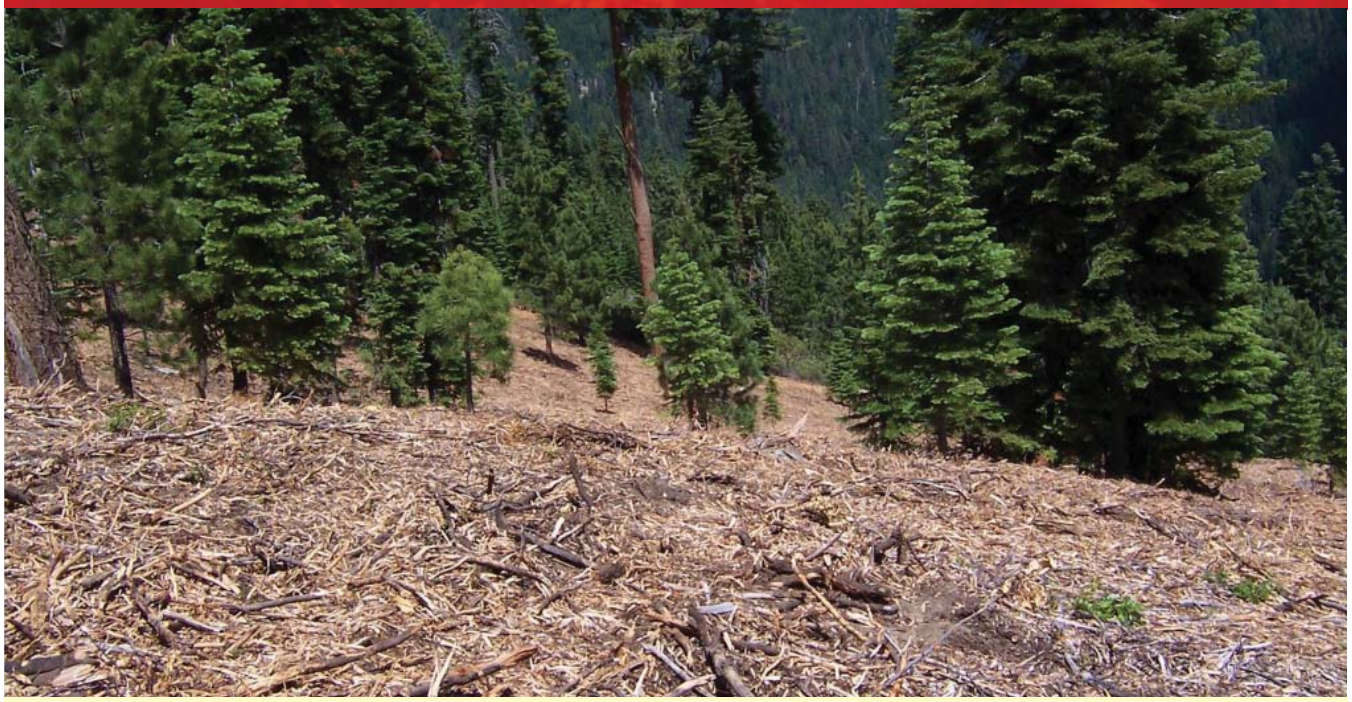
Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS



Masticated area in the Klamath National Forest, California.
The area in the foreground was dominated by shrubs. Credit: Morgan Varner.

Chewing the Landscape: Masticated Fuelbeds Pose Novel Challenges

Summary

Mastication, the mechanical shredding and chipping of small trees and shrubs, has been rapidly embraced by land managers as a treatment to reduce the risk of wildfire in the wildland/urban interface and to provide fire breaks in more remote areas. In the western United States, the use of mastication has more than doubled in the past 5 to 10 years, but until recently little was known about the novel characteristics of this artificial fuelbed or how it might behave when confronted with fire. Mastication does not reduce the total amount of fuel; it essentially takes ladder fuels—live and dead shrubs and small trees—and redistributes them to the forest floor. This thick mat may temporarily suppress growth of new vegetation and hold in soil and fuel moisture. Recent research conducted at 10 sites in southern Oregon and northern California, across a range of forest types and fuel loads, has begun to characterize masticated fuelbeds, determine the potential effects of particle size and moisture on fire behavior, assess the heating potential on soils and possible damage to soil organisms and trees, and determine whether current models for predicting fire behavior of natural fuels will be valid in estimating fire's effects in masticated fuelbeds. Research on the early response of understory and midstory vegetation to mastication and subsequent alternative treatments is also helping determine whether future treatments will be required to discourage regeneration.

