Productivity of a motor-manual forest-fuel reduction treatment: a case study in Central Alberta

Technical report no. 51 - July 2017

Steven Hvenegaard, Researcher, Wildfire Operations
Rex Hsieh, Technologist, Wildfire Operations

NON-RESTRICTED DISTRIBUTION

fpinnovations.ca

FPInnovations is a not-for-profit world-leading R&D institute that specializes in the creation of scientific solutions in support of the Canadian forest sector's global competitiveness and responds to the priority needs of its industry members and government partners. It is ideally positioned to perform research, innovate, and deliver state-of-the-art solutions for every area of the sector's value chain, from forest operations to consumer and industrial products. FPInnovations' staff numbers more than 525. Its R&D laboratories are located in Québec City, Montréal and Vancouver, and it has technology transfer offices across Canada. For more information about FPInnovations, visit: www.fpinnovations.ca.

Follow us on:

301012308: Productivity of motor-manual fuel treatment operations. A case study at the Pelican Mountain FireSmart research area.
Technical Report no. 51

ABSTRACT

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 labor intensive and time consuming. In the winter of 2016/17, FPInnovations documented the productivity of a fuel treatment conducted by workers using chainsaws and handtools 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 to plan and budget for motor-manual fuel treatments and to develop operational best practices.

ACKNOWLEDGEMENTS

This project was financially supported by Alberta Agriculture and Forestry.

The authors thank Alberta's Wildfire Management Branch and personnel in the Slave Lake Forest Area for their ongoing pursuit of operational wildfire science through the development of the Pelican Mountain FireSmart Research Project.

The authors also thank Slave Lake Forest Area personnel for their assistance in coordinating activities with the treatment crew.

REVIEWER

Louis J Price, RPF
Wildfire Technologist
Slave Lake Forest Area
Wildfire Management Branch
Forestry Division, Alberta Agriculture and Forestry

CONTACT

Steven Hvenegaard, Researcher,
Wildfire Operations
780-740-3310
steven.hvenegaard@fpinnovations.ca

© 2017 FPInnovations. All rights reserved. Unauthorized copying or redistribution prohibited.

Disclosure for Commercial Application: If you require assistance to implement these research findings, please contact FPInnovations at info@fpinnovations.ca.

Table of contents

List of figures

List of tables

BACKGROUND

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 personnel 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 the fuel-reduction principles, i.e., reducing surface fuel, increasing height to live crowns, decreasing crown density, and retaining larger and healthier stems.

A productivity study is typically designed to evaluate how productivity can be affected by an operational or environmental variable. Productivity studies of motor-manual forest operations have been typically associated with precommercial thinning 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 impacts of a change in a single operational variable (equipment type).

Modifying a work practice or prescription (Ewing and Lirette, 2001) in precommercial thinning operations is another way that changes in productivity can be evaluated through a change in an operational variable.

This productivity study did not attempt to measure changes in productivity resulting from a change in an operational variable. The motor-manual fuel-treatment operation at this study site provided a good opportunity to observe operations and collect baseline data for current and conventional practices.

OBJECTIVE

We observed and documented fuel-treatment operations performed by a crew that used typical motor-manual fuel-reduction techniques in a black spruce forest stand.

The primary objective of this study was to measure the productivity of the operation. A secondary objective was to assess operational practices and identify opportunities to develop efficiencies. The work took place over three periods, from December 2016 to February 2017. The productivity data and other findings are reported here.

STUDY SITE

The Pelican Mountain FireSmart Research Area has been developed by Alberta Agriculture and Forestry. It is located in central Alberta, 35 km southeast of the town of Wabasca (Figure 1).

