Joint Fire Science Program

Fire Science Brief

RESEARCH SUPPORTING SOUND DECISIONS

Researcher Tadashi Moody ignites a mechanical-plus-fire treatment unit. Photo by Dr. Andy Amacher.

Chainsaws or Driptorches: How Should Fire Risk Be Reduced?

Summary

Forest managers have a standard set of tools they use to reduce fire hazard: mechanical thinning, brush clearing, mechanical treatment of slash (small woody debris), prescribed fire, and various combinations and timings of the use of these tools. Although these tools are widely used, the science is sketchy on the benefits and tradeoffs of the different treatments. In response, the national Fire and Fire Surrogates Study (FFS) set up a national network of research sites to study the effects of fire "surrogates," such as mechanical thinning, mechanical slash treatments, and prescribed fire on forests.

Early findings for the Sierra Nevada FFS site are reported here. The study used four treatments: prescribed-fire-only, mechanical-only, mechanical-plus-fire, and no-treatment controls. All three active fuel treatments significantly reduced fire risk, but the two treatments that used prescribed fire to reduce surface fuels achieved the greatest reductions in potential fire behavior. The mechanical-only treatment (mechanical thinning followed by mechanical slash treatment) reduced crown bulk density and ladder fuels but increased surface fuels, and it was less effective in reducing fire risk. The active treatments also had noticeably different consequences on forest structure and predicted tree mortality. A pretreatment assessment can determine the level of fire hazard from the surface, ladder, and crown fuels, and a prescription can be designed to treat the fuel layers creating the risk.

Key Findings

- In a California mixed-conifer forest, all three active fuel treatments (prescribed-fire-only, mechanical-only, mechanical-plus-fire), significantly reduced fire risk, when compared with the no-treatment units.
- The prescribed-fire-only and mechanical-plus-fire treatments resulted in the lowest average fireline intensities, rate of spread, and predicted tree mortality, if a wildfire should occur.
- The mechanical-only treatment (mechanical thinning followed by mechanical slash treatment) moderated potential wildfire behavior, but during severe fire weather would have resulted in more tree mortality than the two treatments with prescribed fire.
- The no-treatment control units would have the most severe fire behavior and most tree mortality, if a wildfire should occur.
- All three active treatments created forest structure that more closely resembled the historical forest structure, and the native understory plant communities showed a moderate degree of resilience to all active treatments.

The story is familiar by now—after a century of fire suppression and other causes, many western forests are crowded with more small trees, more ground fuels, and more continuous canopies than the forests of the late 1800s. In recent years, huge wildfires have burned record acreages and hundreds of homes. Unlike the patchy fire-mosaic once created by fires of mixed intensities, hot fires have left behind entire mountainsides of snags and left once-fertile soils sterilized and water-repellent. Most people now agree that forest managers should reduce fire hazard in fuel-heavy forests for the safety of firefighters and homeowners, as well as for the benefit of wildlife and forests.

Forest managers have a standard set of tools they use to reduce fire hazard: mechanical thinning, brush clearing, mechanical chipping of slash, prescribed fire, and various combinations and timings of the use of these tools. Managers rely heavily on their own experience in prescribing fuel treatments and although they report many success stories, they also face many unknowns and risks.

Consequently, managers have asked for better science on the benefits and tradeoffs of different treatments. After all, these tools are widely used—on over 2½ million acres of national forest alone in 2006, at a cost of millions of dollars—yet the science is sketchy on which treatments and prescriptions are most effective at reducing fire hazard, how different treatments affect forests ecologically, and how treatments compare for cost-effectiveness.

In response, the national Fire and Fire Surrogates Study (FFS) was started in 2000 to study the effects of fire "surrogates," such as mechanical thinning, mechanical slash treatments, and prescribed fire on forests. "The need for restorative practices is clear," says Scott Stephens, an associate professor in wildland resource science at the University of California Berkeley. "Less clear, however, is the appropriate balance among cuttings, mechanical fuel treatments, and prescribed fire."

