2008

EFFECTS OF MECHANICALLY GENERATED SLASH PARTICLE SIZE ON PRESCRIBED FIRE BEHAVIOR AND SUBSEQUENT VEGETATION EFFECTS

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Final Report to the Joint Fire Science Program
Project Number: 03-3-2-06
February 28, 2008

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INTRODUCTION:

Forest managers have begun to restore ecosystem structure and function in fire-prone ecosystems that have experienced fire exclusion, commodity based resource extraction, and extensive grazing during much of the 20th century. Mechanical thinning and prescribed burning are the primary tools for thinning dense stands and restoring pre-settlement forest structure, reducing the likelihood of devastating crown fires. Mechanical thinning can be costly when trees are non-merchantable and prescribed burning can be risky unless fuel loadings are first reduced. Furthermore, stands that remain dense after commercial thinning can produce undesirable wildland fire- or even prescribed fire- effects on vegetation and soils.

Land managers are interested in using mastication equipment (Fig. 1) for thinning non-merchantable trees as a means of restoring structure and function to dry forest ecosystems. However, it is unknown how the addition of mechanically derived slash influences potential fire behavior and fire effects. The objectives of this project were to test the effectiveness of mastication effort (defined as time needed to break fuels into smaller pieces) to 1) thin dense stands of dry coniferous forest within historically frequent, low-severity fire regimes (Fig. 1) and 2) create surface fuel beds that produce prescribed fire behavior with positive effects on residual trees, understory vegetation, and soils. Specifically, we asked the following questions:

(1) How does slash particle size and fuel bed depth affect fire intensity and severity?
(2) How do different mastication efforts and subsequent prescribed fire affect overstory vegetation?
(3) Does soil heating change from burning different types of masticated slash? and
(4) What are the differences in production costs among levels of mastication effort?

Figure 1. Mastication equipment used in the current study (left photo) and a pre-treatment stand to be thinned (right photo).

PROJECT LOCATION:

The research was located within the Hungry Hunter Ecosystem Restoration Project area on the Methow Valley Ranger District, Okanogan-Wenatchee National Forest. The primary objective of the project was to reduce fire risk within and adjacent to the wildland-urban interface. The restoration project was borne out of a collaborative multi-party process involving the Eastern Washington Provincial Advisory Committee (PAC). The Methow Valley Ranger District and Eastern Washington PAC wanted monitoring and research to be well integrated into the restoration project and the current mastication research fits with this objective.

METHODS:

We established 18 experimental units (~15 acres each) within the Hungry Hunter Ecosystem Restoration Project area that met pre-commercial thinning criteria (e.g. Fig. 1) and allowed for operation of mastication equipment. We used mastication equipment to thin and masticate non-merchantable trees. We randomly selected nine of the units to be masticated and burned, and the remaining nine units to be masticated but unburned. Thinning and mastication of slash fuels was accomplished during May through July of 2007. Underburning was carried out during relatively cool and moist conditions during the period from October 11 to November 1 of 2007. We implemented three levels of mastication – fine, mixed and coarse – with the fine level representing the most time (effort) spent per unit area and the coarse level representing the least time spent per unit area. Contract goals for post-treatment particle size were as follows: (1) fine – 75% <=6 inches in length, 20% >6 inches and <2 feet in length, and 5% >=2 feet in length, (2) mixed – 25% <=6 inches in length, 50% >6 inches and <2 feet in length, 25% >=2 feet in length, and (3) coarse – 20% <=2 feet in length, 75% 2-4 feet in length, and 5% >= 4 feet in length. We replicated each level of mastication effort on three treatment units assigned to be burned and three units excluded from subsequent burning.