Key Findings

- Mechanical mastication, the shredding and chipping of shrubs and small trees, deposits ladder fuels on the forest floor and reduces the likelihood of fire spreading to the forest canopy. This treatment may be preferred in areas where prescribed fire is not an option, such as the wildland/urban interface.
- Prescribed fire applied at two masticated sites effectively reduced the fuel load with few adverse effects to soils. However, crown scorch was two to four times greater than models predicted.
- Laboratory experiments with fire, and field trials with prescribed fire, suggest that damage to soil, soil organisms, and tree roots is likely to be minimal, as long as the soil is moist.
- Shrubs and small trees that sprout from roots rebounded quickly, from 2 to 5 years after mastication, indicating that repeated treatments or alternatives such as prescribed fire may be necessary to suppress new vegetative growth. However, prescribed fire can also promote regeneration of shrub species, by stimulating seeds to germinate.
- Mastication followed by burning when fuels are moist promotes plant diversity of native and nonnative vegetation alike.

Buffer zones

Though mechanical shredding of shrubs has been used in the western United States for nearly 40 years, primarily for rangeland shrub control, mastication was not in widespread use until people saw its utility for dealing with non-commercial materials such as shrubs and small trees. Early equipment used brush cutting heads capable of shredding shrubs, but chopping heads are now available that can deal with larger, but non merchantable, trees that invade the midstory and allow surface fire to move into the canopy. The masticated fuelbed varies in depth, mass, and coarseness depending on the equipment used and the technique used by the operator.

Overall, the material is fairly large compared to a traditional garden mulch, with fragment length ranging from 2 to 3 inches (5 to 7.5 centimeters) long, and masticated fuelbeds are more uniform and much more compact than natural fuelbeds consisting of litter and downed woody debris.

In the past 5 to 10 years, the use of mastication has more than doubled as a tool to reduce wildfire hazard in the wildland/urban interface and at fire breaks in more remote forests. This treatment option has been rapidly adopted despite a poor understanding of how mastication may alter intensity, spread, and effects of wildfire or prescribed fire.

Prescribed fire in masticated shrub fuels under young ponderosa pine near Whitmore, CA. Credit: Jeffrey Kane.

Mastication does not reduce fuel load; it simply changes the structure of the fuelbed by taking ladder fuels and fuels and dropping them to the ground, says Eric Knapp, a research ecologist at the Pacific Southwest Research Station Silviculture Laboratory in Redding, California. With support from JFSP, Knapp and colleagues conducted research on masticated fuelbeds between 2005 and 2008 at 10 sites in southern Oregon and northern California. Most of the sites were dominated by a coniferous overstory with differing types of understory and midstory vegetation. All the sites are in a Mediterranean climate zone, with typically hot dry summers and relatively mild, wet winters, at elevations ranging from 800 to 6,100 feet (243 to 1,859 meters). Nine of the sites are under federal management and one is a private ponderosa pine plantation. Seven of the 10 sites are in areas near human habitation, and three serve as fire breaks on ridge tops in more remote areas.

Midstory and understory vegetation varied from site to site but most systems were populated by two types of shrub—manzanita (*Arctostaphylos* spp.) and *Ceanothus* spp., members of the buckthorn family—and small evergreen hardwood tree species such as tanoak (*Lithocarpus densiflorus*) and madrone (*Arbutus menziesii*).

A heavy load

To predict fire behavior in the novel fuelbeds created by mastication, managers need a means to estimate the amount and type of material on the forest floor. Current models available to estimate fireline intensity, rate of spread, and flame height of fire were developed for natural fuel loads of downed woody debris and litter, and for slash remaining after commercial harvesting. A fuelbed characterization study suggests that masticated fuelbeds differ substantially from natural fuelbeds, and the models currently used to estimate fire behavior may need to be modified for sites subjected to mastication. The fuelbed produced by mastication is generally denser, and the particles more uniform in size, than that found in slash or natural fuelbeds. “Mastication homogenizes the fuelbed and spreads the material over a large area,” Knapp says.

Fuel loading was estimated using two techniques. The planar intercept method, developed by J.K. Brown in the 1970s, is often the preferred method to predict the weight, volume, and depth of natural fuel loads across the gamut of diameters, from fine material less than ¼ inch (1-hour time lag) to large diameter logs and stumps more than 3 inches (1,000-hour time lag). Masticated fuels, however, contain a larger proportion of fine fuels, which can be difficult to count using the planar intercept method.