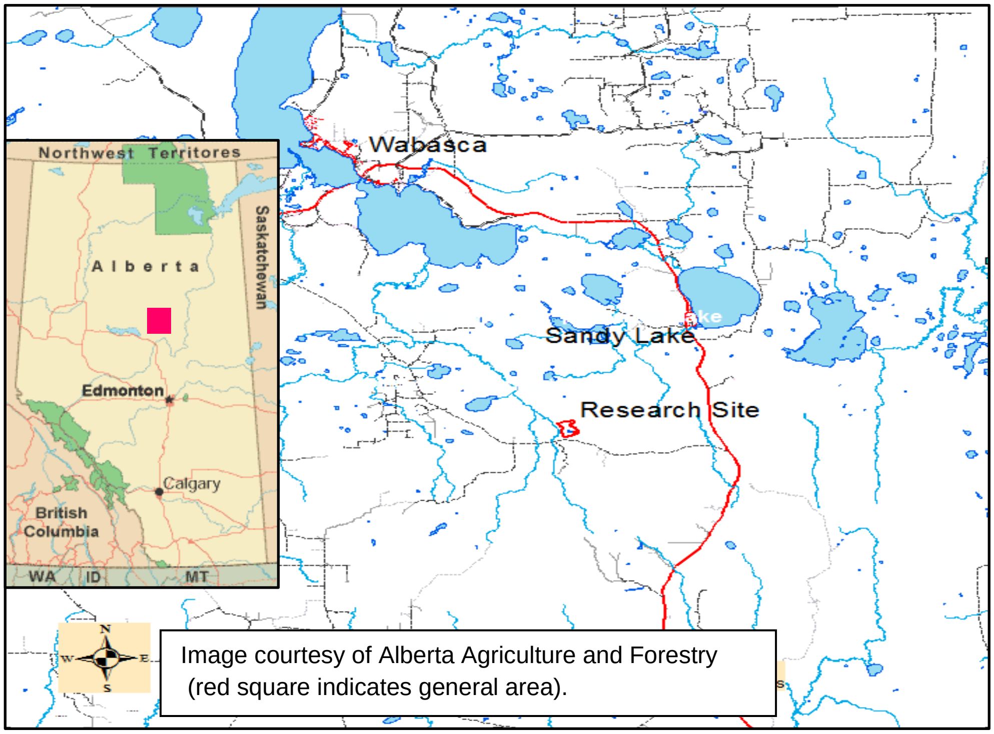

Figure 1. Location of the Pelican Mountain FireSmart Research Area.

Burn Unit 1 (Figure 2) has been prepared for the ultimate purpose of conducting an experimental fire in order to collect research data related to wildfire, forest fuel treatments, and community protection. The motor-manual productivity study was conducted in a 1.5-ha area in the southern portion of Burn Unit 1. The slope in the treatment area is <5%.

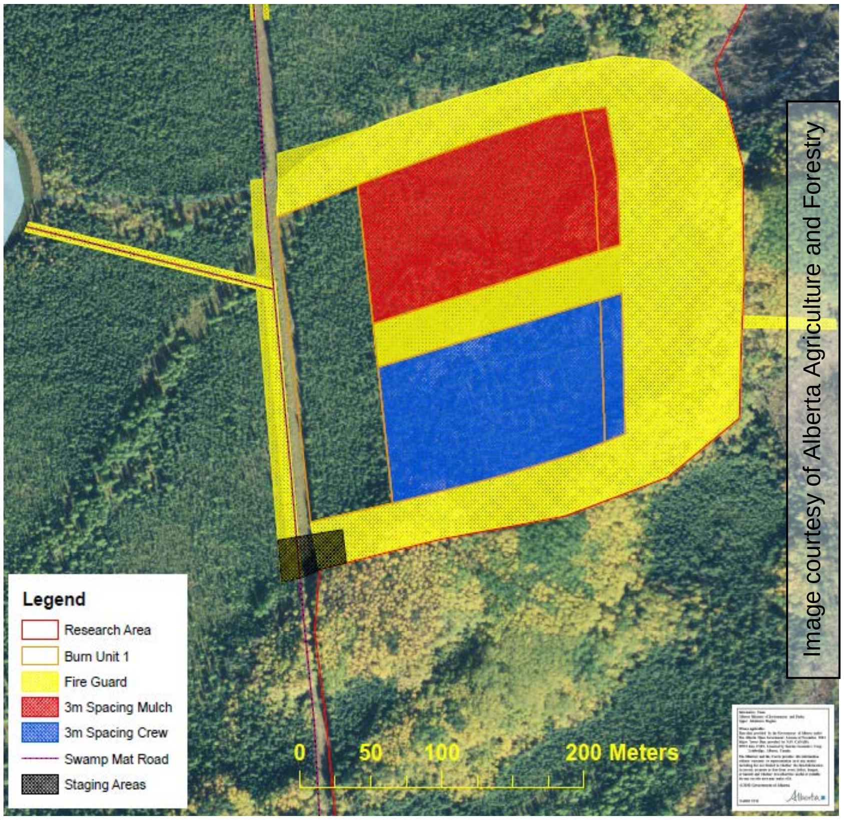

Figure 2. Burn Unit 1 at the Pelican Mountain FireSmart Research Area.

