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Reducing Fuels through Mulching Treatments: What are the Ecological Effects?

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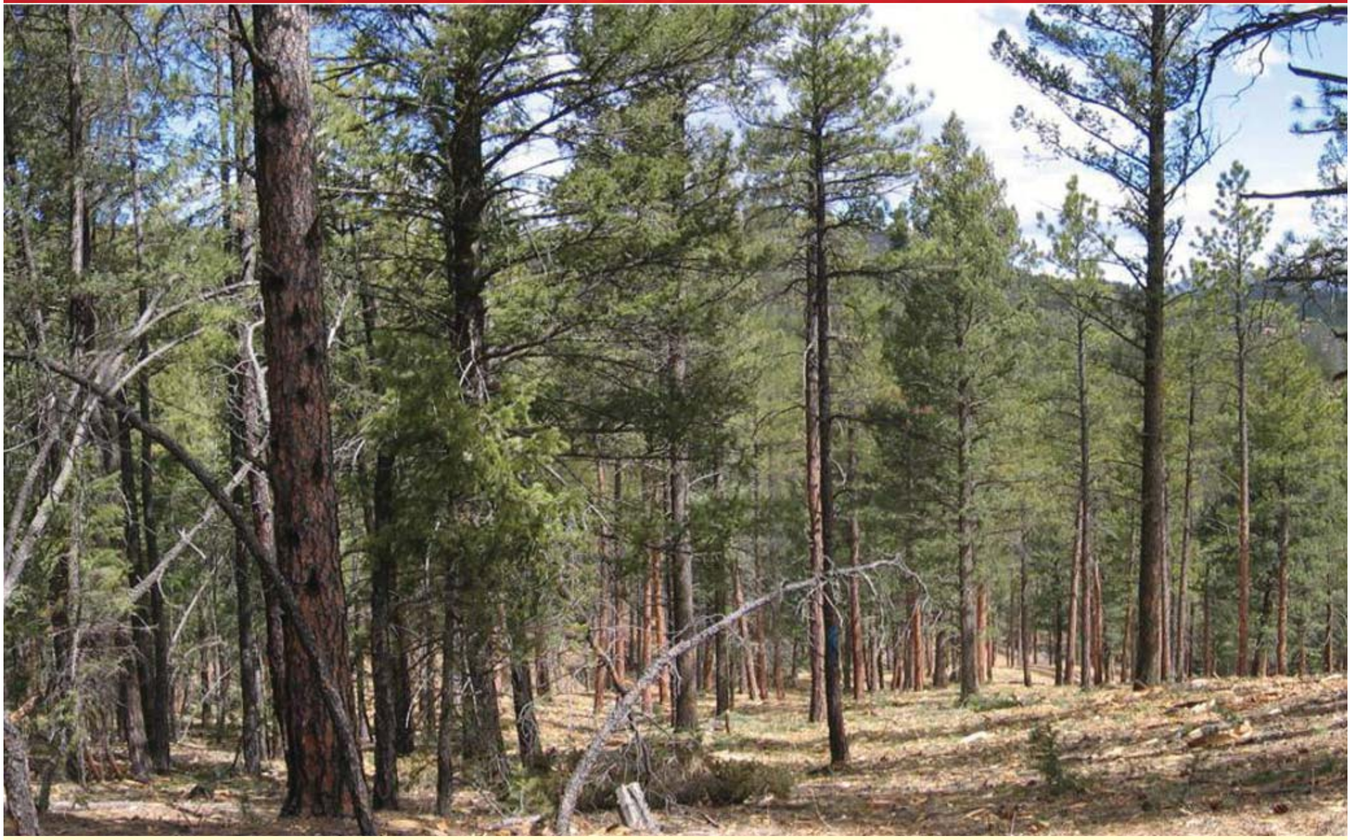
Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS



Ponderosa pine forest on the Pike National Forest in Colorado.
The left side is untreated and the right side has been mulched.