The rigorously controlled FFS research is showing more conclusively how standard fuel treatments affect forest structure, fuel loads, and forest ecosystems. It is also producing findings on how fire surrogates, such as mechanical thinning, mechanical chipping, and prescribed fire, change forests ecologically compared to wildfire. For example, since the seeds of some tree species need fire to germinate, will the use of mechanical treatments instead of prescribed fire change the forest's mix of tree species over time?

Using funds from the Joint Fire Science Program (JFSP), the National Fire Plan, the U.S. Department of Agriculture, and the U.S. Department of the Interior, scientists and managers set up a national network of research sites and an experimental design using realistic management options. The same items are being evaluated at all FFS sites, including fuel loads, predicted fire behavior, forest structure, understory plants, tree diseases, wildlife, insects, soils, cost-effectiveness, and wood utilization. Early findings for the Sierra Nevada FFS site are reported here.

Study designed to test competing ideas on how to reduce fire risk

The highest research priority for the FFS was to examine forests that historically had short-interval, low- to moderate-severity fire regimes—the forests on the foothills and lower mountain slopes of western states, forests that typically have long, hot fire seasons and frequent lightning storms. These forests, which have often missed several fire cycles, have exhibited the most pronounced changes in fire behavior and fire effects. They are also the forests closest to towns, with more and more homes in and near these forests every year.

Accordingly, all 13 sites in the initial FFS network are in forests that historically had frequent, low- to moderate-intensity wildfires. Eight of the 13 sites are in western coniferous forests, ranging from Arizona to Montana and including the Sierra Nevadas in California and the east-side Cascade Range in the Pacific Northwest. At each site, the same suite of 4 treatments was replicated 3 times, thus establishing 12 units at about 25 acres each.

The suite of treatments used various combinations of the most common methods for reducing fuels. Scientists designed the treatments to test the four most common ideas about how to restore forests where wildfire has been suppressed (see table).

Idea about How to Restore Forests	**FFS Treatment Based on That Idea**
Passive management or "let nature do it"	Untreated control unit
Restore ecosystem processes: reintroduce fire	Prescribed fire only, repeated periodically
Restore ecosystem structure: use mechanical treatments only	Cutting only, followed with mechanical fuel treatment and/or physical removal of slash; repeated periodically
Restore both forest structure and ecological processes: use cutting and prescribed fire	Cutting followed with prescribed fire (burning may be a year or more later, because of constraints), repeated periodically; fire alone may be used one or more times between cuttings

Pre-burn and post-burn photos for prescribed fire only treatment; pre-burn photo is representative of pretreatment conditions for all treatment types.

For all treatments, the goal was to produce a forest structure that would be resilient if in the future a wildfire burned through the stand. Fire-resiliency was defined as at least 80 percent of the dominant and codominant trees surviving if a wildfire burned the treated area during moderate fire weather. Fuels Management Analyst Plus® (FMAPlus®) was used to calculate the fire resilience of the treated stands. Specific prescriptions to achieve this goal, such as the number of trees cut, fuel moistures, and burning patterns, differed among FFS sites because of differences in forest types and topography, for example.

Scott Stephens, one of the FFS principal investigators, is the lead scientist for the Sierra Nevada FFS site. The FFS treatment units are located on the University of California Blodgett Research Forest, about halfway between Sacramento and Lake Tahoe. The FFS units were established in 2000 and the mechanical treatments were done the same year. Because of the exacting requirements of burning prescriptions and smoke management, the prescribed fire was not done until fall of 2002.

At Blodgett Forest, the mechanical treatments used a combination of crown thinning and thinning from below. The pretreatment mix of conifer species was kept, so the overstory after thinning was still a mixture of white fir, incense cedar, Douglas-fir, ponderosa pine, sugar pine, and black oak. No attempt was made to return the stands to their 1899 species mix when ponderosa pine was a much more significant component. After thinning, the remaining trees were well spaced with little overlap of live crowns in the dominant and codominant trees.

Both the mechanical-only treatment and the mechanical-plus-fire treatment then used rotary mastication to treat the thinning slash and clear small understory trees and shrubs. "Mastication shreds and chips small, standing trees in place," Stephens explains. The mastication dropped about 90 percent of the smaller understory conifers and hardwoods and left the chipped and shredded wood on the ground.