The stand in Burn Unit 1 is comprised predominately of black spruce (Table 1). Pre-treatment stand characteristics, including overall stem density and mean height, are shown in Table 2. The mean stand age of Burn Unit 1 is 59 years.

Table 1. Stand composition

Layer	Black spruce (%)	Jack pine (%)	Lodgepole pine (%)	White birch (%)	Trembling aspen (%)
Overstorey [a]	93.4	4.6	1.5	0.5	0
Understorey [b]	97.8	0	0	0.7	1.5

[a] Overstorey stems ≥9 cm diameter.
[b] Understorey stems ≤9 cm diameter and >1.3 m high.

Table 2. Pretreatment stand description [a]

Layer	Density (no. stems/ha)	Mean height (m)	DBH (cm)	Live crown base height (m)	Canopy fuel load [b] (kg/m^2)	Canopy bulk density (kg/m^3)
Overstorey [c]	2334 (1660)	8.94 (0.5)	10.5 (0.6)	2.88 (0.9)	0.9 (0.5)	0.15 (0.1)
Understorey [d]	4781 (3716)	3.4 (0.7)	3.1 (0.7)	1.10 (0.5)	0.9 (0.9)	0.4 (0.4)

[a] Standard deviation in parentheses.
[b] Canopy fuel includes needles and live twigs <0.5 cm diameter.
[c] Overstorey stems ≥9 cm diameter.
[d] Understorey stems ≤9 cm diameter and >1.3 m high.

Environmental conditions

Weather conditions varied considerably through the three operational time periods of this study. Prior to the start of the fuel-treatment work, temperatures were above average and several shallow water courses were not completely frozen.

In early December 2016, during the first period of treatment work, the average daily maximum temperature was –1.6°C and the minimum was –10.9°C.[1] At this time there was <5 cm of snow on the ground. On the last day of this period, there was a rapid shift in weather, with dropping temperatures and heavy snowfall.

Weather conditions during the second phase of work, i.e., in early January 2017 were much colder, with average daily maximum being –11.1°C and the minimum being –16.5°C. During this time period, there was approximately 40 cm of snow on the ground.

Additional treatment work was performed on February 15 and 16, 2017; the weather was unseasonably warm. The average daily maximum temperature was 8.2°C and the minimum was –2.2°C. There was no snow cover and the uppermost ground layer was thawing.

MOTOR-MANUAL FUELTREATMENT OPERATIONS

Fuel-treatment workers are often fire-fighting personnel who have been retained for off-season employment. The crew that we observed was comprised of four experienced, seasonal firefighters, each certified in chain-saw operation. On some days a fifth person assisted in the operation.

In the study at Burn Unit 1, the chain saw was the main tool used to conduct the forest fuel-reduction treatment. The crew used the Husqvarna 365, which is the standard issue for fire-fighting crews in Alberta, for brushing and limbing operations. Two chain saws were equipped with a 22-inch (56-cm) bar and one chain saw had a 24-inch (61-cm) bar. Other equipment included machetes, drip torches, a tiger torch with a propane bottle, and brush rakes.

[1] Weather data obtained from Environment Canada's weather station in Slave Lake, Alberta.

The prescription for this fuel treatment was based on FireSmart (Partners in Protection, 2003) guidelines for thinning stems to a 3-m crown spacing and removing lower branches to a height of 2 metres. But, in order to maintain average stem spacing throughout the plot, the textbook prescription was not strictly adhered to 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.

Although most of the stem and limb removal was achieved with the chain saw, a machete was required to remove higher limbs that could not be reached easily with the chain saw.

The crew worked in teams made up of one chain-saw operator and one helper. The chain-saw operator would cut the unwanted stems at ground level and limb the residual stems while the helper would gather, pile, and burn the cut stems and branches. In order to maintain a safe working distance, the chain-saw operator would alternate between two cutting areas while the helper gathered and burned cut debris from the alternate area. The helper had two or more burn piles to feed with the intention of maintaining a fire intensity that could consume all the larger pieces of debris.

The requirements for using personal protective equipment were strictly adhered to. The equipment included hard hat, face shield, safety glasses, hearing protection, chain-saw pants, steel-toed boots, and gloves.