Study sites at Mt. Shasta (MFR), Whitmore (WFR), Iron Mountain (IMR), Sierraville (SFR), Whiskeytown (WHI), Taylor Ridge (TAY), Challenge (CFR), Applegate (APP), Stanislaus (STA), and Mad River (MAD). Credit: Kane et al. 2009, *International Journal of Wildland Fire*.

Mechanically masticated site on the Six Rivers National Forest near Mad River, California. Credit: Jeffrey Kane.

To better gauge the load in these finer fuels, researchers also used a more painstaking method of measuring fuels. They sampled particles gathered from small plots enclosed by metal frames 20 by 20 inches (50 by 50 centimeters), dried them, weighed them, measured their diameters, and calculated the fuel load. "For the small fuels, it doesn't take that many samples to estimate fuel loading, but larger fuels tend to occur with less frequency," says Knapp. "We recommend using the plot method for small fuels and the planar intercept method for larger fuels."

In practice, however, managers may not have the time or money to conduct such meticulous estimates of fuel mass. For eight of the 10 sites, researchers found that fuel depth, which is easily measured, did correlate fairly well with fuel mass, giving managers a quick way to estimate fuel load, and therefore potential fire behavior and intensity.

Masticated fuel particles with fractured surfaces with irregular geometries. Masticated fuels with irregular geometries comprise greater than 50 percent of the overall mass (for 1- and 10-hour fuel classes) for all sites. Credit: Jeffrey Kane.

Not so cut and dry

Mastication shatters shrubs and small trees into fragmented, irregular shards with a higher surface-to-volume ratio than natural downed woody debris like twigs and small branches, which tend to be cylindrical. This novel characteristic led researchers to hypothesize that the material would likely dry more quickly and burn more readily. Knapp's colleague J. Morgan Varner, assistant professor of wildland fire and ecology at Humboldt State University, along with graduate student Jesse Kreye, gathered samples of masticated snowbrush *Ceanothus* and manzanita from two sites—Mad River in Six Rivers National Forest and Taylor Ridge in the Klamath National Forest—and dried and burned them in the laboratory. Uniform pine dowels were also treated in the lab to replicate natural fuel particles. No significant difference in the rate of drying or fire behavior were found. They hypothesize that because the masticated material compacts down into a dense fuelbed, it holds moisture better and doesn't dry as readily, which may compensate for increased moisture loss as a result of particle fragmentation.

Before and after mastication of manzanita (*Arctostaphylos manzanita* ssp. *manzanita*). Credit: Jeffrey Kane.

A prescription to burn

One question of concern is whether conventional computer models used to predict wildfire behavior, such as BehavePlus, can accurately predict the behavior of fire in masticated fuelbeds. Knapp and colleagues explored

the effects of prescribed fire on two sites in northern California, one in the Challenge Experimental Forest in Plumas National Forest, elevation 2,790 feet (850 meters), and another in a privately owned forest near Whitmore, Shasta County, elevation 2,300 feet (700 meters). Both sites were dominated by a ponderosa pine overstory with a dense understory of shrubs and small trees that had been masticated in 2002 and 2003.

The burns were conducted in May and June of 2005 at Challenge and June 2006 at Whitmore. This is the drying period after winter rains and a window of opportunity for prescribed burns. They found that while flame length and rate of spread conformed to expectation, needle scorch was greater than predicted, twice as high at Whitmore and four times as high at Challenge, which had a higher fuel load.

Burning in a masticated ponderosa pine stand near Whitmore, CA. Credit: Eric Knapp.

Though assessing the effectiveness of mastication to combat wildfire spread was not the goal of the research, Knapp did go out after wildfires burned through masticated sites and found that the results largely validated predictions. "Because ladder fuels are reduced, and rate of fire spread is slowed, these masticated areas are pretty valuable from a firefighting standpoint," he says. However, the masticated fuel still produces considerable heat when burned, and mature trees at many masticated sites were killed because of crown scorch.

Soil effects

While mortality of mature trees is a concern, more subtle effects may occur at and beneath the forest floor. Back at the Silviculture Laboratory of the Pacific Southwest Research Station (PSW) in Redding, California, a soil scientist took a closer look at the effects of prescribed fire in masticated fuelbeds. Matt Busse, a research soil biologist, applied fire to fuels in controlled conditions and measured the heat pulse with thermocouples embedded in the plots at different soil depths.

Research at the Silviculture Laboratory of the PSW explored the effects of fire on soils in masticated fuelbeds. Credit: Eric Knapp.