	Fine (3 units)		Fine (3 units)
Burned-	Mixed (3 units)	Unburned-	Mixed (3 units)
	Coarse (3 units)		Coarse (3 units)

Within each experimental unit, we laid out a 130 x 130 foot grid oriented to the cardinal directions, with a total of 12 sample grid points per treatment unit. Surface fuel loadings and overstory trees were sampled at all 12 grid points using transects and circular plots, respectively. Overstory and understory vegetation was more intensively sampled within 65 x 165 foot plots at 4 randomly selected grid points within each unit. The pre- to post-treatment change for each variable was analyzed using a completely randomized design analysis of variance.

Soil heating was measured at 2-4 locations within each mastication treatment type to be burned. At each location, four thermocouples were placed at the mineral soil surface and four thermocouples were placed at two inches beneath the soil surface. Thermocouples were attached to a single data logger which was activated within six hours of the start of each prescribed burns and deactivated when there were no visible smoke in the vicinity of the data logger (up to three days after burning).

To compare production costs among treatments, we recorded the number of hours the mastication equipment worked in each treatment unit. This allowed us to calculate hourly costs, acres per hour accomplished by treatment type, and per acre cost by treatment type. Means were compared with univariate analysis of variance.

KEY FINDINGS:

Fuels

Mastication substantially increased the amount of coarse woody debris on the forest floor, but the amounts varied by fuel size class within and among treatments (Fig. 2). Fuel depth significantly increased in all three treatments. All three mastication treatments significantly increased loading of 1-hour fuels (< ¼ inch in diameter), but decreased loading of 1000-hour rotten logs (>3 inches diameter; Fig. 3). Loading of 10-hour fuels (¼-1 inch diameter) and 100-hour fuels (1-3 inch in diameter) remained similar to pre-treatment values in mixed and coarse treatment units. Loading of 10-hour fuels decreased slightly in the fine treatment units, while 100-hour fuels significantly increased in the mixed treatment units. Coarse and mixed treatments significantly increased the loading of sound 1000-hr fuels, while the fine treatment produced no significant change in these large fuels. Litter and duff depth were largely unaffected by treatments, except that the mixed treatment significantly increased litter depth.

Figure 2. Post-thinning stands showing masticated fuels in a coarse treatment unit (left photo) and patchy fuels in a fine treatment unit (right photo).

Burning also had variable effects on fuels, but were generally reduced in all treatments and in all fuel size classes. Burning significantly reduced 1-hour and 10-hour fuels in all treatments, but the slight reduction in 10-hour fuels in the fine treatment was not significantly different than pre-treatment loading. Burning significantly reduced 100-hour fuels only in the mixed treatment and 1000-hour sound logs only in the coarse treatment. Burning reduced rotten 1000-hour fuels across all treatments. Burning also significantly decreased fuel bed depth, litter depth, and duff depth in all post-mastication treatment units. However, burning the mixed treatment reduced this depths significantly more than either burning in fine or coarse treatments.

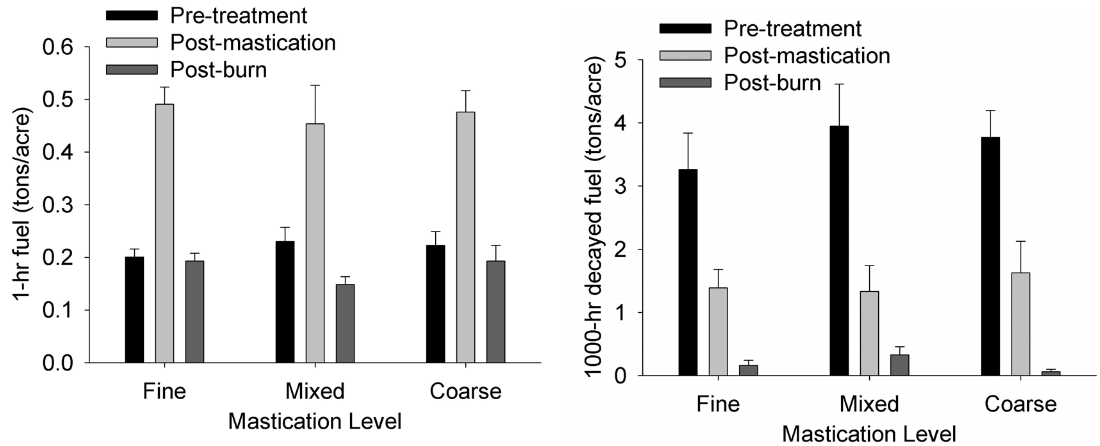

Figure 3. Changes to 1-hour and 1000-hr rotten fuel loadings following mastication and burning treatments.