Reducing Fuels through Mulching Treatments: What are the Ecological Effects?

Summary

Many areas in the western U.S. are being thinned to reduce fire hazard and spread. Often the most economical solution for the disposal of the thinned biomass is to grind and leave the material onsite. These treatments are assumed to reduce the ability of the forest to carry a crown fire, but the effects of the added material on forest ecosystems are poorly known because such treatments do not have a natural analogue. Managers and the public are interested in understanding the impacts of the addition of this woody material on forest ecosystems so they can evaluate the benefits against the potential ecological costs of these treatments. The purpose of this study was to understand the ecological effects of mulching treatments in a broadly replicated study in the dominant coniferous forest types for the southern Rocky Mountains and the Colorado Plateau. The study specifically targeted the effects on fuel loading, vegetation response (understory, species richness, and exotics), tree regeneration, soil microclimate and soil nitrogen, and carbon storage.

Key Findings

- Study results (two to four years post-treatment) revealed very few negative effects from mulching treatments.
- Fuelbed depth serves as a good predictor of surface fuel loadings in treated areas.
- Mastication equipment disperses the woody material in a patchy distribution, resulting in no significant effects on vegetation response at the operational scale.
- Because mulching treatments add only a relatively shallow amount of material (distributed heterogeneously), plant-available soil nitrogen is not negatively affected at the stand level.
- Variability in tree regeneration between and within forest types following treatments makes it difficult to determine fuel treatment longevity and requires further investigation.

Weighing the benefits

The human population is growing, and this expansion has led to human habitation on lands that were once wild. Historically, fire has regulated the accumulation of fuels on the forested landscapes of the western U.S., but no longer can wildfire be allowed to do its job in the wildland-urban interface because of threats to lives and property. Moreover, opportunities to reintroduce fire using prescription burning to treat fuels are limited by the risk of fire escapes and smoke restrictions. Mechanical treatments have thus become a widely used method for reducing crown fire risk in the wildland-urban interface.

(Left) Small non-merchantable material is often piled and hand-fed through a "chipper." Woody debris produced by this method is small, square, and uniform in size—resulting in mainly 1-hour fuels. (Right) Hydro-axe equipped with a horizontal-shaft mastication head. Woody debris produced by this method results in chunked and shredded material of various sizes, with usually a greater proportion of 10-hour fuels.

Thinning treatments typically target small diameter trees, shrubs, and dead trees, which are considered to be non-merchantable. But the leftover biomass must go somewhere. Traditional thinning often involves hauling the biomass off-site or, more frequently, piling and burning. A relatively new technique (employed for about a decade now) involves the reduction of trees and brush in place through grinding, leaving the resulting material—referred to as "mulch"—on the forest floor. This mastication of trees and brush is achieved through equipment such as a hydro-axe which, as Mike Battaglia—post-doctoral researcher on the project—puts it, "is essentially a lawnmower on steroids." Woody debris produced by this method results in chunked and shredded material of various sizes, with usually a greater proportion of 10-hour fuels. Small non-merchantable material is often piled and hand-fed through a "chipper." This method produces woody debris that is small, square, and uniform in size, resulting in mainly 1-hour fuels.

Compared to traditional thinning treatments, this technique proves cost-effective since it can be very expensive to haul biomass off-site. Based on this cost advantage, mulching treatments are increasingly used as an effective method of treatment while avoiding smoke management issues. Managers and the public are interested in understanding the effects of the addition of this material on forest ecosystems so that they can weigh the benefits against the potential ecological costs. What, if any, are the negative side effects of mulching?

Examining the effects

An obvious question arises when considering this relatively new technique: does the addition of wood in the form of mulch alter ecosystem function? A literature synthesis of the ecological effects of chipping and mastication treatments in forested ecosystems uncovered many uncertainties and conflicting results, preventing generalizations about its impact on the landscape. To understand the ecological effects of these treatments, the research team—headed up by principal investigator Michael G. Ryan of the Forest Service—conducted a broadly replicated study in four forest types in the southern Rocky Mountains and the Colorado Plateau. This study, funded by the Joint Fire Science Program, specifically targeted the effects on fuel loading, vegetation response (understory, species richness, and exotics), tree regeneration, soil microclimate and soil nitrogen, and carbon storage.