Specifically, Busse wanted to determine whether prescribed fire would raise soil temperatures to lethal levels—140°F (60°C) or greater for tree roots, and between 122° and 329°F (50° and 200°C) for soil organisms. He also set out to determine whether the soil texture and soil moisture would affect temperatures at soil depths ranging from the soil surface down to 5 inches (12.5 centimeters). "We were surprised to find there were no differences between the types of soil—pumice sand, loam, and clay—in maximum temperatures and heating profiles," says Busse. Soil moisture, however, made a significant difference.

Busse's research team took core samples from four distinct forested types, three in northern California and one in southern Oregon, gently pounding into the soil PVC pipes about one foot (30 centimeters) in diameter down to a depth of 6 inches (15 centimeters). The cores were carefully handled so as not to disturb the sample. "Disturbing the soil changes the porosity and that changes the heat pulse during fire," Busse says.

Researcher taking core samples. Credit: Eric Knapp.

The soil samples were carefully manipulated in the lab to control for different levels of moisture content and imbedded in small outdoor plots 3 feet by 3 feet (1 meter by 1 meter). Then masticated fuelbeds were constructed over the top of the plots, and thermocouples were attached to record heat measurements over a 24-hour period following burning.

Measurements were taken at the soil surface and at four different depths, from the soil surface down to 5 inches (12.5 centimeters) and at four soil moistures from 10–40 percent. Busse's team found that the temperatures exceeded the lethal cutoff only in the top two layers in moist soils. "Only in the dry soil did we get a heat pulse at a reasonable depth, down to four inches," he says. "We recommend that prescribed burns be conducted when the soils are fairly moist, at least 20 percent by volume." Busse says it's fairly easy to estimate moisture content in the field by simply knowing what the soil feels like to the touch. Moisture content of 20 percent feels a bit cool and moist, but not wet.

Busse also explored the effect of fire on soil repellency, an indication of the likelihood that fire may expose the mineral soil and cause erosion. "In the soils we tested, which were not repellent in the first place, we did not see an increase in repellency," Busse says. Assessing repellency can also be easy in the field, using a visual test. "You add water to the soil surface and measure the amount of time it takes to penetrate into the soil," he says. "It beads up on a hydrophobic soil."

To compare the laboratory findings with actual conditions in a masticated fuelbed, field data were collected

using embedded thermocouples at the two previously masticated sites in Challenge and Whitmore. "We were concerned that if the compact masticated fuelbed results in smoldering fire of long duration, that would push the heat into the soil." What he found, however, is that the prescribed fire tended to burn fairly quickly through masticated fuels. "There were hot spots, but they were minor," Busse says. "When you burn masticated fuels, the soil temperatures can get extremely hot, in some cases nearly twice as hot as natural fuels, but in general it takes a heavy fuel load and dry soil conditions to get to lethal soil temperatures." Prescribed burns, of course, can be planned when moisture content is high. If wildfire occurs on a masticated site, however, subsoil damage may be severe.

Vegetative response

While the primary goal of mastication is to reduce the risk of crown fire, other considerations may also come into play. "Mastication is not just a tool for fire hazard reduction," says Jeffrey Kane. It can also allow fire to be reintroduced more safely to overly dense forests.

Kane, whose master's thesis at Humboldt State University focused on fuelbed characteristics and vegetative response of the understory to mastication alone, mastication followed by prescribed burning or incorporation of the material by tilling back into the soil, thinning by hand, or no treatment. The study was conducted in a ponderosa pine forest in the Challenge Experimental Forest.

Kane found that species richness and diversity were greater in the sites where fire or tilling followed mastication, treatments that cause greater disturbance to mineral soil. "Following with a burn reduces fuel load and promotes native plant diversity," he says. On the other hand, many of the hardwoods and shrubs on the experimental sites regenerate by sprouting. "They may grow back in five years," he says. In addition, "fire does not discourage, but actually stimulates the germination of some shrub species."

Kane also tallied the number of native and nonnative vegetative species on the sites and found that fire following mastication also encourages regeneration of nonnative species such as bullthistle, an invasive forb. In short, there are a number of tradeoffs in selecting among follow-up treatments, whether the goal is fire hazard reduction, or to restore sites to historic conditions.

Varner, Kane's thesis adviser at Humboldt State University, cautions that mastication is an expensive treatment, ranging from $500 to $1,500 per acre, and it is unlikely that a single treatment will solve the problem of invasive shrubs and small trees over the long term. It is, however, proving to be a useful addition to the toolkit of land managers.

Further Information: Publications and Web Resources

Busse, M.D., K.R. Hubbert, G.O. Fiddler, C.J. Shestak, and R.F. Powers. 2005. Lethal soil temperatures during burning of masticated forest residues. *International Journal of Wildland Fire* 14(3) 267–276.

