EFFECT OF THINNING AND PRESCRIBED BURNING ON WILDFIRE SEVERITY IN PONDEROSA PINE FORESTS

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INTRODUCTION

Fuel treatments in ponderosa pine (Pinus ponderosa) forests to reduce catastrophic wildfire are controversial. Some groups wholly support fuel treatment while others remain strongly opposed. We undertook a study to partially resolve this controversy by testing whether fuel treatments affected fire severity in four wildfires burning in ponderosa pine forests. Ponderosa pine constitutes the most widely distributed forest type in the western United States and often occurs in areas with increasing human development.

Fires in ponderosa pine forests often differ dramatically from those observed by early settlers. Many of today's fires are stand destroying crown fires as opposed to much lower intensity surface fires (Arno and Brown 1991, Agee 1993, Covington and Moore 1994, Mutch 1994). In addition to changes in fire behavior, stand structure in ponderosa pine forests has also changed in the last century. Historical accounts describe large, park-like and open stands (Weaver 1943, Mutch et al. 1993, Covington and Moore 1994). Currently, ponderosa forests are becoming densely packed with dead and dying trees. These forests are also experiencing stand conversion as more shade-tolerant trees out-compete ponderosa pine regeneration. These changes may be attributed to effective fire suppression efforts over the past 100 years.

Forest managers have long contended that a logical link exists between stand structure changes and more extreme wildfire behavior (Weaver 1943, 1961 Biswell 1960, Cooper 1960, Biswell et al. 1968, Dodge 1972, McLean 1993, Fiedler et al. 1995, Williams 1998). For example, shade-tolerant species and dense regeneration may serve as ladder fuels to move fire into the tree crowns (Weaver 1943, Dickman 1978, Laudenslayer et al. 1989, MacCleery 1995). Fuel treatments such as prescribed fire and mechanical thinning are offered as ways to reduce or retard wildfire spread and intensity in ponderosa pine forests (Babbitt 1995, Fiedler et al. 1995, Agee 1996).

Few quantitative studies have measured objectively the effect of fuel treatment on fire severity. Much of the evidence supporting the efficacy of fuel treatment has been inferred from informal or nonsystematic inquiry. In contrast, our study systematically and quantitatively examined fire severity in treated versus untreated ponderosa pine stands in selected western wildlands. Our main objective was to compare the severity of wildfires in adjacent untreated versus treated ponderosa pine stands.

Numerous recent studies have concluded that some type of fuel treatment results in less severe wildfires (Edminster and Olsen 1995, Fiddler et al. 1995, Fiedler 1996, Scott 1998a, 1998b, Stephens 1998). Although these researchers infer that treatments result in fire hazard reduction, none of these studies measured the effects of treatments after an actual wildfire. Detailed field studies that compare on-the-ground fire severity in untreated versus treated stands following a wildfire have not been conducted to fully address questions surrounding the effective use of fuel treatments. We attempted to provide answers by carefully studying how stand structure differences affect fire severity.

STUDY DESIGN

We selected four wildfires located in the western United States for this study. Although the four sites (described below) met all of the same standards, they were not homogenous. Each site had a different type of fuel treatment resulting in different stand characteristics.

Table 1. Description of sampling sites at the Webb, Tyee, Cottonwood and Hochderffer wildfires.

	Fire			
	Webb	Tyee	Cottonwood	Hochderffer
Treatment Type	broadcast burn in 1989	precommercial thinning in 1970s with underburn for slash removal in 1983	whole tree thinning in 1989, 1990	undetermined tree harvest in 1970s with broadcast burn in 1995
Date of Fire	September, 1994	August, 1994	August, 1994	June, 1996
Date Sampled	July, 1995	October, 1995	September, 1996	October, 1997
Size of Fire	1,415 ha	56,780 ha	18,620 ha	6,640 ha
Elevation	1,067 m	762 m	2,012 m	2,408 m
Aspect	south	west	west	north
National Forest Location	Kootenai NF, Montana	Wenatchee NF, Washington	Tahoe NF, California	Coconino NF, Arizona

The wildfires that burned the stands resulted in unique fire effects at each site. Table 1 summarizes general descriptions for the four wildfires and treatment types.

Sites were selected in ponderosa pine forests that had areas of adjacent untreated and treated stands and that were burned in wildfires.

The following standards were used to select sites for the study:

- stands where ponderosa pine is the major species;
- adjacent treated and untreated stands exposed to the same recent wildfire;
- stands that had accurate treatment records (i.e., maps, timber sale inventories); and
- stands that were treated within 10 years prior to wildfire.

Stands from each category were adjacent to each other to facilitate comparisons. We avoided sites with confounding influences such as roads, wide streams or constructed firelines that may have a significant effect on fire behavior. Since slash resulting from logging operations increases fire hazard, at least in the short run (Fahnestock 1968, Vihanek and Ottmar 1993), only thinned stands where slash residues were effectively removed prior to wildfire incidence were considered.

Selected ponderosa pine stands were categorized as either “treated” or “untreated” depending on the presence of a fuel treatment. The first site, Webb, was treated only with prescribed fire. After sampling on that site, we limited fuel treatments to some type of mechanical tree removal, with or without subsequent prescribed fire. We focused the three later sites on mechanical fuel treatments since prescribed fire was already known to mitigate fire effects (Wagle and Eakle 1979) and we wanted to narrow the focus of this study.