Fire Behavior

Prescribed burns were patchy within all mastication units, but all units had greater than 50% of the acreage blackened. Weather conditions during prescribed burning were relatively cool, with temperature ranging from 39-59^{o}F and relative humidity from 30-70%, which obviously lead to burn patchiness. There were no significant differences in fire behavior variables among treatments (Fig. 4). Ignition was accomplished mostly by strip-head firing and resulted in backing and flanking spread rates of <2.5 chains/hour and head fire spread rates of <1 to 20 chains/hour. Fire intensity was relatively low with flame lengths mostly less than 3.3 feet.

Figure 4. Examples of fire behavior in a fine treatment unit (left photo) and a mixed treatment unit (right photo).

Forest Structure

The mastication equipment used in this study was successful at thinning non-merchantable trees less than 8 inches in diameter (Fig. 5). Overstory tree density and size class distribution prior to mastication treatments were variable and influenced post-treatment overstory. For example, stands assigned to the mixed treatment were largely composed of high density, small diameter lodgepole pine and thinning in these stands significantly reduced total tree density by more than half. In contrast, total tree density was not significantly reduced in the fine and coarse treatments because these stands tended to have a majority of trees in size classes that were not targeted for thinning. Treatment effects on basal area followed the same trends as tree density; only the mixed treatment significantly reduced basal area.

Treatment effects to seedlings and saplings were more pronounced. All mastication treatments significantly reduced saplings (<4 inches diameter, >4.5 feet tall) by >90%. Tree seedling densities were also significantly reduced in the fine and coarse treatments, but the reduction was not significant in the mixed treatment.

Figure 5. Stand density before and after a mixed mastication treatment.

Overstory mortality was minimal following prescribed burning. Mortality was insignificant in the month following underburning of masticated fuels and there were no differences among mastication treatments. Not surprisingly, treatments did not modify burning effects on stand basal area either. Prescribed burning did significantly increase height to live crown in the mixed treatment units, but not in the fine and coarse treatments (although average crown heights did increase slightly). Similarly, percentage of crown scorched was significantly more in the mixed than fine or coarse treatments. The prevalence of lodgepole pine and therefore smaller trees and lower crowns in the mixed treatments made it easier for fire to affect lower branches. In addition, mixed treatments had the highest 100-hr fuel loadings and some of the longest flame lengths were measured in the mixed units.

Soil Heating

Overall, soil heating was relatively low within all mastication treatment units that were burned. The patchy nature of the prescribed burns produced large variability in soil heating, with many thermocouples failing to record any notable increases in soil temperature during the burns. The coarse treatment had the highest average maximum temperature at the mineral soil surface (435^{o}F) and at two inches deep (230^{o}F). The highest temperature (872 ^{o}F) recorded at any site was in a coarse treatment unit. Duration of heating above lethal temperatures (>140 ^{o}F) was also greatest in the coarse units with maximum duration over 2000 minutes. Fine and mixed units had average maximum temperatures at the mineral soil surface of 71^{o}F and 84 ^{o}F, respectively. In these same units, duration of lethal heating never exceeded about 590 minutes and at some locations temperatures never exceeded 140 ^{o}F for any period time.