Most prescribed fire was done at night, when wind, temperature, and humidity were within prescription guidelines. In the prescribed-fire-only units, where no thinning or mechanical work had been done, a strip head-fire burning pattern was used. In the mechanical-plus-fire units, where thinning and mastication had created heavy slash on the forest floor, a backing fire was used for the prescribed fire.

Four years after the first set of treatments in the long-term study was completed at Blodgett, the first research results are available on how the treatments changed forest structure and potential fire behavior.

Left: stand after commercial harvest and mastication; right: same stand after prescribed fire treatment.

All active treatments reduced fire risk, but the method used mattered

All three active fuel treatments significantly reduced fire risk, but to varying levels. The active treatments also had noticeably different consequences on forest structure and predicted tree mortality.

Stephens used post-treatment data and the FMAPlus® program to model the fire behavior and tree mortality that could be expected if a wildfire burned through treated units during moderate, severe, and extreme fire weather. He found that if a wildfire occurred, the fire behavior would be significantly different among treatment types.

"Prescribed fire significantly reduced the total combined fuel load," Stephens says. The prescribed-fire-only treatment units had the lowest average fireline intensities, rate of spread, and mortality of overstory trees, and the mechanical-plus-fire treatments had the second-lowest scores. Prescribed fire, whether it was the only treatment or was done after thinning, dropped fuel loads significantly in all but the very largest fuel classes. Even though the prescribed-fire-only treatments did not significantly reduce crown bulk density, the modeled fire behavior and tree mortality were significantly reduced.

The modeled fire behavior was more severe for the treatments without any prescribed fire at all. "Mechanical-only treatments were an improvement over controls," Stephens notes. But the mechanical-only treatments had fireline intensities, rate of spread, and tree mortality much higher than the two treatments with prescribed fire. The no-treatment or control units had the most severe fireline intensities, rate of spread, and tree mortality.

All fuel layers are not equal: choosing which fuel layers to treat

Forests have three fuelbeds, or fuel layers: *surface fuels*, including forest floor litter and down wood; *ladder fuels*, including understory shrubs and smaller trees that carry fire upward; and *overstory fuels*, including tree canopies.

"Managers can manipulate the surface fuels, ladder fuels, and overstory fuels," Stephens comments. "The general principle is that the most hazardous fuelbed is usually the surface fuels. Then, the ladder fuels, and then the crown fuels. So the order of importance for treating fuels is generally the same."

Stephens explains that managers can use the same methods he used to estimate the level of fire hazard contributed from each fuel layer. "The FMAPlus® program can be used at a district level." It can use data from stand inventories or photo series guides; the model does not require geographic information system (GIS) data.

A pretreatment assessment of a stand can determine the level of fire hazard from the surface, ladder, and crown fuels in each stand. By modeling alternative treatments and predicting post-treatment fuel loads from each, managers can better evaluate how effective treatments will be on a site-specific level. They can use the information to calculate the tradeoffs among surface, ladder, and crown fuel reductions, which will help them design prescriptions for their particular stands.

The same method can be used to predict wildfire behavior if a wildfire should burn through the treated area. Stephens points out that the method used to model fire risk reduction, and the FFS study in general, are at the stand-level scale. The FMAPlus® program is very useful for analyzing fire risk in stands, but it does not provide data on where in a landscape treatment will be most effective at reducing fire risk for the larger area. The FFS study is also designed to study stand-level reductions in fire risk and ecological effects. The study will not provide information on what proportion of the landscape or which specific stands to treat. However, other JFSP research projects are aimed at these questions (See the February 2008 issue of the JFSP Fire Science Brief, *Behavior Modification: Tempering Fire at the Landscape Level*.)

How fire risk is reduced affects understory plant communities

In the late 1800s, John Muir wrote that "the inviting openness of the Sierra woods is one of their most distinguishing characteristics. The trees of all the species stand more or less apart in groves, or in small irregular groups, enabling one to find a way nearly everywhere…"

The forest mosaic that Muir described was created by short-interval, low- to moderate-severity fire regimes, which existed historically for millions of acres of western forests. For these forests, the objective of reducing fire hazard converges nicely with the ecological objective of restoring forests to the inviting openness and irregular mosaic that Muir saw a century ago.

