Mastication Fuel Treatments in the Southwest

Over the past decade, fuel treatments using mechanical mastication have become increasingly common. Mastication provides a means to treat fuels that are otherwise difficult to treat with prescribed fire. However, a number of questions have arisen regarding the effectiveness and impact of the treatments. We spoke with land managers across the Southwest who have implemented mastication treatments and observed their performance and effects. Some of their insights are presented here along with summaries of research conducted on mastication treatments.

Mastication involves the reduction of vegetation into small chunks by grinding, shredding or chopping using a front-end or boom-mounted rotary blade or drum-type head. Increasingly mastication is used on sites in which it is difficult to use prescribed fire—either due to high fuel loads, risk of escape, smoke concerns, or the presence of homes and other structures. By converting fuels into small chunks, standing live and dead fuels are converted into compact, surface fuels, which are usually left on the forest floor. In some cases, mastication may be used to make the later introduction of prescribed fire easier and more controllable. Also, mastication increasingly is applied to create a buffer around prescribed fire units in sensitive locations.
When done properly, mastication treatments reduce risk of extreme fire behavior through the rearrangement of the most critical fuel layers.

However, it is important to note that in most mastication treatments the biomass stays on site, so the fuel loading is not reduced, just reconfigured.

In the Southwest, mastication fuel treatments are employed in a number of major ecosystem and forest types. In interior chaparral, mastication is used to reduce shrub density/cover and fire hazard. Mastication is also utilized to reduce shrub cover and density and to restore grasslands in pinyon-pine and juniper ecosystems. In ponderosa pine and mixed conifer forests, mastication helps redistribute ladder and canopy fuels to the ground layer and reduce the risk of crown fire. Mastication is also applied in bosque riparian areas to restore native ecosystems that have been invaded by salt cedar (*Tamarix spp.*) and Russian olive (*Elaeagnus angustifolia*).

Southwest Fire Science Consortium, Northern Arizona University, School or Forestry, P.O. 15018, Flagstaff, Arizona 86011 swfireconsortium@gmail.com, phone: 928-523-1148, http://swfireconsortium.org

Mastication Equipment

a)  b) 

At a basic level, mastication machines can be categorized as either horizontal shaft–otherwise known as drum masticators (a), or vertical shaft–also known as rotary disc masticators (a). The heads can be mounted on a variety of vehicles, including the booms of tracked vehicles such as feller-bunchers (b), or masticating heads can be integrated into the motor body of rubber-tired, loading-type vehicles such as skidders (a). Photos: Kari Greer

There are a number of clear benefits associated with mastication fuel treatments, but there are also a number of interrelated research questions and management concerns regarding the effectiveness and impact of the treatments.

- What are the characteristics of masticated fuel beds and how do they impact fire behavior and effects?
- What is the response of understory vegetation to mastication?
- Can prescribed fire be used successfully in mastication treatments to reduce surface fuels?

Despite the increasing use of this tool across the Southwest, little research has been done in the region to address these basic questions. However, we can look to a growing body of research done in Colorado, California, and Oregon on mastication in similar forests as are found in the Southwest. In addition, land managers now have a great deal of experience in implementing and assessing the performance and effect of these treatments in southwestern ecosystems. Their insights are a valuable resource for evaluating sites in which mastication might be a suitable treatment. We start by describing the very different performance of mastication treatments in mitigating fire behavior in two recent southwestern wildfires, and then describe what researchers and practitioners have learned regarding fuel loading, vegetative response, and fire and ecological effects in mastication treatments.

Mastication and Fire Behavior: The Tale of Two Forests

The true test of any fuel treatment is how it influences fire behavior–slowing the rate of spread, reducing intensity and the potential for crown fire. Fire and land managers report that under the right conditions

mastication treatments have a mitigating influence on fire behavior; however, there are also cases where mastication treatments have had little impact on fire behavior and even contributed to higher fire intensity.

Land managers on the Prescott National Forest in central Arizona have been using mastication treatments (known on the Forest as "brush-crushing") to reduce fire hazard in interior chaparral by reducing the density of manzanita (*Arctostaphylos spp.),* shrub live oak (*Quercus turbinella*), and mountain mahogany (*Cercoparpus spp.*) in high risk areas near wildland-urban interface and as a pretreatment for prescribed fire. Scott Spleiss, a fuels specialist with the Prescott National Forest, says that burning in interior chaparral is tricky but mastication helps reduce the complexity. "When mastication is complete, it is much easier to run a prescribed fire through the reconfigured fuel bed," says Spleiss. "It is more predictable – a safer way to deal with the fuel." The Prescott has been treating thousands of acres per year in this manner, mastication followed by prescribed fire.