We studied aspects of stand structure that affect changes in fire severity since previous studies have inferred that fuel treatment resulting in stand structure manipulations mitigate fire hazard. To determine the fuel treatment’s effect on stand characteristics, three variables describing stand structure were measured: stand density (trees/hectare), basal area (meters^2/hectare) and average diameter (cm) of trees on the plot.

Crown characteristics, such as crown weight and height to live crown, were also measured since they are known to drive crown fire behavior (VanWagner 1977, Rothermel 1991). To measure fire effects, we recorded one rating of fire severity at each plot and percent crown scorch for each tree on the plot. Fire severity was classified by observing foliage scorch and crown needle consumption (Wagener 1961, Wyant et al. 1986). The following criteria to determine fire severity rating were adapted from Omi and Kalabokidis (1991):

- Unburned, fire did not enter the stand (rating=1);
- Light, surface burn without crown scorch (rating=2);
- Spotty, irregular crown scorch (rating=3);
- Moderate, intense burn with complete crown scorch (rating=4);
- Severe, high intensity burn with crowns totally consumed (rating=5).

RESULTS

The treated plots in this study have lower fire severity ratings and less crown scorch than the untreated plots. From these results we infer that the types of fuel treatments studied reduce fire severity rating and crown scorch. The treated plots burned less severely in terms of below-ground fire severity. Based on the statistical results and field reconnaissance, sites with mechanical fuel treatment appear to have more dramatically reduced fire severity compared to sites with prescribed fire only. Although fire severity ratings and percent crown scorch are lower at treated plots and higher at untreated plots at all sites, the Webb site's differences were the least extreme. Apparently, mechanical fuel treatments at the Tyee, Cottonwood and Hochderffer sites allow for more precise and controlled results compared to prescribed fire. For example, mechanical fuel treatment programs may specify the exact number of post-treatment residual trees per hectare and the treatment can be applied uniformly across the stand. By contrast, prescribed fire fuel treatment often varies across a stand and results in less precise stand structure changes.

For the Webb, Tyee and Cottonwood sites, the stand characteristics contributed to the differences in fire severity. The fuel treatments at these three sites resulted in forests with much lower density and larger trees. Stands with fewer trees have less continuous crown and ladder fuels. Larger trees generally have crowns higher off the ground and have thicker bark which makes them more fire resistant. This twofold benefit of treated stands results in lower potential for crown fire initiation and propagation and for less severe fire effects. Stand structure for the Hochderffer site is not significantly different among the treated and untreated stands; other factors contributed to less severe fire effects in the treated stands since fire severity and percent crown scorch differences cannot be explained by stand structure manipulations.

MANAGEMENT IMPLICATIONS

Our findings indicate that fuel treatments do mitigate fire severity. Treatments provide a window of opportunity for effective fire suppression and protecting high-value areas. Although topography and weather may play a more important role than fuels in governing fire behavior (Bessie and Johnson 1995), topography and weather cannot be realistically manipulated to reduce fire severity. Fuels are the leg of the fire environment triangle (Countryman 1972) that land managers can change to achieve desired post-fire condition. However, in extreme weather conditions, such as drought and high winds, fuel treatments may do little to mitigate fire spread or severity.

There are at least three ways to reduce tree densities and accomplish fuel treatment: wildfire, prescribed fire and mechanical thinning. The first, reliance on wildfires, is impractical. Letting natural fires play their historical role may have unwanted effects in forests that have undergone major stand structural changes over the past years of fire exclusion. In many ponderosa pine forests choked with dense, small-diameter trees, or encroached by shade-tolerant trees, natural fires may no longer play a strategic role.

The second strategy for restoring these forests is large-scale prescribed burning. This is likely to be effective in stands that have moderate or low tree densities, little encroachment of ladder fuels, moderate to steep slopes which preclude mechanical treatment, and expertise in personnel to plan and implement such large prescribed burns. Large-scale implementation of this strategy will require funding for the planning and implementation over current expenditures and may require modifications to current air quality legislation. Future results of such expenditures may be seen down the road in lessened wildfire suppression costs, reduced fire severity, and reduced air quality impacts.

Mechanical tree removal, the third strategy, works best on forests that are too densely packed to burn, that have nearby markets for small-diameter trees, and areas where expertise and personnel are not available for prescribed burning programs. Mechanical tree removal may be accomplished by many different types of harvest, including precommercial thinning, selection or shelterwood harvest coupled with small-diameter tree removal, and thinning from below (Fiedler 1996). The goal is to manage forests for much lower tree densities leaving larger residual trees. Harvests to reduce wildfire hazard will remove small-diameter trees in contrast to traditional timber harvests.

Mechanical fuel treatments can be very labor intensive, especially on steep slopes and in remote areas, and may not be commercially attractive due to the small diameter trees that need removal. To make fuel treatments more cost-effective for small-diameter trees, consistent markets are necessary. Fiedler et al. (1997) assert that mechanized tree harvest on moderately-steep terrain coupled with removal of large amounts of biomass can generate considerable revenue. Periodic underburns and programs for restoring natural fire are critical to maintain these post-harvest stands.

Fuel treatment programs may be costly and time-consuming. But wildfire problems aren't going away soon. We suggest focusing programs, funding and management attention where the risk resulting from severe wildfire is greatest: urban-interface, tree plantations, critical watersheds and habitat for threatened and endangered species. Treating high-volume areas using mechanized equipment could offset costs associated with fuel removal on steep slopes with little timber. Costs associated with wildfire suppression, in terms of funding suppression efforts and personal safety, far outweigh the costs of fuel treatment on similar landscapes.

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