

USGS crew evaluating forest thinning one year after a late-season burn. Photo by Eric Knapp.

Tested by Fire: What Happens When Wildfires Meet Fuel Treatments?

Summary

Strong scientific evidence has long been needed on the effectiveness of fuel treatments when subsequent wildfires encounter treated areas. This project studied what happened when wildfires met fuel treatments, using results from five large wildfires in mixed-conifer forests in the Western United States. The relation between fuel treatment effectiveness and wildfire severity differed by treatment type. Recent treatments (less than 10 years old) that reduced surface fuels were generally effective, whether or not thinning had been done first. Combination treatments, with thinning followed by slash disposal, showed the most impressive results, and in fact the effectiveness of combination treatments increased with weather severity. The study's results suggest that fuel treatments such as thinning and prescribed burning may reduce the intensity and severity of subsequent wildfire. Treatment of surface fuels appears to be the most important factor for success. This study of real-world results helps support the argument that well-designed fuel treatments are worth the effort.

Key Findings

- Fuel treatments in mixed-conifer forests can reduce subsequent wildfire severity, but effectiveness depends on the type of treatment.
- Fuel treatment effectiveness depends on weather severity. Combination treatments that included both thinning and slash disposal were effective even in extreme fire weather in mixed-conifer forests.
- Fuel treatment effects may extend beyond the treated unit. This effect was most pronounced for *in*effective fuel treatments—fire severity was significantly greater behind them.
- Fuel treatment effectiveness depends on treatment age. Treatments that reduced surface fuels were effective for up to a decade in mixed-conifer forests.
- Fuel treatments increase the risk of non-native plant establishment, but severe wildfires increase that risk far more.

Strong scientific evidence has long been needed on the effectiveness of fuel treatments when subsequent wildfires encounter treated areas. Real-world examples do exist—fire managers have often seen crowning wildfires hit fuel-treatment areas and drop to the ground. After the fire, managers have shown these patches of green trees in blackened landscapes as examples of effective fuel treatments. But, as others have pointed out, fire behavior can vary for many reasons, such as changes in topography or wind shifts.

It is also well-known, that at times, fuel treatments can *add* to fire hazard. When stands are thinned, more sunlight, water, and nutrients are available, feeding new growth of grasses and plants, which increases the surface fuels. Thinning also lets more wind enter the stand, a danger if a wildfire occurs.

Much of the data on fuel treatment effectiveness comes from scientists' use of models to simulate wildfire behavior. Modeling results have helped increase our understanding of what factors make fuel treatments effective and cost-efficient, but real-world results could be different from modeling runs, for a number of reasons. "Modeling experiments are perhaps best viewed as hypotheses awaiting an empirical test," says Philip Omi, professor emeritus at Colorado State University's Department of Forest, Rangeland, and Watershed Stewardship.

Past studies of real-world fires burning treated areas used widely differing definitions, criteria, and sampling designs, and the studies did not produce clear information on fuel treatment effectiveness and the conditions that influenced it. With funding from the Joint Fire Science Program (JFSP), Omi and his colleagues set out to develop rigorous scientific evidence on what happened when wildfires met fuel treatments.

Large wildfires as a natural experiment for testing fuel treatments

The scientists had to rely on chance to produce the circumstances needed for their study: wildfires burning

through one or more treated areas, with untreated areas that could be used as controls also within the fire perimeter. Ideally, these postfire study areas would be large enough that treated and untreated units could be paired in ways that controlled for other factors, thus yielding scientifically sound results on the fuel treatment questions.

Much like fire crews, the scientists were in a state of readiness during the 2003 and 2004 fire seasons so they could mobilize for wildfires that met their study criteria. Erik Martinson, research associate at Colorado State University, was in charge of much of the fieldwork and later analysis for the study. Graduate students Don Carpenter, Jon Freeman, and Vicky Williams assisted with data collection.

Omi and Martinson followed the status of large wildfires through the National Interagency Coordination Center's Incident Management Situation Reports. They contacted districts where wildfires exceeded 10,000 acres and checked if the fires met the other study criteria. Fires had to have both treated and untreated areas within their perimeters, with treatments less than 10 years old preferred. Treatment areas had to be large enough for multiple plots with buffers. Also, at least three treatment areas had to be within 600 feet of untreated burned areas. The treated and untreated areas, which were considered pairs for study purposes, had to be topographically similar and could not be separated by a major road or natural barrier that could have acted as a firebreak, nor could they be close to major suppression actions that might have changed the fire behavior. Finally, the paired plots had to be located so the wildfire reached them at about the same time from the same direction.

