evolution of operational practices and improved cost-effectiveness.	

Title	Managing forest fuels for community protection in the interior of British Columbia: productivities and costs of thinning from below
Authors	Mitchell, J.
Date	2007
Data collection methodology	Productivity, pre- and post-treatment stand characterization, manual piling, falling
Keywords	Thinning, fuel loading, urban-forest interface, Interior British Columbia, fuel reduction
Ecosystems	Interior Douglas-fir biogeoclimatic zone

Abstract or relevant findings

To reduce the potential occurrence and effects of a wildfire in a stand adjacent to a residential subdivision in the interior of British Columbia, the University of British Columbia's Alex Fraser Research Forest aimed to reduce forest fuels within the stand by thinning from below, skidding as much debris to the landing as possible, and then piling the remaining debris for burning. Feric, a division of FPInnovations, monitored the falling and skidding phases and a test piling operation in the winter of 2005, and determined the costs and productivities of these activities.

Title	Production rates for United States Forest Service brush disposal planning in the northern Rocky Mountains
Authors	Loeffler, D., Hoyt, S., and Anderson, N.
Date	2017
Data collection methodology	Literature review, survey questionnaire
Keywords	Brush disposal, prescribed fire, timber sales, U.S. Forest Service Northern Region, fuel management
Ecosystems	Boreal black spruce

Abstract or relevant findings

Timber harvesting operations generate brush and other vegetative debris, which often has no marketable value. In many western U.S. forests, these materials represent a fire hazard and a potential threat to forest health, and must be removed or burned for disposal. Currently, there is no established, consistent method to estimate brush disposal production rates.

This new guide can be used to improve brush disposal planning and may serve as a model for other regions to collect and provide updated information that reflects current forest conditions, practices, and productivity.

Precommercial thinning and vegetation control

Title	**Five case studies of precommercial thinning in British Columbia and Alberta**
Authors	Hedin, I.B.
Date	1982
Data collection methodology	Worker productivity, stand characteristics, slope and ground conditions
Keywords	Precommercial thinning, motor-manual productivity, spacing
Ecosystems	Coastal B.C., Interior B.C., regenerating lodgepole pine in Central Alberta

Abstract or relevant findings

Precommercial thinning (PCT) (juvenile spacing) is an important stand treatment in both natural and planted stands. For our first investigations into PCT in 1981, we undertook five case studies: three on Vancouver Island, B.C., one in the British Columbia interior, and one in Alberta. The data from these will help foresters in planning or supervision of PCT operations and will help in the development of new techniques to overcome the limitations of present techniques. During the thinning trials, the following tools were used—chain saws, clearing saws, and non-powered ratchet shears.

Title	**Semi-mechanized precommercial strip thinning: A practical operations guide**
Authors	St. Amour, M.
Date	2007
Data collection methodology	Worker and machine productivity (time/ha), stand characteristics, slope and ground conditions
Keywords	Brushcutters, thinning, precommercial strip thinning, productivity, semi-mechanized operation
Ecosystems	Eastern Canada, high-density stands

Abstract or relevant findings

The mechanization of precommercial thinning has increased significantly in eastern Canada following the development of machines that are better adapted to semi-mechanized strip-thinning. Forestry companies and contractors have taken advantage of this equipment to mitigate a shortage of workers and improve their working environment. Specialized machines (brushcutters) clear corridors in high-density forest stands to facilitate access for personnel operating clearing saws to further thin the leave strips.

This guide has been designed to inform companies and contractors of the various factors that must be considered when planning a mechanized precommercial strip-thinning operation.

Title	**A trial of semi-mechanized precommercial thinning in Quebec**
Authors	St. Amour, M.
Date	1998
Data collection methodology	Worker and machine productivity (time/ha), stand characteristics, slope and ground conditions
Keywords	Brushcutters, thinning, precommercial strip thinning, productivity, semi-mechanized operation, Silvana Selective cleaning machine
Ecosystems	Cote-Nord region of Quebec, high-density regeneration following harvest

Abstract or relevant findings

Despite the machine's good performance, the treatment with the machine failed to help the motor-manual workers. As a result, their productivity did not improve enough to reduce the total cost of the treatment compared with that of a strictly motor-manual operation. In addition, the work quality in the semi-mechanized operation was inferior to that in the strictly motor-manual operation. The passage of the machine wounded some of the crop trees by crushing them or rubbing off bark due to the wheels or the brushcutting head.