Those treatments were put to the test in May 2012 when the Gladiator Fire ignited from a structure fire on private land and moved on to the Prescott National Forest.

The fire received a lot of attention early on when it made a big run as a running crown fire. A Type 1 Incident Management Team was assigned and the number of firefighters on the fire climbed to 1,800. For the first few days, the team could only watch as the fire made significant runs. That changed when the fire hit a series of mastication treatments. "The fire slowed and even quit in some places. It moderated to the point where we could bring the full force of the personnel we had on the fire to go direct," says Spleiss.

According to Spleiss, the overhead teams initially drew a perimeter around the fire of 30,000–40,000 acres, but after the influence of the treatments, they were able to contain the fire at around 16,000 acres. "That made you feel good as a fuels specialist," says Spleiss. "We weren't just wasting our time out there. We felt like we were protecting resources–doing good."

The performance of mastication treatments on the Lincoln National Forest in southern New Mexico has been more mixed.

The picturesque mountain village of Ruidoso is surrounded by the Lincoln National Forest in ponderosa pine forests with an understory of pinyon-juniper, Gambel and shrub oak. Over the past two decades, the community has faced a series of destructive interface fires. After the 2000 Cree Fire destroyed a number of homes and forced a massive evacuation, the U.S. Forest Service ranked Ruidoso as the second most vulnerable community at risk for wildfire in the nation. That designation led to a $1,331,975 grant through National Fire Plan Community Assistance Program to reduce hazardous fuels. Working with local partners, the Forest Service implemented an aggressive fuel

treatment program to create a buffer around the community.

Mastication has been a large part of the hazardous fuels reduction strategy. Since 2006, the Forest has masticated about 5,000 acres. Many of these treatments were large, consisting of 600 and 800 acre blocks in ponderosa pine forests and 1,000 and 1,500 blocks in areas that used to be grasslands but have converted to pinyon-juniper woodlands.

In 2011, the White Fire ignited under red flag conditions with observed wind gusts estimated at 60 mph, and sustained winds of 40–45 mph. The fire burned over 10,000 acres in about 6 hours. Flame lengths were estimated at up to 80 feet with short range spotting. Temperatures were in the 70's, with relative humidity in the single digits. The fire encountered a number of mastication treatments but according to John Kennedy, a fuels specialist on the Lincoln, "it just blasted right through them."

A fuel treatment effectiveness report issued after the fire stated that the mastication treatments did not alter fire spread or behavior, and that suppression forces were not able to use the treatments as holding lines because of the rapidly spreading high intensity fires burning under extreme conditions.

While the White Fire may have been an outlier in terms of fire conditions (and fuels specialists on the Lincoln National Forest certainly believe it was), the performance of the mastication treatments still raises questions regarding the usefulness of expensive mechanical treatments when extreme burning conditions are becoming more common.

Dan Ray, a fuels specialist on the Lincoln National Forest, still thinks such treatments are useful. "We have seen that under 90 to 95% conditions, these treatments are very effective."

Fuel Treatments and the "New Normal"

While the White Fire may be an outlier in terms of the conditions under which it was burning, those conditions are becoming more common. The same fuel treatment effectiveness report for the White Fire says:

Rapid increase in energy release component (ERC), and fire danger occurred in the late 1990's to present. The combination of a wind event with long-term shift in dryness contributed to the effects of the fire. What was extreme 20 years ago is now moderate, and extreme has nearly doubled due to persistent drought that began in the 1990's. Fuels treatments are based on developing treatment prescriptions relative to 90-95th percentile weather, however those percentiles have shifted over several decades of increasingly warm weather trends.

Source:
White Fire Fuels Treatment Effectiveness Summary, April 2011, Lincoln National Forest

Ray says that the 2011 Donaldson Fire provided a more relevant test of the mastication treatments. The Donaldson Fire started on private land and moved on to Forest Service and Mescalero Apache tribal land. The fire encountered a number of mastication treatments and firefighters were able to take advantage of the treatments to put in control lines and to conduct burn out operations. "Those treatments were very successful and the fire effects were fairly beneficial in the burnout areas that had been masticated," says Ray.

Low Crown Fire Potential, But High Intensity and Severity

While there are ecological and fire management trade-offs in the implementation of any fuel treatment, mastication requires special attention to possible changes in fire behavior and effects. Even though mastication can reduce the potential for crown fire, surface fire intensity can be high and this can impact soils and vegetation.