The FFS study will generate findings on how the ecological effects of mechanical thinning, wood chipping, and prescribed fire compare to wildfire effects. Some of the research questions are the effects on seed germination and plant resprouting, small mammal and bird communities, and cycling of soil nutrients in these fire-adapted forests. More years are needed for many of these effects to be clear, but some early ecological results are already in on forest structure and understory plant communities.

The Blodgett Forest, like many western forests, had a long history of frequent wildfires. The historical fire cycle in these forests increased the nutrient cycling in the understory, allowed more sunlight to reach the understory, and resulted in more available water compared to current conditions.

All three active treatments in the FFS study changed the forest structure to various degrees, creating forest structure that more closely resembles the historical forest (using information from an 1899 forest survey). On the Blodgett Forest, the treatments did not significantly change the species composition. Overall, little change has been seen so far on both conifer and hardwood species composition.

It was no surprise that the native understory plant communities, which include deerbrush, gooseberry, baldhip rose, and snowberry, showed a moderate degree of resilience to all active treatments, at least initially. Both treatments with prescribed fire exposed more mineral soil and allowed more light to reach the forest floor, thus increasing growing space, and forbs and grasses reestablished quickly. In the mechanical-only units, the amount of exposed mineral soil stayed about the same; the lack of fire-cued germination and stimulation of sprouting may explain why these units have so far had less shrub recovery than the units that included prescribed fire treatment.

However, the lack of fire in the mechanical-only units may have helped keep out invasive plants, which often thrive in disturbed environments. The mechanical-plus-fire treatment changed forest structure most substantially, and in these units invasive plants had a small but statistically significant increase. Bull thistle is the most abundant invasive plant in the units at this point. Native species richness (number of different species) decreased significantly in the mechanical-plus-fire units. Although it's still early in the FFS study, this last finding suggests that a risk in plans to reduce fire risk and restore forests is that invasive plants may spread into treated stands.

The long-term FFS study will continue to yield findings for many years on how fuel treatments affect fire risk, forest structure, and ecological effects. Updates are posted regularly on the FFS website.

Management Implications

- Differences in forests require site-specific design of fuel treatments, but general principles can be used in developing prescriptions to reduce fire risk.
- A pretreatment assessment can determine the level of fire hazard from the surface, ladder, and crown fuels, and the prescription can be designed to treat the fuel layers creating the risk.
- The most hazardous fuel layer is usually the surface fuels, and thus in most cases, surface fuels would logically be given the highest priority for treatment.
- In the Blodgett Forest FFS site, all three active treatments reduced fire risk, but the two treatments that used prescribed fire to reduce surface fuels achieved the greatest reductions in fire risk. The mechanical-only treatment, which reduced crown bulk density and ladder fuels but increased surface fuels, was less effective in reducing fire risk.
- The no-treatment option was ineffective at reducing fire risk.
- The mechanical-plus-fire treatment changed forest structure most substantially, which may explain why this treatment resulted in a small, but statistically significant, increase of invasive plants.

Further Information: Publications and Web Resources

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All photos courtesy of the University of California, Fire Science Lab.

Scientist Profile

Scott Stephens is an associate professor in wildland resource science at the University of California Berkeley. He is interested in the interactions of wildland fire and ecosystems. In addition to his research in California's Sierra Nevada Range, he is also investigating the fire history and ecological patterns in Mexico's Sierra San Pedro Martir Mountains (Baja California), the only large, mixed-conifer ecosystem in western North America where logging never occurred and large-scale fire suppression was never initiated. He has given congressional testimony several times on current science relevant to fuel treatment and other fire management issues.

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Left to right, the burn crew: Jennifer York, Jason Moghaddas (front), Tasdashi Moody, Andrew Corr, Sam Greinke, Danny Fry, Nadia Hamey, Emily Moghaddas, Dan Stark, Scott Stephens, and Frieder Schurr.