Martinson explains that these specifications were necessary so that the study would include, as much as possible, pairs of test and control plots that isolated the effects of fuel treatments from other factors—all the "yes, but what about this?" factors that might weaken their findings. As the scientists narrowed the number of possible study sites, they also checked on the availability of data on stand histories, fuel treatments, vegetation types before the fire, topography, and fire growth and perimeter for each site. Wherever possible, the scientists collected data in untreated areas directly "behind" (with respect to the direction of fire spread) the study plots, so they could test whether treated units protected untreated areas beyond the treatment-unit boundaries. Finally, they had to be able to collect field data before any timber salvage occurred.

The study group included five fires. The scientists found four fires that met their criteria during the 2003 and 2004 fire seasons. They also included the 2002 Hayman Fire in Colorado, since before beginning their JFSP study, they had completed work using the same criteria on it.

Surprising correlations between fuel treatments and wildfire severity

The five study sites yielded valuable data on the performance of fuel treatments in western mixed-conifer forests when tested by severe fire (three of the five wildfires had burning indexes in the high 90s). "The correlations were not always what we expected," Omi comments.

The relation between fuel treatment effectiveness and wildfire severity differed by treatment type—treatment of surface fuels, treatment of canopy fuels (thinning), and combination treatments that thinned stands and treated slash.

Recent treatments (less than 10 years old) that reduced surface fuels were generally effective, whether or not thinning had been done first. In fact, surface treatments

Table 1. Summary of Study Site Characteristics

showed the strongest correlations between treatment effectiveness and stand conditions. "We found recent prescribed burns to be the most consistently effective fuel treatments," Omi says. The most effective surface treatments not only reduced fuel loads on the forest floor, but also acted as a low thinning mechanism by removing smaller trees and thus increasing the distance from the ground to the canopy's lower edge (canopy base height). The removal of smaller trees also reduced the amount of canopy fuel.

Thin-only treatments, where ground slash had not been treated, were generally ineffective. These treatments reduced canopy and stem density, but untreated slash augmented fire severity. However, in Oregon's Davis Fire, canopy consumption was reduced in precommercial thinning units less than 1 year old, compared to unthinned stands nearby, likely because the thinning slash was still green when the fire came through. Even so, the fire in the newly thinned units was hot enough that all the trees died. In the Hayman and Aspen Fires, thin-only treatments had slightly worse fire severity than neighboring untreated areas.

Other sites in Oregon's Davis Fire (where slash treatments had been completed after thinning) and combination-treatment sites in Colorado's Hayman Fire showed the most impressive results of the study. Martinson reported that the combination treatments, with thinning followed by slash treatment, had less than 80 percent canopy

Fire	Hayman	Aspen	Davis	Fischer	Power	
Start Date	6/8/2002	6/17/2003	6/28/2003	8/8/2004	10/6/2004	
National Forest/ Location	Pike/ Colorado	Coronado/ Arizona	Deschutes/ Oregon	Wenatchee/ Washington	Eldorado/ California	
Fire size (acres)	138,320	91,390	20,995	16,425	16,796	
Treated units (acres)	19,760	771	2,371	366	2,779	
Number of years since surface treatments	1; 10-13	~7	None present	None present	10; 15-20	
Age of canopy treatments (years)	2	~7	<1, 2	None present	1, 5	
Age of combination treatments	1; 9-10	None present	0-2	1	None present	
Forest type	Ponderosa pine, Douglas-fir	Ponderosa pine, white fir, live oak	Ponderosa pine, white fir	Ponderosa pine	Jeffrey pine, incense cedar, white fir	
Burning index*	96	99	96	72	84]



Although forest types and historical fire regimes differed considerably among the sites, all were in mixed-conifer forests in the Western United States.

* Burning Index percentile is an indicator of potential wildfire danger relative to historical fire weather.



In this aerial photo taken after the Hayman Fire, green crowns are visible in the area on the right, which was thinned 2 years before the wildfire. The fire consumed most of the forest canopy in the untreated area (left side of photo). Yellow line was added to photo to show boundary of treatment area. Photo by Erik Martinson.

scorch while stands on adjacent untreated areas were nearly completely consumed in the fire.

Although greater canopy base height did not make the thin-only treatments effective when tested by wildfire, this factor did show a significant correlation with effectiveness for combination treatments. "Taken together, our findings suggest that altering canopy fuels will affect wildfire outcomes only where surface fuel hazards have been abated," Martinson explains. "But where surface fuel hazards have been abated, reducing canopy fuels may provide added benefits."

"Canopy fuel variables need to be considered in treatment prescriptions," Martinson continues. "But in the end they may or may not influence wildfire severity." The data showed that surface fuels are the most critical variable, a finding consistent with theory, but certainly all the fuel layers and their interactions can affect the outcome.

A widely held opinion is that fuel treatments must be overwhelmed at some threshold of weather extremity. But that may not necessarily be so. Somewhat surprisingly, Omi notes, the effectiveness of combination treatments increased with weather severity, as indicated by the Burning Index of the National Fire Danger Rating System. Combination treatments that reduced both canopy and surface fuels were the only ones that showed this relationship. It is not yet known, of course, if this relationship will hold under the more extreme weather conditions predicted by climate change scenarios.