STUDY METHODS

Forest fuel inventory

Pre-treatment and post-treatment sampling forest fuel sampling was conducted by the Alberta Wildland Fuels Inventory program crews. Wildland Fuels Inventory personnel processed sampling data from seven inventory plots in order to produce forest fuel inventory data that details fuel loading of the critical fuel strata (overstorey and surface fuels).

Productivity data

The motor-manual fuel treatment under study was conducted during three different periods, in December 2016, and January and February 2017.

During the first period of work, from December 1 to 4, 2016, we measured the amount of area that was processed each day and the operational time. At the end of each day, we walked the perimeter of the area processed that day and recorded a GPS track to determine the area processed. Since the crew size changed from day to day, we recorded man-hours as the measure of manpower utilized for each day.

During the second work period, from January 4 to 8, and on January 18, 2017, we were not on site, so we used data (hours of work) provided by the crew leader. We calculated daily productivity as area (ha) per man-hour. We used 5.25 h/day as the conversion factor to produce a productivity rate expressed as hectares per day.

During the third period of work, February 15 to 16, 2017, we were on site and recorded the number of man-hours worked.

We used Allegro hand-held data loggers to conduct detailed timing of the chain-saw operator and the helper. For each of these roles, major operational tasks were identified and an activity code was assigned to each task. We used the data logger to capture the amount of time that personnel spent on each task within a given time frame. We also used the data logger to count the number of times that an operator performed a specific movement or operation.

RESULTS

Forest fuel inventory

Post-treatment stand characteristics, including overall stem density and mean height, are shown in Table 3. Preliminary post-treatment fuel inventory analysis indicates that the overstorey stand density was reduced from 2334 stems/ha (Table 2) to 1228 stems/ha (Table 3).

Table 3. Post-treatment stand description [a,]

Layer	Density (no. stems/ha)	Mean height (m)	DBH (cm)	Live crown base height (m)	Canopy fuel load [b] (kg/m^2)	Canopy bulk density (kg/m^3)
Overstorey [c]	1228 (483)	n.a.	n.a.	3.5 (0.4)	0.6 (0.2)	0.1 (0.03)

[a] Standard deviation in parentheses.
[b] Canopy fuel includes needles and live twigs <0.5 cm diameter.
[c] Overstorey stems ≥9 cm diameter.

Productivity

Productivity for November 30 to December 4, 2016 is shown in Table 4. The average productivity for this time period was 0.008 ha/man-hour with a crew productivity of 0.168 ha/day (based on four men working 5.25 h/day). The progression of the fuel-treatment work through site is shown in Figure 3.

Table 4. Productivity during the first treatment period

Date	Man-hours (no./day)	Area processed (ha)	Productivity (ha/man-hour)
November 30	22.5	0.20	0.009
December 1	23.0	0.10	0.004
December 2	25.0	0.30	0.012
December 3	23.0	0.20	0.009
December 4	12.0	0.06	0.005
Total	**105.5**	**0.86**	**0.008 (overall)**

