Working Papers in Southwestern
Ponderosa Pine Forest Restoration

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Effects of Forest Thinning Treatments on Fire Behavior

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Working Papers in Southwestern Ponderosa Pine Forest Restoration

Ecological restoration seeks to heal degraded ecosystems by reestablishing native species, structural characteristics, and ecological processes. The Society for Ecological Restoration International defines restoration as "an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability. . . . Restoration attempts to return an ecosystem to its historic trajectory" (Society for Ecological Restoration International 2004).

In the southwestern United States, most ponderosa pine forests have been degraded during the last 150 years; many areas are now dominated by dense thickets of small trees and have lost their once diverse understory. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, low-intensity surface fires—often after first thinning dense stands—and reestablishing productive understory plant communities. The Ecological Restoration Institute at Northern Arizona University is a pioneer in researching, implementing, and monitoring ecological restoration of southwestern ponderosa pine forests. By allowing natural processes such as fire to resume self-sustaining patterns, we hope to reestablish healthy forests that provide ecosystem services, wildlife habitat, and recreational opportunities.

Every restoration project needs to be site specific, but the detailed experience of field practitioners may help guide practitioners elsewhere. The Working Papers series presents findings and management recommendations from research and observations by the ERI and its partner organizations.

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Introduction

One of the goals of restoration in southwestern ponderosa pine ecosystems is to reduce the risk of unnaturally severe wildfires. Many factors influence fire behavior – including drought, topography, insect infestation, and weather – but fuels are the only factor that people can realistically manage (Zimmerman 2003; Pollet and Omi 2002). This publication summarizes what is known about restoration treatment effects on fire behavior in ponderosa pine forests, and suggests treatment options that can alter future fire behavior.

Forest Structure and Fire Severity

Historic fire regimes in southwestern ponderosa pine forests involved frequent low-severity fires (Weaver 1951; Swetnam and Baisan 1996). Typically, these fires maintained relatively light fuel loads within the landscape by burning herbaceous vegetation, downed needles, and woody debris, as well as smaller tree saplings and seedlings. The result was a generally open-structured forest. Today most of these same forests are much denser (Covington et al. 1997) and the majority of fires, whether ignited by people or lightning, are suppressed to protect natural resources, human communities, and structures. The result has been an accumulation of fuels that greatly increases the likelihood of wildfires of unprecedented severity.

Of particular concern is the occurrence in recent years of widespread crown fires that are dangerous to human lives, damaging to human communities, and ecologically harmful (Covington 2000). A *passive crown fire* torches an individual tree or group of trees, while an *active crown fire* spreads wildfire from tree to tree through the canopy of a forest stand (Zimmerman 2003).

Forest restoration treatments typically incorporate tree thinning and/or prescribed fire, both of which are intended to reduce overall fuel loads. These actions are sometimes followed by activities such as seeding of native understory plants and control of invasive species (see *Working Paper 4: Fuels Treatments and Forest Restoration: An Analysis of Benefits*). Treatments that reduce fuel loads can reduce fire severity and spread by limiting the initiation of passive crown fire and making it more difficult for active crown fire to spread. Treated tracts can also function as areas in which firefighters can work to contain a large wildfire.

Treated areas, though, are never entirely fireproof and do not always serve as fire barriers. In the right conditions, severe fires can burn through treatments or "spot" over them. But as treatments accumulate over the landscape or are placed in strategic locations, they have the potential to make a significant impact on the behavior of individual wildfires and overall fire patterns (Finney 2001). Over time, reducing excessive fuel loads may allow the possibility for natural regimes of frequent, low-severity fires to once again prevail in some areas, thereby maintaining sustainable forest structures and further reducing the likelihood that stand-replacing wildfires will occur in the future (Omi and Martinson 2004).

Treatment Effects on Fire Behavior: Examples

Research of various sorts (Box 1) has consistently shown that the risk of crown fire can be lowered if fuel loads are reduced, small-diameter trees are removed, and ladder fuels are minimized (Fulé et al. 2001a and 2001b; Pollet and Omi 2002; Finney et al. 2003; Schoennagel et al. 2004). Table 1 shows how reductions in basal area, overall tree density, and density of small-diameter trees reduce the likelihood of crown torching, according to observational studies of three large wildfires in ponderosa pine forests (Pollet and Omi 2002). In these fires, stands with higher basal areas, higher density of trees, and a larger proportion of small-diameter trees consistently showed a greater degree of crown scorch than other areas.

These results echo the effects of the 2002 Rodeo-Chediski Fire in Arizona, which burned through a mosaic of previously thinned and unthinned areas. A postfire assessment showed that 35 percent of stands that had been thinned within the previous 15 years (with an average stand density of 157 stems per acre) experienced high-severity crown fire, while 55 percent of stands that had not been thinned (449 stems per

Table 1. Treatment effects on crown scorch for three fires in ponderosa pine forests.