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Manager's Viewpoint
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Embracing "New information": A Manager's Perspective

Written By: Don Yasuda

Purpose of this opinion piece

Manager's Viewpoint is an opinion written by a fire or land manager based on information in a JFSP final report and other supporting documents. This is our way of helping managers interpret science findings. If readers have differing viewpoints, we encourage further dialog through additional opinions. Please contact Tim Swedberg to submit additional viewpoints (timothy_swedberg@nifc.blm.gov). Our intent is to start conversations about what works and what doesn't.

Background

Scott Stephens reports on the early findings from the central Sierra Nevada Fire and Fire Surrogate Study (FFS) comparing three initial treatments against a control. This Manager's Viewpoint will focus around a discussion of the initial findings and management implications from this project and the challenges of incorporating new science findings like this into management evaluations and decisions.

Familiar Story

As Dr. Stephens writes, "the story is familiar by now." The key findings from the Blodgett FFS are consistent with findings from other FFS sites and match the observations from on-the-ground experience by forest managers who have been implementing similar practices for the last decade. In addition to modeled expected changes in fire behavior, we are beginning to gather data from real fires burning into treated areas. In California, the best example comes from a similar experiment on the Blacks Mountain Experimental Forest which burned in the Cone Fire in 2002 (See Fire Science Brief, Issue 4, January 2008). Similar experiences are being documented in other areas of the country (See Science Brief, Issue 1, October 2007 and Success Stories at http://www.forestsandrangelands.gov/success/index.cfm).

New Information and Unanswered Questions

There is a rich and building body of publications coming from the Blodgett FFS site examining the effects of the study treatments on soils, leaf litter invertebrates, insects and disease, fire and fuels, silviculture, and wildlife. Managers need new science findings to help review and adjust their assumptions (adaptive changes) and feel confident in making decisions to move forward in planning and implementing actions. Yet often new science findings have the opposite effect. They are less than definitive and raise many new questions or uncertainties. So, despite this "familiar story", there remains huge scientific and social uncertainty about how to reduce fuels and manage vegetation in forested systems.

These uncertainties arise in questions such as:

- How much vegetation and fuels do I need to remove to change fire behavior?
- How does removing vegetation and fuels affect other resources like wildlife and plants?
- What are the on-the-ground effects of removing vegetation and fuels to soils and water?
- What are the costs of doing this work and how do I identify priority areas to treat?
- How do I compare the effects of treatment with the probability and effects of wildfire or other disturbance?

Scope and Scale of Treatments and Effects

Since the FFS study was designed to answer most of these questions, it would seem that we are well on our way to finally putting some of these questions to rest. For some situations, we are very close. The method of assessing predicted wildfire behavior presented by Dr. Stephens can be used to reduce uncertainty when the objective is to protect values within the treated unit. However, as Dr. Stephens appropriately points out, the FFS study was not designed to address landscape questions about treatment placement or landscape effects. Unfortunately, these are the scale of questions that managers struggle the most with when planning projects or developing strategic out-year programs of work. Fortunately, other efforts, some sponsored by the JFSP, are tackling these issues, including the Stewardship and Fireshed Assessment effort I'm currently involved with (Bahro et. al. 2007).

So here's the rub, science findings are best extracted from studies of small areas where confounding conditions like natural variations in the landscape can be controlled or explained, yet managers must apply these findings back over a landscape that includes the very natural variation that was excluded from the finding. This contradictory and illogical application of science findings are driven from both ends. The scientist is driven to exclude variation in order to find statistically significant relationships. The manager is driven to use these new science findings and, without other information about the areas not studied, is pressured to overextend it, often under the misplaced notion of using "the best available science".

Integrating Science and Management: The Role of Science Briefs and Manager's Views

The JFSP can play a critical role in working through this conundrum through these Science Briefs and Manager's Views. These are opportunities for scientists to explain their findings and work with managers to ensure the information is appropriately applied and considered. I'll provide two examples from the Blodgett FFS Science Brief of how I see this working.