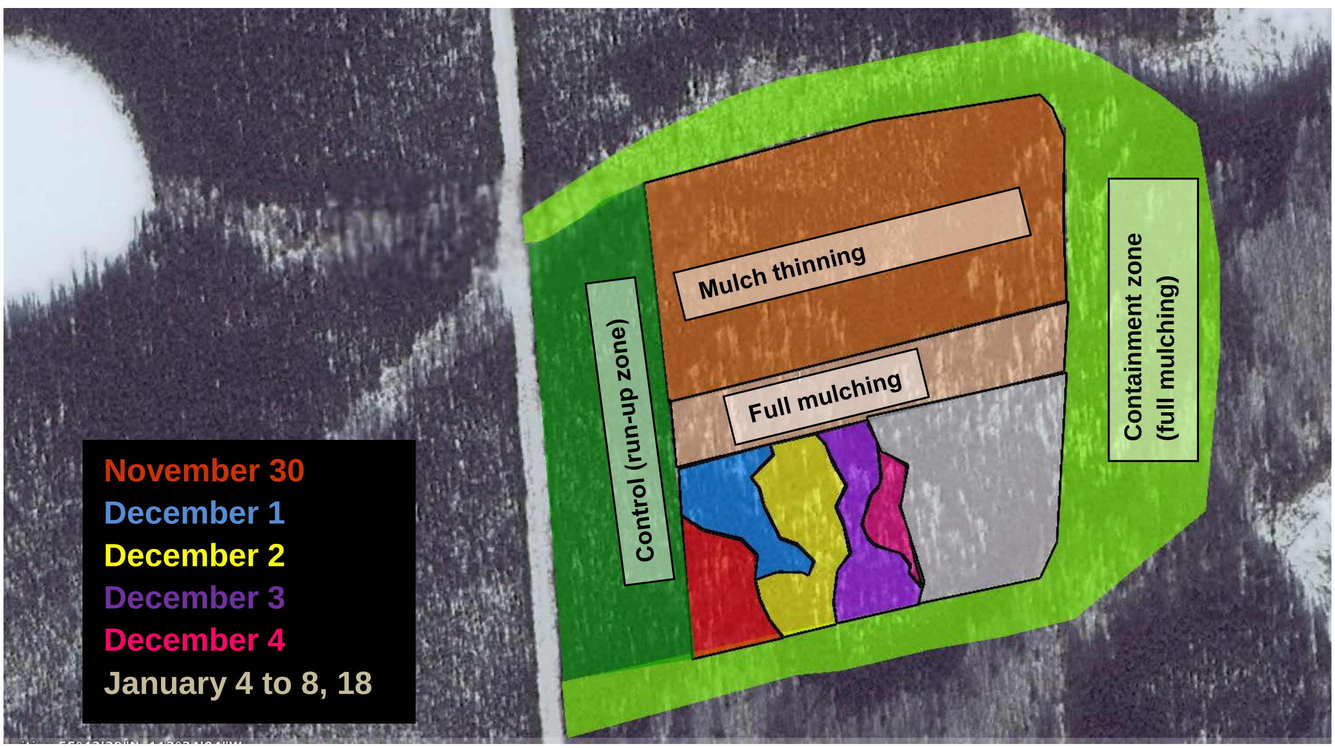

Figure 3. Daily progression of the fuel-treatment work.

The remaining area (0.64 ha) was completed in 6 days (January 4 to 8 and January 18, 2017). Each day the crew worked 21 man-hours and this resulted in an average daily productivity of 0.005 ha/man-hour.

During the third period of work, February 15 and 16, 2017, additional thinning work was done throughout the entire plot in order to be more compliant with the FireSmart standard of 3-m crown spacing. This work was also done to create stem spacing similar to that being created in the mechanically treated areas, as part of a paired study in the same burn unit. Alberta Agriculture and Forestry personnel performed 65 man-hours of thinning and piling operations. When this additional time is factored in, the overall man-hours for the treatment totalled 296.5 and the overall productivity was 0.0051 ha/man-hour. Based on a 5.25-h working day for four workers, this would equate to a daily productivity of 0.106 ha/day.

Table 5. Overall productivity during three treatment periods

Timeframe	**Man-hours**	**Area processed (ha)**	**Productivity (ha/man-hour)**
November 30 to December 4, 2016	105.5	0.86	0.008
January 4 to 8, January 18, 2017	126.0	0.64	0.005
February 15 and 16, 2017	65.0		
Overall	296.5	1.5	0.0051

We conducted detailed timing of a chain-saw operator in the morning and afternoon of each day in the first treatment period. Our data indicate consistent trends in the amount of time spent on each of the tasks that we tracked. A summary of these tasks (Table 6) shows that chain-saw operators were productively engaged in brushing or limbing activities for 67.7% of the time.

Brushing with a chain saw requires bending over to cut the stem near ground level. Our detailed timing shows that one chain-saw operator bent over to cut stems at ground level 50 times in a 97-min time frame.

Limbing operations were conducted concurrently with the brushing operations. Limbing of lower branches was accomplished by running the chain saw up and down the stem. Branches were abundant on some stems; therefore it was often necessary to run the saw along one stem up to four times in order to remove all the branches. Detailed timing shows that chain-saw operators raised the chain saw to shoulder height an average of 5 times/min to remove branches.

Gathering and moving debris were the major activities performed by the helper. For 69.6% of the time the helper was engaged in moving branches or stems to a burn pile (Table 6). To perform these tasks, the helper must bend over many times in a day. In one detailed timing set (46 min) the helper bent over to gather or pick up debris 180 times.