Wildfire name Location Size Date	Treatment type	Basal area (ft^2/acre)		Density (stems/acre)		Average tree diameter (inches)		Crown scorch (%)	
		Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Webb Fire Kootenai NF, MT 3,500 acres 1994	Prescribed fire 1989; no thinning	100.1	60.3	258	30	9.5	17.0	67.0	23.0
Tyee Fire Wenatchee NF, WA 140,300 acres 1994	Thinned 1970; prescribed fire 1983	107.6	68.9	504	88	8.1	12.1	100.0	74.0
Hochderffer Fire Coconino NF, AZ 16,400 acres 1996	Thinned 1970; prescribed fire 1995	108.7	101.2	310	225	8.6	9.5	99.0	29.0

acre) burned intensely (Schoennagel et al. 2004). Stands with greater production of understory vegetation and with an open tree structure burned with less severity than did stands with more trees and less grass. It is important to note, though, that thinned stands in which slash had been left in place were more likely to burn at high severity than even unthinned stands; a variety of methods are available for removing this abundant dry fuel after thinning (see *Working Paper 13: Treating Slash after Restoration Thinning*).

These observational studies are consistent with the outcomes of modeling exercises conducted following restoration treatments in two areas in northern Arizona (Fulé et al. 2001a and 2001b; Box 2). In those studies, thinning of smaller trees followed by prescribed fire resulted in fire behavior characterized by less canopy consumption, shorter flame lengths, and a slower rate of spread than in untreated areas; in addition, it was shown that a much stronger wind would be needed to sustain a crown fire in treated areas than in untreated areas.

But treatments alone do not determine fire behavior. A study assessing treatment effects on the behavior of the Hayman Fire in Colorado concluded that treatments largely, but not entirely, succeeded at minimizing fire severity (Finney et al. 2003). On days of extremely low humidity and unusually high wind speeds of up to 84 mph, the fire burned through treated as well as untreated areas; on days of more moderate fire behavior, however, previously implemented treatments helped to slow fire spread and lower its severity. Researchers concluded that areas that had been recently broadcast burned (within the previous year) appeared to be more effective at reducing fire severity than areas that were broadcast burned years earlier, and that large fuel breaks were substantially more successful at reducing fire progress than small fuel breaks.

Recommendations

There is no one-size-fits-all recommendation for how mechanical thinning or prescribed fire should be used at a given location in order to reduce wildfire risk. Fire behavior is variable enough that it is impossible to precisely predict future fire behavior from a given stand density and structure. In addition, ponderosa pine landscapes across the southwestern states are naturally highly variable. But some general points are important.

Thinning of both canopy and ladder fuels is generally needed to reduce crown fire potential. The modeling tools available at **www.fire.gov** can help assess how much thinning will be needed to reduce potential fire behavior by a certain amount. Though it can be expensive, thinning does not carry the risks of prescribed fire and can be carried out through much of the year (though often not when soils are wet; see *Working Paper 5: Limiting Damage to Forest Soils During Restoration*).

Slash treatments affect future fire behavior. Leaving slash in place after an otherwise effective thinning treatment can increase rather than reduce fire hazard. See *Working Paper 13: Treating Slash after Restoration Thinning* for ideas on how to deal with slash.

Prescribed fire is important in reducing fuel loads and cycling nutrients. Prescribed burning is typically cheaper than mechanical thinning and can often be done without heavy equipment that impacts soils. It releases nutrients into the system and often results in a flush of herbaceous growth, thereby more closely emulating natural fire regimes than thinning alone. Burning in combination with thinning may be the most successful fuel treatment combination (Strom 2005). Prescribed fire, when used alone, can reduce potential fire behavior for a maximum of about ten years (Finney et al. 2005; Strom 2005).

Fuel reduction treatments provide short-term benefits, while restoration provides long-term benefits. Treatments that combine thinning with prescribed fire and that focus attention on a wide range of post-treatment conditions (including herbaceous vegetation, wildlife habitat, watershed benefits, and recreation) do the best job of reducing fire danger and improving forest health in the long term (Covington et al. 2001; Omi and Martinson 2004). Restoration treatments that focus on healthy forest structure allow low-severity fire to easily and inexpensively shape forest conditions in the future – and this, in turn, reduces the need for future maintenance thinning.

Size matters. Larger treated areas more effectively reduce fire behavior than smaller areas (Finney et al. 2003).

Treatments that leave too much fuel behind can be a waste of money and effort. New growth follows thinning or prescribed fire and puts a time limit on the effectiveness of these treatments. By itself, prescribed burning can be effective in reducing wildfire severity for up to ten years (Finney et al. 2005; Strom 2005). If management goals include reducing fire danger, then treatments that leave heavy fuels behind in the form of slash or living trees don't work – they waste resources and will force managers to implement more treatments in coming years. Only treatments that allow the possibility of future low-severity fires that manage fuels represent a long-term solution to the problem of unnatural wildfire intensity.

Landscape patterns matter. Landscape-scale planning techniques such as those developed by Finney (2001) and Sisk et al. (2004) can help assess where treatments should be concentrated in order to achieve the greatest degree of fire risk reduction and other corollary benefits. Software tools available at **www.fire.gov**, along with GIS technology, can help assess where treatments are most important and where resources should be concentrated.