Modeling Fire Behavior to Determine Treatment Effectiveness

The Fire Science Brief describes a pretreatment assessment process to use the fire model tool FMAPlus® to assess how alternative treatments of different fuel layers affect the level of fire hazard so that the fire effects of different intensities of treatments can be calculated. This seemingly simple description of a method to assess hazard reduction from different treatment prescriptions can be overextended by managers to a pseudo-requirement that it be used on all treatment units when evaluating projects. Their rationale (or the rationale provided to them in public comments) may be on the lines of "it's a method that's been suggested by scientists, it's readily available, and doing anything less appears arbitrary." The problem isn't that the additional information on fire hazards and effects cannot be calculated for each treatment unit (at some cost and effort), but how does the manager trade off a quantified fire risk with habitat values for a species? Is a 5% reduction in fire hazard an acceptable trade for a 50 acre change (reduction in some unquantified amount) in habitat quality?

A discussion that bridges the gap between science and management might go like this: "The pretreatment assessment process is a useful tool to explore likely fire outcomes for different treatments in novel or unique vegetation and fuels conditions. It's also a useful communication tool to explain fire behavior in relation to the fire environment and management, especially with non-technical stakeholders. It is also a useful process when point protection is the primary objective but should not be necessary to run on every treatment unit in a landscape project or for very similar projects where the outcomes can reasonably be predicted without the model."

Addressing the Risk of Invasive Plants in Treated Areas

The Fire Science Brief identifies a Management Implication that treatments that change forest structure substantially may contribute to an increased risk of spreading invasive plants. In this case, bull thistle is identified as having a "small, but statistically significant, increase" in the mechanical-plus-fire treatment which changed the forest structure most substantially. This finding is not new, field practitioners and botanists have noted similar situations. For most, this finding will only reinforce the need to do a thoughtful invasive plant/noxious weed assessment as part of project planning and incorporate appropriate prudent mitigation and control measures into the project design. For others, however, this finding could lead to pressure on managers to treat less intensively in general in order to lower the risk of invasive plant spread. The problem isn't that managers desire to spread noxious weeds, but it may be an unfortunate, unavoidable consequence of doing a treatment for some other priority objective, like reducing the risk of large, high severity wildfires. Again, although we may be able to quantify the risk of invasive plant spread, how do we trade off that risk score with a fire hazard risk score?

As with the previous example, an integrated scientist/manager approach to Management Implications might sound like: "Activities that have a moderate or high level of soil disturbance coupled with increased sunlight at the forest floor could favor the spread of invasive plant species. The characteristics of the particular invasive species should dictate the level of concern and offer clues to alternative or mitigating measures. For example, bull thistle, is prevalent in many landscapes and appears less invasive and persistent than other species like cheatgrass. It is hypothesized that treatments that reduce the extent of moderate and high severity fire effects are likely to result in less bull thistle across the landscape over time, and this hypothesis can be evaluated by examining treated areas and burned areas over time."

Manager's Dilemma

The manager's dilemma is how to make decisions in the face of uncertainty. Decisions on managing natural resources have been termed "wicked problems" (Rittel and Webber 1973, USDA Forest Service 2004) because they involve tough social decisions that must be made where there are tradeoffs between positive benefits to some and negative consequences to others, no agreed process to choose exists, and there is no "correct" answer.

I believe it is necessary for scientists to work closely with managers when there are emerging issues that suggests a "go slow" approach to understand the risk of unacceptable adverse outcomes and to develop expectations on how further learning can clarify the risk and suggest options for change. It is equally necessary for scientists to work with managers when emerging issues are not quite "ripe" yet for drastic changes in management direction or activities. Only by working closely together can scientists and managers develop an adaptive management framework that allows continued management of resources while we learn how to manage these risks. I also believe that such efforts will help focus research on the "right questions at the right scales" and contribute to greater collaborative learning (Bahro et al. 2007).

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Manager Profile

DON YASUDA is a biological scientist for the USDA Forest Service, Pacific Southwest Region. He is part of the regional Stewardship and Fireshed Assessment Cadre, providing strategic decision support to national forests and their stakeholders on planning and implementing strategic programs of work to address threats to resource values. He is interested in adaptive collaborative management of natural resources in forest systems. He works closely with fire and fuels specialists and silviculturists assessing opportunities and effects of fuels and vegetation management. He has contributed to the recent JFSP Biomass and Risk Roundtables.