USDA

United States
Department of
Agriculture

Forest Service

Pacific
Northwest
Region

Okanogan-
Wenatchee
National Forest

January 2009

A User’s Guide to Thinning with Mastication Equipment

Background

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 reducing tree density and restoring pre-settlement forest structure, reducing the likelihood of devastating crown fires (Harrod et al. 2007). Mechanical thinning can be costly when trees are non-merchantable and prescribed burning can be difficult to control unless fuel loadings are first reduced. Furthermore, stands that retain dense non-commercial trees after commercial harvest can produce undesirable wildland fire or even prescribed fire effects on vegetation and soils (Graham et al. 2004).

Mastication is a mechanical fuel treatment used as a means to thin dense, non-merchantable forest stands. Types of mastication equipment are varied, have variable capabilities and limitations, have different treatment effects, and have different production rates. It is important to choose the right type of equipment to meet management objectives. The purpose of this guide is to provide resource managers with information to consider when using mastication equipment to thin dense stands.

Site and stand selection

Care is required when using mastication and a number of factors need to be considered. Factors to consider in selecting a site for mastication can include stand density, size, and species (bark thickness and season affecting wound susceptibility) of the trees to be removed, slope, soils, potential fire risk, proximity to high value resources and Wildland-Urban Interface (WUI). Slope steepness is perhaps the most limiting factor in site selection for mastication. Slopes that exceed 35% are generally considered inappropriate for most ground-based equipment and the ability to operate on steeper hillsides is impacted by the type of machine and operator abilities and experience. Some soil types are predisposed to increased erosion if disturbed (Brady and Weil 1996) and a certain amount of surface soil movement can be expected by tracked mastication equipment (Figure 1). While experience and abilities of the operator can affect the amount of disturbance, areas with highly erosive soil types may be inappropriate for mechanical treatment at certain times of the year.

Mastication equipment is best utilized in dense, non-merchantable stands (Figure 1) or stands that have been logged with high density of sub-merchantable trees remaining. Consideration should be given to the desired density of the residual stand. In order to provide adequate space to operate, a residual stand must have a minimum of 22x22 foot spacing for most types of equipment. Smaller diameter trees are more easily, quickly and effectively thinned and masticated into small diameter pieces than larger trees. The largest diameter trees to consider for mastication should not exceed roughly 8 inches since larger diameters result in heavy surface fuel loading and low production rates.

Figure 1. Example of some surface soil disturbance with mastication equipment (left photo). Potential stand for mastication (right photo).

Equipment Types

Cutting heads on mastication equipment fall into two general categories based on their rotational axis; vertical shaft or horizontal shaft. Windel and Bradshaw (2000) provide a catalog of many of the equipment designs. A vertical shaft mastication head is a large heavy disk with hardened steel cutting teeth that spins like a giant lawnmower (Figure 2). Vertical shaft heads have also been used to turn articulating blades. A horizontal shaft mastication head consists of a rotary drum with cutting teeth (Figure 2). The horizontal shaft mastication head often requires less machine power to run than a vertical shaft. Higher power requirements result in larger and heavier equipment with potentially more detrimental soil effects (compaction and displacement). Both types of cutting heads are often mounted on an excavator boom (Figure 3). This arrangement allows the operator to reach up to 30 feet in any direction, thus limiting the amount of maneuvering and potential ground disturbance needed to reach all the material to be treated. Horizontal shaft mastication heads may also be mounted directly to the front of tracked vehicles (Figure 3); a setup that would have limited usefulness in thinning, but may be an effective tool for building firelines or clearing brush in suitable vegetation and terrain.

Figure 2. Examples of mastication heads. Vertical shaft (left photo) and horizontal shaft (right photo).

Figure 3. Examples of types of equipment commonly used for vertical shaft heads. Vertical shaft head mounted on self-leveling excavator (left photo) and rotary head fixed on tracked vehicle (right photo).

The type of equipment the mastication head is mounted to can influence operational efficiency and potential soil impacts. A very effective machine, especially if the area to be treated contains much sloping ground, is a self-leveling excavator (Figure 3). This equipment allows the operator to maintain a nearly level cab resulting in easier, more efficient use of the mastication head and more uniform weight distribution of the machine. By having better weight distribution, the machine can more effectively operate on steeper slopes with less ground disturbance than conventional equipment. Wide tracked machines offer lower overall ground pressure and combined with a deep tread height can improve traction and keep overall ground disturbance to a minimum.

Fuel and forest structure changes

Changes to fuels and forest structure presented here are summarized from a study that utilized an excavator mounted vertical shaft head (Harrod et al. 2008). Other types of equipment will have different effects on fuels and structure. Harrod et al. (2008) studied changes to fuels and forest structure following thinning using 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. Mastication effort had less impact on the resulting piece size than did the size of the material being masticated, so changes to fuels and forest structure presented are averages of all mastication efforts combined.

Mastication thinning has variable effects on fuel loadings. Average surface fuel bed depths can increase by as much as 2 inches following mastication. Total surface fuel loadings increase, but the magnitude varies by fuel size class and is highly dependent on the material being masticated. For example, 100 hr fuel loading can double following mastication of very dense, small diameter (~4 inch) trees.