Title	**A semi-mechanized method for the release of post-fire natural regeneration**
Authors	St. Amour, M. and Cormier, D.
Date	2007
Data collection methodology	Worker and machine productivity, stand characteristics, slope and ground conditions
Keywords	Brushcutters, post-fire regeneration, precommercial strip thinning, productivity, semi-mechanized operation, productivity
Ecosystems	Quebec, high-density regeneration following wildfire

Abstract or relevant findings

This study demonstrated that semi-mechanized stripcutting can reduce treatment costs in high-density post-fire stands.

Treatment quality was good, with workers able to preserve between 2500 and 2600 stems per hectare.

Title	**Concentrating removal in patches to improve manual thinning productivity**
Authors	Ewing, R. and Lirette, J.
Date	2001
Data collection methodology	Worker and machine productivity (time/ha), stand characteristics, slope and ground conditions
Keywords	Commercial thinning, manual operations, concentrated removal, productivity
Ecosystems	Quebec, natural stands and plantations
Abstract or relevant findings	
Motor-manual thinning operations can represent an important source of work for forestry workers and a source of fiber for companies, but they remain more expensive than fully mechanized operations. FERIC studied three approaches based on concentrating the removal of stems to improve the productivity of motor-manual thinning, and found that this approach could significantly reduce wood costs.	

Title	**Stand cleaning with Husqvarna 165X clearing saws in Northern Alberta**
Authors	Holmsen, S.
Date	1988
Data collection methodology	Worker productivity, stand characteristics, slope and ground conditions
Keywords	Vegetation control, cleaning, motor-manual method, brush saws, plantations, evaluation, productivity, costs, time study
Ecosystems	White spruce plantation with high-density deciduous ingrowth
Abstract or relevant findings	
For many sites, successful reforestation requires vegetation management programs to free the coniferous seedlings from competing vegetation. In August 1987, FERIC monitored a motor-manual vegetation control project in a 6-year-old white spruce (*Picea glauca*) plantation near Grande Prairie, Alberta. The average productivity was 0.049 ha/PWH. Based on an 8-hour shift at the 77% utilization level experienced in this project, the average production was 0.30 ha/shift.	

Title	**Comparison of four single-stem methods for controlling trembling aspen**
Authors	Holmsen, S.
Date	1990
Data collection methodology	Worker productivity, stand characteristics, slope and ground conditions
Keywords	Vegetation control, manual method, hardwood competition, herbicides, hack and squirt, girdling, comparison, evaluation, productivity, costs
Ecosystems	Natural regeneration of lodgepole pine/white spruce with aspen ingrowth; plantation (lodgepole pine, Douglas-fir, white spruce) with aspen ingrowth
Abstract or relevant findings	
In 1989, four single-stem vegetation control methods were used on trembling aspen overstorey on two study sites, at Prince George and Kelowna, B.C. The study compared cost and productivity of four treatments: hack and squirt, GEL CAP, EZJECT, and girdling.	

Falling operations

Title	Helicopter logging in British Columbia: pole logging with the Kamov KA-32A
Authors	Dunham, M.
Date	2002
Data collection methodology	Faller and yarding productivity (time/ha), stand characteristics, slope and ground conditions
Keywords	Helicopter logging, Kamov KA-32A, aerial logging, partial cutting, selective harvesting, productivity, costs, coastal British Columbia
Ecosystems	Coastal British Columbia, old growth forests in Coastal Western Hemlock biogeoclimatic zone

Abstract or relevant findings

Falling of cedar poles began in mid-May and was completed by late June. Late winter snowfall periodically interrupted the falling schedule. In the 22 scheduled falling days during this period, 75 faller-shifts were worked.
Based on the net volume, each faller produced an average of 37.8 m^3/6.5-hour shift worked. Falling productivity was low because the fallers had to find, select, and fall the appropriate trees in closed canopy conditions. The late winter snowpack, up to 1.5 m deep on lower slopes, further reduced productivity.