Prior to the 2000 Cerro Grande Fire outside of Los Alamos, NM, a cut, pile, and burn treatment was implemented along one of the boundaries of the Los Alamos National Laboratory and the Santa Fe National Forest. The treatment was used for a burn-out operation during the Cerro Grande Fire, and helped suppression forces keep the fire out of the Lab. After the Cerro Grande, the Forest decided to widen the treated area with a mastication treatment on the Forest side of the boundary, upslope from the original cut and pile treatment. When the 2011 Las Conchas Fire was again threatening the town of Los Alamos and the Lab, the same area was used for a burnout operation. In this case, the overstory trees in the original cut and pile treatment again survived, but there was almost 100% mortality in the mastication treatment directly adjacent. Standing on the boundary now, you can almost draw a line between the surviving forest that was cut and burned and the adjoining masticated area that was completely destroyed.

William Armstrong, a fuels specialist with the Santa Fe National Forest, attributes this to the high intensities created within the surface fire that burned through the masticated fuels.

"What we are finding is that if we end up with a continuous cover of masticated debris and chips it is difficult to deal with. In the Las Conchas Fire, we found that when a

Treatment Longevity

Longevity is always a concern with any fuel treatment. How long is a given treatment effective and when will the same stand need to be treated again? Obviously, the answer to this question varies by ecosystem. Scott Spleiss of the Prescott National Forest reports that many of the mastication treatments in interior chaparral that played a role in stopping or slowing the Gladiator Fire were fifteen years old. He says that in ponderosa pine systems, fuels manager would lose their treatment investment much quicker and would have to retreat every few years.

wildfire fire burns through where you have a relatively thick layer of masticated material – and by deep I only mean 2-3 inches – the fire burns really hot with high intensities, and certainly some high severities," says Armstrong. "Even though it didn't crown out, it cooked all the crowns and killed everything. Under extreme dry conditions the entire masticated layer becomes available to burn."

He adds that the outcome of this treatment has led him to question the effectiveness of mastication treatments for reducing fire severity.

"If your objective is to reduce potential for crowning or to provide anchor points for suppression operations, mastication has value, but if your objective in treatment is to reduce fire severity, I'm not sure mastication is the treatment of choice," says Armstrong.

Vegetative Response to Mastication

Even in the absence of fire, masticated fuels may have detrimental impacts to ecosystems. There is concern, for example, that understory species may not be able to germinate and establish under a thick bed of masticated fuels.

Mike Battaglia and colleagues, working in ponderosa pine, mixed-conifer, and pinyon-juniper ecosystems, found that herbaceous cover in ponderosa pine and pinyon-juniper forest types appears to increase following canopy opening, despite suppression of herbs with deep mulch. "Herbs and forbs can be suppressed when the treatments produce deeper mulch layers, but rarely do treatments get to that depth across large areas," says Battaglia. They also found no differences in shrub cover two to four years post-treatment in any of the forest types (Battaglia et al. 2010).

In another study, Jeff Kane and colleagues (2010) found that resprouting species grow back rapidly, while seeding species take longer to recolonize an area after mastication. They also found that the number of native species increased when the amount of wood covering the ground was reduced, either by burning or by incorporating the wood into the ground by tilling. They attributed this to shading of the soil surface, either from the shrubs themselves or of masticated wood, which may suppress herbaceous understory vegetation. When the residual masticated layer forms a matt or continuous cover, native species can be suppressed, while invasive species thrive.

Is Prescribed Fire an Option?

The Prescott National Forest prescribe burns most of their mastication treatments and this likely played a large role in the effectiveness of the treatments in the Gladiator Fire. However, many land managers report that it is hard to prescribe burn masticated fuels since it is difficult to find a window of conditions under which the material will burn during the time of year when most prescribed burning takes place, usually fall or early spring.

Battaglia and colleagues found that changes to the fuelbed related to mastication treatments could result in increased smoldering. This can result in soil sterilization in some situations (Battaglia et al. 2010). In addition,

Kreyes, Varner, and Knapp (2011) found flaming combustion and lethal heating occurred at durations that dramatically exceed that of typical litter-driven surface fire.

Eric Knapp and colleagues conducted prescribed burns in two masticated areas in California ponderosa pine forests. They found that under prescribed fire conditions, flame lengths were low to moderate (approx. 1 ft for backing fire, 2.3 ft for head fire) and the rate of spread was also slow (111–187 ft/hr for head fire) (Knapp et al. 2011). However, increased flaming and smoldering duration were also observed, which can result in excessive soil heating.

However, Knapp and colleagues also found that high soil and duff moisture at the time of the burning limited heat penetration into the soil. This suggests that prescribed burning can be successfully used to reduce masticated fuels without killing residual trees if fire-line intensity is kept low using conservative firing techniques (backing fire, narrowing of distance between strips with strip headfires, or burning when air temperature is low). Burning when soil moisture is high may also help reduce damage to trees.