Changes in canopy characteristics will vary depending on the type of stand being masticated. Stands with trees >8 inches in diameter dominating the canopy layer will not realize large changes to canopy fuels. The stands studied by Harrod et al. (2008) had high densities of trees less than 8 inches in diameter, but had a dominant overstory of 10-14 inches trees. In these stands, foliage and 10 hr fuel were decreased more than other canopy fuels and total canopy fuel was reduced by about 15% (Table 1). However, canopy fuels will change greater in plantations or other young forests following mastication treatments.

Not surprisingly, reduction in tree density is the most significant change to forest structure post-mastication, particularly where dense stands of saplings or small trees are being thinned. Mastication equipment is effective at removing nearly all small trees and reductions in total density can be more than 60% (Figure 4).

Table 1. Canopy loadings in ton/acre for pre- and post-mastication, and post-burn and mastication. Values calculated using FMAPlus (Fire Program Solutions 2005) based on field data (Harrod et al 2008).

Canopy Loadings	**Foliage**	**1 hr**	**10 hr**	**100 hr**	**1000 hr**	**Canopy Total**
Pre-Mastication	18.2	5.7	20.5	11.3	1.8	57.5
Post-Mastication	15.7	4.6	17.3	10.4	1.8	49.7
Post-Mastication & Burn	15.7	4.6	17.3	10.4	1.8	49.7

Figure 4. Example of change in tree density. Left photo is pre- and right photo is post-mastication.

Changes to fire behavior characteristics are commensurate with observed changes to fuels and forest structure. Pre-treatment stand conditions are often susceptible to passive or active crown wildfire (Table 2). Mastication of small diameter stands can reduce canopy closure and raise canopy base height thereby making it more difficult for fire reach tree crowns or be sustained within the crowns (Table 2). Burning following mastication will further reduce future wildfire characteristics, at least for the short-term (<10 yrs; Figure 5).

Figure 5. Examples of post-burn fuels, changes in canopy base height, and stand density. Left photo was taken right immediately after burn and right photo was taken 1 yr after.

Table 2. Fire behavior characteristics for pre- and post-mastication, and post-burn and post-mastication stands. Values calculated using FMAPlus (Fire Program Solutions 2005) based on field data (Harrod et al 2008).

Treatment	ROS[1]	FL[1]	FI[1]	CFL[1]	CFI[1]	CROS[1]	RAC[1]	SH[1]	CBH[1]	FT[1]
Pre-Mast.	5.3	3.7	101	1.6	16.0	7.7	122.9	23.4	2.3	passive
Post-Mast.	2.7	2.0	24	6.1	291.8	0	201.6	7.6	16	surface
Post-Mast. & Burn	1.7	1.3	10	6.2	300.4	0	192.4	3.4	17	surface

[1]ROS – rate of spread (ch/hr), FL – flame length (ft), FI – fireline intensity (btu/ft/sec), CFL – critical flame length (ft), CFI – critical fireline intensity (btu/ft/sec), CROS – crown rate of spread (ch/hr), RAC – rate for active crowning (ch/hr), SH – scroch height (ft), CBH – crown base height (ft), FT – fire type (passive crown fire, surface fire).

Cost and production rates

Mastication is comparable to other fuel treatment techniques. Compared to prescribed burning, mastication allows for greater precision with regards to tree selection and provides for better protection of leave trees. For these reasons, it can be applied with less risk and with greater certainty regarding the end product. Although hand thinning, piling, and burning may have similar advantages (and total costs), mastication can be accomplished in one entry, reducing the overhead costs associated with multiple contracts and entries.

Methods with greater precision and less risk are usually more expensive, and mastication is no exception. It is best used in areas that warrant substantial investment and where its unique benefits are important for meeting objectives. For example, mastication thinning of high density stands along recreation roads or adjacent to private land would provide adequate fuel and fire risk reduction in one entry, at low risk, without smoke, and result in a visually appealing condition. Once short-term objectives are met, low intensity maintenance burns could then be used with less risk and at lower cost.

Mastication costs can vary considerably but will typically range from $400 to $600 when thinning in forested environments. As with any treatment, project design can greatly affect both fixed and variable costs. Careful planning is required in order to control costs. Stand conditions are an important factor affecting variable costs and should be given particular consideration when selecting the stands and trees to be masticated. Stands with greater density will require more work, but even dense stands can be treated at reasonable cost if the size of trees to be masticated are kept within the efficient operating range of the machine. However, requiring mastication of trees with heights exceeding the reach of the equipment or with diameters so large that they slow the masticating head can cause costs to skyrocket[1].

Managing fixed costs is also important in keeping project costs reasonable. The size of the treatment area, operating restrictions, unit size, and distance between units can all affect the percentage of non-productive time and should be given careful consideration during project planning. The overall program size is also an important consideration since ownership costs are affected by the amount of time this specialized and expensive equipment will be kept busy through the year.

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[1] Machine capabilities will vary. A vertical shaft masticating head mounted on a large excavator may be able to reach 30’ in height and easily masticate diameters up to 6”. Trees larger than this may require special measures such as felling and bucking before mastication can take place.

Summary

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. Mastication effort is 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.

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