Fire behavior effects beyond fuel treatment units

Funding constraints force managers to prioritize the areas where fuels are treated. One factor in setting these priorities is the objective of protecting untreated areas. Although simulation studies suggest that fuel treatments may provide this "value-added benefit" beyond unit

boundaries, much is uncertain about the degree to which this occurs.

Scientists found only a few sites on the Power Fire in California and the Davis Fire where possible effects of fuel treatments beyond the units treated could be evaluated. Various other influences such as topographical changes or wildfire edges ruled out other sites on the five fires.



Scientists identified fuel treatment units within wildfire perimeters and near similar untreated sites that had also burned in the wildfire. The similar treated and untreated areas were considered pairs for study purposes. Photos by Jonathan Freeman.

The scientists found some evidence that fuel treatment effects may extend beyond the treated unit—but this influence was found mostly for ineffective treatments. Fire severity was significantly greater behind ineffective fuel treatments than in adjacent "unprotected" areas. (In this context, "behind" is defined by the direction of fire spread.) On the Power and Davis Fires, when wildfire burned across ineffective fuel treatments and reached the forest behind them, the combined canopy scorch plus consumption measured 155 percent, compared to 58 percent canopy scorch plus consumption in stands not near these fuel treatment areas.

Although forest stands behind effective fuel treatments did have slightly less canopy scorch and consumption than comparison units, the difference was small. Thus even though fire severity was reduced in effectively treated units, that accomplishment seemed to do little to protect the forest beyond unit boundaries.

Omi emphasizes that the sample size was very limited for testing effects beyond treatment units, and that the size and placement of treated areas, slope steepness, and other variables would affect results in other places. Nevertheless, the data give some support to the hypothesis that fuel treatment activities may affect fire behavior beyond their perimeters.

Effective fuel treatments and management options

Other relationships were observed in the study. Fuel treatment effectiveness was clearly related to treatment age.

Treatments that reduced surface fuels were effective for up to a decade, but older treatments of any type were not found to have a significant effect on fire severity at any site.

In this postfire study, soil heating was measured by ground char. Overall, the ground char differences between treated and untreated areas were smaller than the crown scorch differences. Not surprisingly, the ground char was lowest in units where surface fuels had been treated, and highest in thinned units that did not have slash treatment. Ground char did not correlate strongly with treatment effectiveness, but it did correlate strongly with the establishment of non-native plants after the fire.

Research ecologist Geneva Chong, with the U.S. Geological Survey, investigated the relations among fuel treatments, wildfires, and native and non-native plants on the study sites. The data so far extend only one or two seasons after the fires, too soon to draw conclusions on long-term trends.

Chong found evidence that fuel treatments give nonnative plants a chance to get established, by thinning out the forest canopy and leaving more bare ground. But high-severity fire had more significant effects. Wildfire destruction of forest canopy and ground fuels was significantly correlated to decreases in native plant species and increases in non-native plant species, at least in the first year after the fires. Although some non-native species get established after effective fuel treatments, those fuel treatments lower the risk of severe wildfires, which carry higher risks of non-native plant establishment.

All three scientists, Omi, Martinson, and Chong, urge caution in applying the study's findings to areas beyond the mixed-conifer forests sampled. The regional differences in these forests, differences in historical fire regimes, as well as the highly variable mountain terrain and weather of the Western United States, add up to a huge potential for variable results. Omi points out that forest managers must also consider other objectives, such as the restoration of wildlife habitat. Given these cautions, the study's results do suggest that fuel treatments such as thinning and prescribed burning may reduce the intensity and severity of subsequent wildfire. The treatment of surface fuels appears to be the most important factor for success.

It is always difficult to quantify what was saved by fuel treatments—how many lives and homes were saved, the losses of wildlife and recreation that were prevented. This study of real-world results helps to support the argument that well-designed fuel treatments are worth the effort.

Further Information — Publications and Web Resources

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Management Implications

- Fuel treatments that reduced surface fuels were generally effective, with or without the reduction of canopy fuels. But combination treatments, with thinning followed by slash disposal, gave the most protection against severe fire behavior.
- Fuel treatments older than a decade did not have a significant effect on fire severity at any study site, regardless of treatment type.
- The most effective treatments in this study had thinning followed by slash treatment. Thinning without slash treatment may increase wildfire severity, with consequences beyond the boundaries of treatment units.
- Effective fuel treatments may increase management options, such as making firefighting safer and buffering communities or valued resources.
- Effective fuel treatments that reduce wildfire severity may also reduce the risk of invasive plant spread. Also, low-severity burning can increase the number of native plant species.

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Scientist Profile



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