In addition, fire behavior and effects models do not really work in these fuels (see box below for description of recent efforts to fix this problem). Thus, these traditional tools have limited utility in masticated fuel beds. There have been efforts to customize fuel models based on field measurements, but, so far, model predictions have not successfully predicted fire behavior.

Key Lessons

Working in ponderosa pine, lodgepole pine, mixed conifer, and pinyon-juniper forests in Colorado, Mike Battaglia and colleagues found that mastication results in surface fuel loads that are 3–4 times that of untreated areas and that fine fuels, including 1 hour fuels (up to ¼ inch in diameter) and 10 hour fuels (1/4 to 1 inch in diameter), make up about 70% of masticated fuel loads (Battaglia et al. 2010). In addition, the research

Modeling Fire Behavior

Knapp and colleagues created custom fuel models for masticated (primarily shrub) fuels based on fuel loadings and observations of fire behavior in prescribed burn at two sites in California. The 1-hour numbers included litter that had accumulated on top of the masticated fuels. Custom models were created starting with the parameter values of the moderate load activity fuel model (sb2) of Scott and Burgan (2005) with the following modifications:

Model parameter	Mast-L Low loading	Mast-M Moderate loading	Mast-H High loading
1-h fuel load (tons ac^{-1})	3.5	5.7	7.8
10-h fuel load (tons ac^{-1})	2.5	5.9	13.1
100-h fuel load (tons ac^{-1})	0.3	1.2	5.8
1-h surf area to vol ratio (ft^2ft^{-3})	750.0	750	750
Fuel depth (ft)	0.36	0.52	0.89

Sources: Knapp et al. (2011); Scott and Burgan (2005)

showed that masticated fuel beds are more compact than untreated fuel beds.

For land managers, this means that special attention has to be paid to how masticated materials are distributed. The type of mastication equipment used, mastication intensity, and the size and/or age of treated fuels are all important drivers of the proportion of fuels in different time-lag classes (Kane et al. 2010).

As mentioned earlier, in the aftermath of the 2000 Cerro Grande Fire, the city and county of Los Alamos, New Mexico and the Santa Fe National Forest, began an aggressive effort to reduce hazardous fuels in and around the community and the Los Alamos National Laboratory, the birthplace of the atomic bomb and a site where nuclear experiments and research continues. Mastication was used to treat many of the sensitive areas in and around Los Alamos. In this case, sensitive areas included typical interface areas where homes and infrastructure make prescribed fire difficult, but also other areas where the storage of nuclear materials and waste made prescribed burning impossible due to the threat of radioactive releases.

William Armstrong, a fuels specialist with the Santa Fe, has been involved in many of the treatments and has now seen what does and doesn't work. He says that the key to the success of mastication treatments is the depth of the residual chip layer. He describes the work done in Acid Canyon in the center of the town of Los Alamos as a successful example of what can be done with mastication. After the Cerro Grande Fire, the area was identified for fuel mitigation. The canyon is a ponderosa pine forest on county open space parkland that is surrounded by neighborhoods and is popular for recreation. The treatment prescription called for the cutting and removal of trees between 4" and 12" dbh and the mastication of anything less than 4" in diameter.

The mastication work was done using a chipper with a directional outlet that could be rotated to distribute material to avoid piles and the accumulation of layers of dense material on the ground.

"What we are learning is that mastication works but much of it depends on the thickness of the residual mastication layer. In Acid Canyon, the amount of masticated material was such that we didn't end up with a carpet of debris, everything was very dispersed. The result was a reduction in potential fire intensity, an open canopy. Also, native grasses have come up. It was a very effective treatment in terms of mitigating potential fire behavior, and from the standpoint of the county, the aesthetics are very pleasing," says Armstrong.

Decisions related to fuels management always involve important tradeoffs in terms of positive and negative ecological impacts and in promoting and mitigating certain fire behaviors. According to land managers, mastication is no different in this regard and should be implemented only with close communication with all resource specialists.

"It is one of those treatments that depends. It is not universal. It is not good for every place, every circumstance, and every stand condition," says Armstrong. "We need to be thinking about what the implications are when we try it. We need to have more knowledge about where it might work, where it might not, where it might be a benefit… and where we might be making things worse."

Written by Josh McDaniel, January 2013.

Resources

Pacific Southwest Research Station, Masticated Fuels Research - http://www.fs.fed.us/psw/programs/ecology_of_western_forests/projects/masticated_fuels

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The Southwest Fire Science Consortium is a way for managers, scientists, and policymakers to interact and share science in ways that can effectively move new fire science information to management practices.

Southwest Fire Science Consortium, Northern Arizona University, School of Forestry, P.O. 15018, Flagstaff, Arizona 86011 swfireconsortium@gmail.com, phone: 928-523-1148, http://swfireconsortium.org

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