Enough uncertainty exists that adaptive management is crucial. Reducing fuel loads is both a science and an art. Fire behavior and forest ecology are both complex, and some effects of restoration treatments will inevitably not be those predicted. For that reason, it is vital to incorporate adaptive management techniques such as evaluating the results of past treatments during the planning of new ones (Murray and Marmorek 2003).

Box 1: How Do We Know How Treatments Affect Fire Behavior?

Understanding the effect of treatments on fire behavior is a challenge. All wildfires are unique, and variables such as drought, topography, tree health, overall fuel loading, and weather all affect how stand conditions correspond with fire behavior. Yet observational studies, experimental studies, and modeling have established some general relationships between forest structure and fire behavior. Anecdotal knowledge, based on close observation by trained fire personnel, has been an important addition to the base of more formal research.

Observational Studies

If researchers look retrospectively at what fuel treatments were in place before a wildfire started, they can use that information in conjunction with ecological information collected post-fire to determine how the treatments influenced fire severity and behavior.

- **Advantages:** Wildfire regimes, including the effects of catastrophic wildfire, are utilized to provide the study's data.
- **Disadvantages:** There is little control. Researchers may have limited knowledge of the specific and changing conditions present at the time of the fire. Information about previous treatment prescriptions may be limited.

Experimental Studies

These studies usually involve implementing a treatment prescription and then igniting a fire to assess how the fire moves through the treated landscape, as compared to untreated areas.

- **Advantages:** Experimental studies provide an opportunity for researchers to assess at first hand how fire behavior can be modified as a result of different treatment types.
- **Disadvantages**: It is difficult to test how a treated area will respond to a high-severity wildfire because it is rarely acceptable for researchers to light such a fire; therefore, this type of design has limited value in truly understanding the risk of catastrophic fire.

Fire Modeling

Several fire behavior prediction software packages can model fire behavior given a set of forest conditions, such as fuel loads, fuel moisture, canopy bulk density, slope, elevation, and wind speed. The programs can then predict the speed and direction of the fire, flame length, rate of spread, fuel consumption, smoke production, and crown fire indices. Many of these programs are available for free download (see inside back cover).

- **Advantages:** Simulating fire behavior on the computer allows researchers to observe and compare how fire severity changes within different treatment prescriptions and ecosystem parameters, without having to undergo the cost of treatments.
- **Disadvantages:** It can be difficult to accurately model all of the variability within a given landscape. As a result, patterns observed in fire simulations can be different than what is observed on the landscape, even when existing fuel loads and weather conditions are incorporated into the model.

Box 2: Fire Modeling Results from Experimental Restoration Treatments

Detailed fire modeling efforts have predicted how effective two large-scale forest restoration projects in northern Arizona have been in reducing wildfire danger. At Mount Trumbull on the Arizona Strip treatments were designed to replicate historic forest conditions. All trees pre-dating 1870 were not thinned, regardless of species; three replacement pines were left for every one snag, stump, or fallen conifer. Oak and locust were not thinned. Prescribed fires followed thinning. Fire behavior after treatment was modeled using NEXUS Fire Behavior and Hazard Assessment System (Scott and Reinhardt 1999). The modeling projected more moderate fire behavior in thinned areas than in the control plots (Fulé et al. 2001b).

Treatment effects on modeled fire behavior, Mount Trumbull

	Crown bulk density (lb/ft^3)	Crown fuel loading (tons/acre)	Basal area (ft^2/acre)	Pine density (trees/acre)	Percent of crown burned	Rate of spread (ft/min)	Flame length (ft)
Control plots	0.00372	4.89	145.7	354.0	68	111.5	38.0
Treated plots	0.00319	2.63	80.5	70.5	20	63.3	11.8

In the Fort Valley Experimental Forest, just northwest of Flagstaff, three different thinning treatments, followed by prescribed fire, and a control were incorporated into experimental blocks to assess how fire behavior would be affected. The thinning treatments differed in how many living trees were retained around stumps, snags, stump holes, and other evidence of once-extant trees (for more details on the thinning methods, see *Working Paper 9: Restoration of Ponderosa Pine Forests to Presettlement Conditions*). The largest trees were retained in all treatments. Once the treatments were complete, forest conditions were modeled using NEXUS (Scott and Reinhardt 1999). The modeling (detailed in Fulé et al. 2001a) predicted that considerably higher wind speeds would be needed to produce crown fire conditions in treated areas than in untreated areas.

Effects of types of thinning on modeled fire behavior, Fort Valley

	Stand density (trees/acre)	Basal area (ft^2/acre)	Crown bulk density (lbs/ft^3)	Average crown base height (ft)	Crowning index (mph)
Control plots	480.6	164.3	0.0052	21.5	28
1.5/3 thinning	56.8	67.8	0.0021	29.1	55
2/4 thinning	68.8	77.7	0.0026	31.9	47
3/6 thinning	98.3	97.2	0.0032	27.4	40

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For More Information

To download fire-modeling software programs, visit **www.fire.org**

For more information about forest restoration, contact the ERI at 928-523-7182 or **www.eri.nau.edu**

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