Table 6. Breakdown of the chain-saw operator's time, by task

Worker	Brushing (%)	Limbing (%)	Mechanical stop (%)	Personal stop (%)	Travel (%)	Moving debris (%)
Chain-saw operator	31.0	36.7	4.7	2.1	21.2	4.3

Table 7. Breakdown of helper's time, by task

Worker	Moving debris		Mechanical stop (%)	Personal stop (%)	Gathering debris (%)	Ignition (%)	Raking debris (%)	Tending fire (%)
	Empty (%)	Full (%)						
Helper	35.1	34.5	0.0	2.1	21.0	0.5	3.5	3.3

DISCUSSION

Opportunities to enhance efficiency

Several advantages can be stated for using manual crews rather than machinery to conduct fuel treatments. Using manual crews provides valuable employment for seasonal workers. Workers usually require minimal training because many are off-season fire fighters and therefore already have chain-saw certification. For uncertified personnel, this work is a good opportunity to advance chain-saw skills and attain certification. Some specialized equipment can be used but personnel quickly adapt and learn operating skills for these tools. In forests that are close to communities, maintaining aesthetics is often an objective and manual crews can apply more precision in achieving this objective than if the work is done with larger equipment.

Even though there are many benefits of using manual crews, cost-effectiveness and scale of application are major considerations for fuels managers in determining the most appropriate treatment method. Fuels managers across Canada have indicated that manual fuel treatments are the most expensive method of treatment (Hvenegaard, 2012); operators and administrators need to consider ways to increase efficiency and reduce cost.

The key advantages of using the chain saw for motor-manual treatments are its versatility and availability, and its familiarity amongst wildfire personnel. The chain-saw operator is able to remove unwanted stems and limb residual stems with the same tool. Because it is standard issue for fire operations, the Husqvarna 365 chain saw and parts are readily available. 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, we should attempt to identify potential opportunities that can 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 using clearing saws had difficulty moving through the forest stand and productivity was lower than that of operators using chain saws.

During this study at Pelican Mountain FireSmart Research Area, the chain-saw operator would typically work continuously for the duration of one tank of fuel (approx. 1.5 h). The combination of the two primary movements (lifting the chain saw and bending over) with other activities for 1.5 h appeared to be quite strenuous and tiring. The crew members alternated between the two roles of operating the chain saw and being the helper, and this likely helped to reduce fatigue and mitigate the potential for repetitive stress injuries. In the interest of addressing these issues it may be worthwhile to explore ways to reduce the extent of the workers' exertion and strain.

The degree of fatigue could be reduced through the use of alternative power tools and manual tools. Limbing could be done with less strain and fatigue by using a smaller and lighter chain saw. Machetes come in a wide variety of sizes and are useful for one-handed limbing. For removing small branches, a machete is usually adequate. Brush hooks have a longer handle (91 cm) and a greater mass, which necessitates two-handed operation. With the longer reach, greater mass and two-handed operation, less overall effort may be needed to remove branches along a stem with one swipe.

Using a clearing saw for removing stems in the thinning operation would result in the worker bending over less, with the potential for reduced fatigue. If the worker is also fitted with a load-bearing harness, there would be less strain on the arms. With some consideration given to technique, this could result in a potential for increased productivity. Clearing saws are often used for motor-manual thinning in silviculture operations; comparative studies show increased productivity on flat ground when clearing saws are used (Holmsen, 1989).

Impact of stand density

It was apparent that production dropped as the crew moved into high-density areas. Although several inventory plots had been established throughout the treatment area, the crew's daily work was not closely aligned with these plots and we could not measure production as a function of stand density. The results of this study present an overall productivity rate for the entire plot. Further studies will help to determine productivity in forest stands of a given stand density. These data would benefit fuels managers in planning their budgets for fuel treatments.

Travel and other essential activities

The Alberta Agriculture and Forestry crew were scheduled on a 9-h work day, which started at 0730 and ended at 1730 (with 1 h taken for lunch). Travel time (one way) to the staging area varied with the weather, ranging from 45 min under good road conditions to 75 min under marginal conditions. An additional 15 min were required to unload the side-by-side utility vehicle from the trailer and travel 700 m to the treatment site. Daily treatment operations typically commenced by 0900 and were completed at 1500.

Additional time at the start and end of the day was required for equipment servicing.

Cost analysis

The fuel treatment was administered through Alberta Agriculture and Forestry and was conducted by their seasonal staff who were retained to work on winter fuel-treatment projects. The overall cost for the entire 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 costs reported for manual treatment costs by other Canadian wildfire management agencies (Hvenegaard, 2012).