Title	Helicopter logging on the Queen Charlotte Islands: productivities and costs of a Sikorsky S-64E Skycrane in clearcuts, patch cuts and single-tree selection cuts
Authors	Krag, R. and Evans, C.
Date	2003
Data collection methodology	Faller and yarding productivity (time/ha), Stand characteristics, Slope and ground conditions
Keywords	Helicopter logging, Sikorsky S-64E Skycrane, Partial cutting, Clearcut, Patch cut, Single-tree selection, Productivity, Costs, Ground disturbance, Residual stand damage, Coastal British Columbia.
Ecosystems	Coastal British Columbia, old growth forests in Coastal Western Hemlock

Abstract or relevant findings

This report focuses on the performance of the helicopter yarding operation. It describes the falling, yarding, and loading phases and compares productivities, costs, and site and stand impacts of helicopter logging on difficult terrain in clearcut, patch cut, and single-tree selection prescriptions.
Compared to clearcutting, falling and yarding productivities showed minor to moderate decreases and harvesting costs showed corresponding increases as retention levels increased. Falling productivity was influenced by the steep, difficult terrain and the partial cutting treatments.

Title	**Time consumption and productivity in manual tree felling with a chainsaw – a case study of resinous stands from mountainous areas**
Authors	**Câmpu V.R. and Ciubotaru A.**
Date	2017
Data collection methodology	Faller productivity, stand characteristics, slope and ground conditions
Keywords	Time study, work time structure, harvesting systems, resinous temperate forest, Husqvarna
Ecosystems	Mixed spruce forest stands in Romanian Southern Carpathians
Abstract or relevant findings	
The purpose of this research is to establish time consumption and productivity when using a Husqvarna 365 chainsaw for resinous tree felling in mountainous regions. The research was conducted in the Romanian Southern Carpathians, in two mixed spruce (*Picea abies*) and fir (*Abies alba* Mill.) tree stands.	

Variations in equipment types

Title	**Comparison of chain saws and clearing saws for precommercial thinning in British Columbia**
Authors	Holmsen, S.
Date	1989
Data collection methodology	Productivity data collection for motor-manual operations, pre- and post-treatment stand characterization
Keywords	Precommercial thinning, chain saws, clearing saws, productivity
Ecosystems	Interior lodgepole pine, Western Hemlock
Abstract or relevant findings	
Traditionally, the spacing tool of choice has been the chain saw because it is a more versatile and less expensive tool than the clearing saw. However, with increased emphasis now placed on stand improvement and management, selecting the most appropriate tool will play an increasingly important role in spacing activities. This report evaluates the productivities and post-treatment data resulting from a comparison study of chain saws and clearing saws on two different sites in British Columbia. The results of this study indicate that terrain and stand conditions will determine the choice of tool for precommercial thinning operations.	

Title	**Comparison of clearing saw cutting attachments for weeding young conifer plantations**
Authors	Holmsen, S.
Date	1988
Data collection methodology	Productivity data collection for motor-manual operations, pre- and post-treatment stand characterization
Keywords	Vegetation control, motor-manual operations, brush saws, cutting attachments, seedling damage, plantations, productivity
Ecosystems	Interior Cedar – Hemlock biogeoclimatic zone
Abstract or relevant findings	
FERIC conducted productivity assessments of three cutting attachments for Husqvarna clearing saws. Pre-treatment vegetation and post-treatment seedling damage were examined.	

Title	**Use of a portable capstan winch and associated hand tools in manual thinning**
Authors	Ewing, R.
Date	2001
Data collection methodology	Productivity, monitoring thinning operations
Keywords	Manual thinning, Simpson model SP portable capstan winch, synthetic-fiber rope, hand tools
Ecosystems	Lac-St-Jean region of Quebec

Abstract or relevant findings

Manual “cut and pile” operations are physically demanding. Furthermore, productivity is generally low and wood costs are usually high compared with mechanized systems in larger scale industrial operations. Carrying the bolts from within the strip to the extraction trail and piling them is an arduous and time-consuming task for the feller.

In November 1999, FERIC conducted a field trial of a portable, low-cost capstan winch and various hand tools to move pre-bunched stems to the extraction trail in a manual, commercial first thinning operation.