Eighteen sites were established for four ecosystems: lodgepole pine (*Pinus contorta*), mixed conifer (*Pinus ponderosa*, *Pseudotsuga menziesii*, *Pinus flexilis*, and *Pinus contorta*), ponderosa pine (*Pinus ponderosa*), and pinyon pine/juniper (*Pinus edulis/Juniperus* sp.). These sites are distributed across a wide geographic range throughout Colorado, representing treatments across several federal, state, and other land agencies. The sites were treated between 2004 and 2006 and first assessed in 2007 or 2008. For each study site, the team also identified an untreated reference area. Untreated sites were located within 1 km (0.6 mile) of treated sites, on sites with similar aspect, elevation, soils, and forest type.

Good news

The outlook seemed promising because mulching treatments do indeed achieve the objective of reducing crown bulk density—thereby mitigating crown fire potential—*and* have the above-mentioned additional economic and air quality advantages over traditional fuel reduction treatments. However, because these treatments have no parallel in nature, it was unclear what would happen when you throw a bunch of wood chips on the ground. There must be trade-offs to the benefits, right?

Study results revealed very few negative effects, and those effects that were less-than-positive turned out to be relatively minor, at least according to results two to four years post-treatment. Battaglia qualifies, "We can't be sure about long-term results at this point, but we can speculate that the effects probably aren't going to slide in a real negative way."

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Also surprising to the research team was the way mulched fuel is spread on the landscape and the effects of this distribution. The machinery churns out wood chips in such a way that a fair amount of area is left with very little fuel. There are patches of thicker fuels, but this distribution does not impede the understory vegetation at the stand level. In addition, you can put down only as much biomass as you removed in the first place, keeping the depth to a reasonable amount. So although effects do differ by ecosystem—it's not one size fits all—by and large the news is good. (Refer to the final project report [#06-3-2-26] on the Joint Fire Science Program website for specific findings by forest type: http://www.firescience.gov/JFSP_Search_Advanced.cfm.)

Measuring fuelbed loading: A new technique

Mulching substantially increased woody surface fuel loads in all of the ecosystems studied—two- to three-fold, in general. And the research team discovered that depth serves as a good predictor of these fuelbed loadings, which consist of a mixture of litter, duff, 1-hour, and 10-hour fuels. "Measuring depth is easier and more accurate than counting sticks," explains Battaglia. A publication on protocols for measuring surface fuels in masticated fuelbeds can be located at http://www.firescience.gov/projects/06-3-2-26/project/06-3-2-26_measuring_fuel_loads_in_mulched_fuel_reduction_treatments.pdf. This publication contains step-by-step instructions on measuring fuel loadings via depth, as well as equations for predicting mulched fuelbed loadings in tons per acre by forest type (that is, those types studied as part of this project; the equations still need to be tested in other geographic regions). In addition, the publication includes information on and equations for determining the expected average depth based on tree biomass treated.

Vegetation response: More good news

So what effects do mulching treatments have on vegetation in terms of understory, species richness, and exotics? At the operational scale (or stand level) treatments did not suppress understory vegetation in any of the four ecosystems studied. Across an entire stand, mulch dispersal is patchy, resulting in mixed depths and thus mixed vegetation response. So overall, these treatments did not affect understory vegetation. In addition to this non-uniform dispersal of mulch, increases in resources (such as light and water) associated with canopy thinning tend to outweigh any suppressive effects of the material on herbaceous vegetation. Regarding species diversity, even at the sub-plot level (or fine scale), no ecosystem showed differences in species richness between treated and untreated areas. And a third piece of good news relates to non-native species. None of the ecosystems studied showed differences in exotic plant cover resulting from treatments. There is, however, some reason to be concerned regarding possible longer-term issues with non-natives. Although the machinery was washed between treatments in different areas, the presence of exotic species was observed more often in mulched versus untreated areas. These species were relatively infrequent and occurred at low abundance on average, but they do have the potential to increase in quantity with time and should be monitored.