Economics

Cost seemed to relate more to tree size, both diameter and height, than to mastication effort. Our original hypothesis was that contract requirements for producing smaller slash pieces would result in longer production rates and be more costly. However, mastication effort, as defined by acres completed per hour, was not significantly different among mastication treatments (average of all treatments was 0.227 ac/hr). The average cost of mastication in all treatments was $452/acre. There was considerable variability in production rates and if we look at individual units, some interesting trends appear which should be considered when using this type of equipment over larger areas. Units with larger diameter and taller trees to be thinned took more time and, therefore more cost, to complete regardless of treatment type. For example, the mixed treatment units had high densities of small diameter lodgepole, but required less mastication effort than either the fine or coarse units, which generally had fewer but larger diameter trees to be thinned. As compared to other treatment options, the mastication equipment used in this study might be better suited to thinning dense stands of very small diameter trees (<4”) rather than stands with larger trees.

Underburning masticated fuels was comparable to underburning in other slash generated fuel types. Again, there were no significant differences in average cost per acre among treatment types. Average acre costs ranged from $120-128/acre, including line construction and post-burn patrol.

Mastication followed by burning is cost comparable to other methods of treatments that might be considered for dense stands and is potentially more efficient. An alternative treatment might include chainsaw felling of non-merchantable trees, hand piling of the resulting slash, and subsequent underburning. Total cost of this series of treatments would be about $505/acre (based on recent contract costs on the Okanogan-Wenatchee National Forest), which is comparable to the average $577/acre cost realized in this study. Furthermore, mastication and burning took place in the same year because fuels easily dried, whereas a comparable treatment generally takes at least two years in order for fuels to dry and depth to decrease (snow crushing tops and branches). Such production efficiencies should be considered when choosing treatment types.

CONCLUSIONS:

Mastication followed by burning is a viable treatment option for reducing fuels and stand density within dense stands for non-merchantable trees. Mastication allows for prescribed burning of slash in the same year of treatment, which is time saving compared to alternative treatments. Masticated fuels are easily burned, even under cool and moist weather conditions, and there appears to be very little mortality to overstory trees. Burning masticated slash does not lead to excessive soil heating and therefore, may not effect soil nutrients. Mastication effort was less important than the size of the material being masticated. Therefore, contract specifications should focus on tree removal and general mastication criteria that maximize production rates. Cost of mastication is comparable to other treatment options and ultimately may be cheaper if more acres are offered for contract.

DELIVERABLES:

Proposed	Delivered	Status
Website	http://www.fs.fed.us/r6/wenatchee/fire/mastication/index.shtml	done
Field Tours	Methow Valley Ranger District public collaborative group toured the study site. **May 2003.** Methow Valley Ranger District public collaborative group toured the study site. **October 2005.**	done done
Poster	Harrod, R.J., D.W. Peterson, R. Ottmar, and P. Ohlson. 2005. Effects of mechanically generated slash particle size on prescribed fire behavior and subsequent vegetation effects. Poster presented at JFSP annual meeting in San Diego.	done
Dataset	Post-mastication treatment fuel loading by treatment type (fine, medium, large masticated material).	done
Final Report	Harrod, R.J., D.W. Peterson, R. Ottmar. 2008. Effects of mechanically generated slash particle size on prescribed fire behavior and subsequent vegetation effects. JFSP Final Report	done
Managers Guide	Pre-commercial thinning using mastication equipment- a users guide	In progress. April 1, 2008.
Publications	Mastication and burning treatment effects on fuels and forest structure Mastication and burning treatment effects on forest understory	Submitted by June 1, 2008. Submitted by December 31, 2008.

ACKNOWLEDGEMENTS:

We thank the management and staff of the Methow Valley Ranger District, especially Arlo VanderWoude and Michael Dunn, for their hard work in implementing the mastication and burning treatments. We thank Erich Kyle Dodson for his assistance with data analysis and manuscript preparation. We gratefully acknowledge the hard work and dedication of Pete Ohlson and his field crew (Brandon Sheeley, Kathleen Moran, Caitlin Cray, Matias Rudback, Chad Yenney, Helen Lau, Eric Just, Bruce Akker, Maureen Akker, Darci Carlson, Daneille Clay, Alisha Toombs, Megan Whitmore, and Amy Duncan) who contributed their skills to field data collection for this project.