Planting operations

Title	Planter productivity in prepared and unprepared ground: a case study
Authors	Stjernberg, E.
Date	1991
Data collection methodology	Productivity data collection for motor-manual operations, pre- and post-treatment stand characterization
Keywords	Mechanical site preparation, productivity of manual tree planters
Ecosystems	ESSFf biogeoclimatic zone (Englemann Spruce-Subalpine Fir)
Abstract or relevant findings	
FERIC studied planting productivity on one area that had been disc trenched and on another that had not received any mechanical treatment. Planters considered both areas easy to plant. Actual planting activities (walk, reconnaissance, screefing, and planting) required a similar percentage of total time in both unprepared and prepared areas. However, screefing occupied 20% of time in the unprepared area and 2% of time in the area that had undergone site preparation.	

Title	**Planting large seedlings: Preliminary studies in Quebec**
Authors	St. Amour, M.
Date	1995
Data collection methodology	Productivity, timed studies
Keywords	Productivity, planting, bareroot stock, container stock, seedlings
Ecosystems	
Abstract or relevant findings	
Large seedlings are being planted in Quebec as an alternative to the application of herbicides. To date, several million of these large seedlings have been planted, and preliminary results on their survival and growth are promising. FERIC conducted time studies on planting operations during the 1993 and 1994 seasons. Seedling size, type of packaging, and site preparation methods were the main factors that affected planter productivity. The study indicated that seedling size had a direct effect on planter productivity, primarily because of the increased time spent preparing the planting hole and the more frequent provisioning required by using large seedlings. Plastic tubs were the most efficient type of container for transporting and delivering the large stock, since refill times were shorter. The tubs were also easier to handle and to recover from the field, and they fit into the rack systems currently used for conventional stock.	

Title	**Strategies for in-fill planting to supplement advance regeneration**
Authors	Cormier, D.
Date	2001
Data collection methodology	Productivity, density and distribution of advance regeneration
Keywords	Advance regeneration, protection of advance regeneration, in-fill planting, productivity, costs
Ecosystems	Post-harvest softwood and mixedwood forests

Abstract or relevant findings

Significant efforts have been made to preserve advance regeneration during harvesting operations. Despite efforts to protect regeneration, complete coverage of a site by advance regeneration is often improbable as a result of an imperfect initial distribution of the regeneration and the presence of extraction trails. This study illustrates the benefits of preserving the existing advance regeneration and serves as the basis for assessing various in-fill planting strategies designed to improve stocking at the lowest possible cost.

Title	**Injury reduction and performance enhancements in tree planters: productivity and quality analysis**
Authors	Stjernberg, E.
Date	2003
Data collection methodology	Productivity, timed studies, physiological data collection, terrain and ground cover evaluation
Keywords	Tree planters, productivity, injury reduction, performance enhancements, quality
Ecosystems	Northern Alberta cutblocks with some site preparation

Abstract or relevant findings

The Forest Engineering Research Institute of Canada (FERIC) participated in a study involving injury reduction and performance enhancement for tree planters. The tree planters were assigned one of three treatments: consuming a placebo drink supplement, consuming an electrolyte carbohydrate beverage as a drink supplement, or following a physical training regimen for 8 weeks prior to the planting season. FERIC determined the productivity and quality of planting of planters working in the different treatment groups, and determined if other factors, including experience, gender, time of day, and terrain conditions, influenced the results.

Title	**The risk of slips, trips, and falls for tree planters on steep slopes with slash**
Authors	Nishio, G.
Date	2013
Data collection methodology	Productivity, timed studies, data collection on frequency of slips, trips, and falls, site characterization
Keywords	Steep slopes, mechanical site preparation (MSP), tree planters, injuries, slash, tethering
Ecosystems	Clearcut harvest blocks near Princeton, B.C. and Chilliwack, B.C.

Abstract or relevant findings

FPInnovations completed a study that investigated the slope limits of mechanical site preparation (MSP) and steep slope–related injury risk for tree planters on 35–50% slopes near Princeton, B.C. and 54–80% slopes near Chilliwack, B.C. Slope and GPS data were collected for tracked disc-trenching and excavator mounding equipment on moderate slopes. Planter productivity, slope, and other site data were collected on both moderate and steep slopes with slash.

The trial data analyses indicated that tree planters experienced a higher frequency of slips, trips, and falls due to slash-related obstacles on slopes greater than 50%.

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