Management Implications

- Prescribed burns in masticated fuels should be conducted when soils are moist to reduce the damage to subsurface soil, beneficial soil organisms, and tree roots.
- Strip head fires can generate too much heat and cause mortality through scorch. Less intense backing fires may reduce the incidence of scorch.
- The planar intercept method of estimating fuel load underestimates the number of fine fuels (1- and 10-hour) while the plot based method underestimates the larger (100 to 1,000-hour) fuels. A hybrid method, using a plot-based method for fine fuels and the planar-intercept method for large fuels may provide a better estimate of fuel loading.
- Fuel load can also be estimated by measuring fuelbed depth.

Rapid re-sprouting of *Ceanothus* shrubs in an area masticated 20 months prior to the photograph. Credit: Jeffrey Kane.

Kane, J.M. 2007. Fuel loading and vegetation response to mechanical mastication fuels treatments. Thesis, Humboldt State University, Arcata, CA. 80 pp.

Kane, J.M., J.M. Varner, and E.E. Knapp. 2009. Novel fuelbed characteristics associated with mechanical mastication. *International Journal of Wildland Fire*. In press.

Kane, J.M., E.E. Knapp, and J.M. Varner. 2006. Variability in Loading of Mechanically Masticated Fuel Beds in Northern California and Southwestern Oregon. USDA Forest Service Proceedings RMRS-P-41. http://www.fs.fed.us/psw/programs/ecology_of_western_forests/publications/publications/kane_IAWF06.pdf

Kreye, J.K. 2008. Moisture dynamics and fire behavior in mechanically masticated fuelbeds. Thesis, Humboldt State University. Arcata, CA. 88 pp.

Kreye, J.K. and J.M. Varner. 2007. Moisture dynamics in masticated fuelbeds: A preliminary analysis. Pp 173–186 *in* The Fire Environment—Innovations, Management, and Policy: Conference Proceedings. USDA Forest Service, Rocky Mountain Res. Sta. Proc. RMRS-P-46. Fort Collins, CO.

USFS Pacific Northwest Research Station. Masticated Fuels Research. Online at: http://www.fs.fed.us/psw/programs/ecology_of_western_forests/projects/masticated_fuels/

Scientist Profiles

Eric E. Knapp is a Research Ecologist at the Pacific Southwest Research Station, Silviculture Laboratory, in Redding, California.

Eric Knapp can be reached at:
Pacific Southwest Research Station
3644 Avtech Parkway, Redding, CA 96002
Phone: 530-226-2555 • Email: eknapp@fs.fed.us

Matt D. Busse is a Research Soil Biologist at the Pacific Southwest Research Station, Silviculture Laboratory in Redding, California.

Matt Busse can be reached at:
Pacific Southwest Research Station
3644 Avtech Parkway, Redding, CA 96002
Phone: 530-759-1721 • Email: mbusse@fs.fed.us

Jeffrey Kane is a doctoral student in the School of Forestry at Northern Arizona University. He completed his master's degree at Humboldt State University. His masters' thesis focused on fuel loading relationships and vegetation response to mastication and other fuel treatments.

Jeffrey Kane can be reached at:
School of Forestry, Northern Arizona University
Flagstaff, AZ 86011-5018
Phone: 928-637-4128 • Email: jeffreykane@gmail.com

J. Morgan Varner III is an Assistant Professor of Wildland Fire Management in the Department of Forestry and Wildland Resources at Humboldt State University.

Morgan Varner can be reached at:
Humboldt State University
1 Harpst St., Arcata, CA 95521
Phone: 707-826-5622 • Email: jmvarner@humboldt.edu

Results presented in JFSP Final Reports may not have been peer-reviewed and should be interpreted as tentative until published in a peer-reviewed source.

The information in this Brief is written from JFSP Project Number 05-2-1-20, which is available at www.firescience.gov.

An Interagency Research, Development, and Applications Partnership

JFSP *Fire Science Brief* is published monthly. Our goal is to help managers find and use the best available fire science information.

Learn more about the Joint Fire Science Program at *www.firescience.gov*

John Cissel
Program Manager
208-387-5349
National Interagency Fire Center
3833 S. Development Ave.
Boise, ID 83705-5354

Tim Swedberg
Communication Director
Timothy_Swedberg@nifc.blm.gov
208-387-5865

Writer
Elise LeQuire
cygnete@mindspring.com

Design and Layout
RED, Inc. Communications
red@redinc.com
208-528-0051