Productivity of larger crews

Motor-manual fuel treatments are often conducted using crews of different sizes. Typically, contract eight-person Firetack crews are used. Obtaining productivity data for this crew configuration would be helpful in planning and budgeting for fuel treatments. The most reliable productivity data would be obtained from case studies.

However, with some extrapolation of the results from this case study, one can make a coarse estimate of potential productivity. Based on the overall productivity of 0.0051 ha/man-hour, 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.

The 8 h of work applied in this calculation is the productive time that the crew would actually be on site performing treatment work (cutting, pruning, burning, and minor equipment servicing). Achieving 8 h of productive time may not be feasible for crews that need to drive long distances to reach the work site. For example, if a crew needs to drive 1 h to reach the fuel-treatment site and takes 1 h for breaks through the day, the overall length of the scheduled working day would be 11 h. But, if an eight-person crew is limited to a scheduled work day of 8 h and driving time is 1 h each way, productive time would be reduced to 5 h/day and the overall productivity would be 0.20 ha/day (1.02 ha for a 5-day work week).

A larger crew may be able to develop efficiencies related to the crew members' skill sets, the choice of equipment, the treatment technique, and the extent of supervision. Some intangible factors are difficult to isolate as independent variables but should be considered in the overall results.

Next steps

This study explored motor-manual fuel-treatment operations conducted by a manual crew using conventional tools and methods in a dense black spruce forest stand from December 2016 to February 2017 in central Alberta. The collected data will contribute to understanding baseline productivity of manual crews in this specific forest environment.

The results of this study are based on the productivity of the four-person crew working in winter conditions. Longer days and warmer weather conditions in summer will be conducive to longer work days and more favourable driving conditions, and therefore increased productivity.

The results can be compared to the costs and productivities documented in the semi-mechanized fuel treatment that was conducted in the north section of Burn Unit 1. The costs and productivities associated with these two different treatments address one side of the cost-effectiveness concern.

The effectiveness portion will be addressed by undertaking an experimental fire in order to observe and document changes in fire behaviour when this type of treatment is challenged by an approaching crown fire.

Future research should implement “side-by-side” comparative studies to isolate specific research variables such as alternative equipment and modified treatment techniques. Future testing of alternative equipment or techniques will require that participants are trained and proficient with that piece of equipment or treatment technique.

CONCLUSION

This project documented resource requirements and productivity for a motor-manual forest-fuel reduction treatment in dense black spruce in winter conditions in central Alberta. Fuels managers recognize that motor-manual fuel-reduction treatments are time consuming and expensive; this study provided quantified data that can help fuels managers plan and budget for fuel treatments. With further studies and discussion of treatment operations, innovative methods can be developed to create efficiencies and increase the productivity of motor-manual operations.

REFERENCES

Agee, J. K., & Skinner, C. N. (2005). Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211(1):83–96.

Ewing, R. H., & Lirette, J. (2001). *Concentrating removal in patches to improve manual thinning productivity* (Advantage Report, Volume 2, Number 14). Pointe-Claire, Quebec: Forest Engineering Research Institute of Canada.

Hedin, I. B. (1982). *Five case studies of commercial thinning in British Columbia and Alberta* (Technical Note TN-62). Vancouver, British Columbia, Forest Engineering Research Institute of Canada.

Holmsen, S. D. (1989). *Comparison of chain saws and clearing saws for precommercial thinning in British Columbia* (Technical Note TN-137). Vancouver, British Columbia: Forest Engineering Research Institute of Canada.

Hvenegaard, S. H. (2012). *National Wildland Fuels Management Survey (Revised)* (Contract Report CR-729(R)). Hinton, Alberta: FPInnovations, Wildfire Operations Research Program.

Partners in Protection (2003). FireSmart: Protecting your community from wildfire. 2nd ed. Partners in Protection, Edmonton, AB. Retrieved from: https://www.firesmartcanada.ca/resources-library/category/manuals

Head Office

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

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

Québec
319, rue Franquet
Québec, QC
Canada G1P 4R4
T 418 659-2647

OUR NAME IS INNOVATION

© 2017 FPInnovations. All rights reserved. Copying and redistribution prohibited.
® FPInnovations, its marks and logos are trademarks of FPInnovations