(Left) Lodgepole pine forest less than one year post-treatment that has been mulched with a hydro-axe. (Right) Herbaceous and lodgepole pine recruitment five years after mulching treatment.

Ecosystem	Untreated	Mulched
Pinyon-Juniper	• 6 species • cheatgrass abundant at 3 sites	• 16 species • cheatgrass at essentially the same sites
Ponderosa	• essentially absent	• 11 species • Canada thistle, prickly lettuce, mullein, dandelion most common
Mixed conifer	• none	• 4 species • Canada thistle most common
Lodgepole	• essentially absent	• 6 species • Canada thistle most common

Exotic species observed across the four ecosystems.

How long will the treatments last?

As of yet, there's no clear answer to this question. Assessments of tree regeneration at each study site indicated that regeneration response was variable—and not just between forest types but within them, as well (refer to the final report for specifics by forest type). Questions remain regarding whether the variability in seedling regeneration in mulched areas was due to (1) lack of exposed mineral soil seedbed, (2) favorable soil microclimate created by the mulch, (3) variability in annual seed production, (4) climatic conditions since treatment, or (5) an ecosystem-specific response. The research team has been further funded by Joint Fire Science to find answers to these questions. Managers, stay tuned.

Mulch and soil: Depth matters

As you might expect, the addition of mulch moderates soil temperature, reducing temperatures in summer and increasing them in winter. The added material can also increase soil moisture content, depending on the depth applied. For these reasons, mulch can increase plant productivity, unless it's applied too deeply, which can then impede plant growth.

Regarding the effects of these treatments on plant-available nitrogen, the study shows depth matters. The treatments added between 1 to 3 centimeters (0.5 to 1.5 inches) of material on average, and application was patchy—so a significant extent of the treated areas received no appreciable mulch addition. It was therefore not surprising that there was no negative impact on plant-available soil nitrogen at the stand level. Yet more good news. (It should be noted that these findings represent results from studies on coniferous forests in Colorado; other geographic regions with different seasonal precipitation patterns and soil productivity could differ in response.) Taking it a step further, to find out how much material is too much, the researchers created deep (8–15 centimeters / 3–6 inches) uniformly applied mulch beds for scientific comparison and found that these had significant effects on soil nitrogen. Plant-available nitrogen was significantly lower (>50 percent) in these experimental beds in some of the ecosystems the team evaluated compared to untreated areas.

Example of a fuelbed created by a hydro-axe, resulting in different fuel sizes, irregular shaped fuel particles, and a mix of wood and needle litter.

And what about carbon?

The researchers expected that total stand carbon would be similar between untreated and mulched stands shortly after fuel reduction activities because the mechanical operations simply convert standing biomass into a surface layer of mulched material—a mere rearrangement of the carbon that's there. The investigators caution, however, that an assessment of changes in carbon storage over time is warranted. In short, carbon continues to accumulate in untreated stands as trees grow; in contrast, carbon storage decreases through time in treated stands due to the decomposition of the woody fuel deposited on the forest floor. Similar to carbon released through burning of thinned biomass, carbon is released to the atmosphere through decomposition of the woody material—just at a slower rate than through burning. And Battaglia brings up an additional point to consider: "Typically, when biomass falls on the ground, you have decomposition, but new trees are also coming up. Mulched stands, however, tend not to return to the same density as before—so there's additional carbon lost. It's just something to think about."

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Ongoing investigation

We know that mulching treatments alter the surface fuel load, but we do not yet know how what kind of fire behavior this altered fuelbed will lead to because current fuel models for use in fire behavior prediction do not accurately reflect mulched fuelbed characteristics. In addition, custom fuel models created thus far have proven unsuccessful in modeling fire behavior. Furthermore, studies on the moisture dynamics of mulched fuelbeds are limited. For instance, if the fuelbed is shallow, precipitation events could wet the entire fuelbed profile. In a deep fuelbed, however, only the surface might be affected while the particles below remain dry. On the other hand, during very dry periods, the lower levels of a deep mulch fuelbed might remain moist although the surface is quite dry. These complexities in fuel moisture dynamics could impact fuel consumption, fire spread, and fire effects. More information—garnered from validation studies on actual fires—is therefore needed on parameters such as fuelbed moisture dynamics, fuel loads, fuelbed bulk density, surface-to-area volume ratios, and fuel size class distribution to develop fire behavior fuel models appropriate for mulched fuelbeds. The team is still awaiting the fire behavior monitoring plots they installed in treated areas to be burned, and they are currently seeking opportunities to observe fire behavior on other sites, as well.

We also know that these treatments can cause short-term increases in non-native plants, but it remains unknown whether they will increase or decrease in abundance with time. Their presence and potential for expansion is a concern, especially as mulch decomposes and its physical barrier is reduced. The presence of exotics needs to be formally monitored over time.

Moreover, the mechanisms governing tree seedling establishment and growth in treated areas remain unclear. In short, we don't know whether the deposition of a mulch layer will suppress or enhance seedling germination. Understanding the mechanisms that favor and discourage germination in mulched areas will improve our understanding of the impacts of these treatments on future forest structure and treatment longevity.

Lastly, the research team is currently studying the length of time that mulch serves as a nitrogen sink in treated areas because it may have impacts on site productivity, biomass production, and treatment longevity. In addition, the team recommends that long-term decomposition studies be installed to determine how fast mulched fuels decompose and thus reduce carbon sequestered.

Lodgepole pine forest two years after it was treated with a Fecon Bull Hog masticator head, which shreds the standing trees into various sized chunks that are then deposited onto the forest floor.

So the news is by and large good. Mulching treatments achieve their main goal of reducing the potential for crown fire, offer economic and air quality advantages over traditional thinning treatments, and have surprisingly very few associated negative effects—and those that do exist prove relatively minor. Certainly, further investigation is required to determine how fire will behave in mulched areas and the longevity of these treatments. So the next important step is to get on prescribed burns in these areas and also to conduct experimental burns to answer these lingering questions. Hopefully more good news is on the way.

Management Implications

- Fuelbed depth serves as a good predictor of surface fuel loadings in mulched areas. (Protocols for measuring surface fuels in masticated fuelbeds can be located at: http://www.firescience.gov/projects/06-3-2-26/project/06-3-2-26_measuring_fuel_loads_in_mulched_fuel_reduction_treatments.pdf.)
- Due to the heterogeneous distribution of mulch, herbaceous vegetation is not suppressed at the operational scale.
- Despite their low abundance, non-native species were observed more often in treated areas of all ecosystems studied. They may become more abundant with time and should be monitored.
- Variability in tree regeneration between and within forest types following mulching treatments makes it difficult to determine fuel treatment longevity; further study is being conducted.

Further Information: Publications and Web Resources

Battaglia, M.A., Rocca, M.E., Rhoades, C.C., and Ryan, M.G. 2010. Surface fuel loadings within mulching treatments in Colorado coniferous forests. *Forest Ecology and Management* 260 (9): 1557–1566.

Joint Fire Science Program Project Final Report, Project #06-3-2-26: http://www.firescience.gov/

Protocol for measuring surface fuels in mulched areas: http://www.firescience.gov/projects/06-3-2-26/project/06-3-2-26_measuring_fuel_loads_in_mulched_fuel_reduction_treatments.pdf

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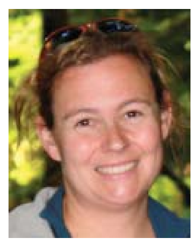

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