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Fuel treatment longevity in a Sierra Nevada mixed conifer forest

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ABSTRACT

Understanding the longevity of fuel treatments in terms of their ability to maintain fire behavior and effects within a desired range is an important question. The objective of this study was to determine how fuels, forest structure, and predicted fire behavior changed 7-years after initial treatments. Three different treatments: mechanical only, mechanical plus fire, and prescribed fire only, as well as untreated control, were each randomly applied to 3 of 12 experimental units. Many aspects of the initial fuel treatments changed in 7 years. The overall hazard of the control units increased significantly indicating continued passive management has further increased already high fire hazards. Mechanical only fire hazard decreased after 7 years and are now similar to the two fire treatments, which both maintained low hazards throughout the study. Tree density declined significantly 7 years after the initial fire only treatments, while basal area in both fire treatments was unchanged relative to immediate post-treatment conditions. Our findings indicating reduced fire hazard over time in mechanical only treatments might provide an opportunity for a staggered treatment schedule that included prescribed fire which could increase overall treatment longevity to approximately 20 years. Changes in our mixed conifer forests after fuel treatment were generally larger than those reported from ponderosa pine forests in the Rocky Mountains.

1. Introduction

It is recognized that past and current management practices including harvesting, livestock grazing, and fire exclusion have increased fire hazards in western US forests that once burned frequently under low-moderate intensity fire regimes (Fulé et al., 2012; Stephens et al., 2012). Such forest conditions concern fire managers because the increased fuel loads and altered forest structure have made many forests vulnerable to fire severities outside of desired ranges (Miller et al., 2009). Changing climates in the next several decades will further complicate fire management by increasing temperatures and fire season length (McKenzie et al., 2004; Westerling et al., 2006), which further emphasizes the need to promote resilient forested ecosystems (Millar et al., 2007).

Research has determined that the reduction of surface fuels is the most important component of reducing forest fire hazards since this leads to lower fireline intensity and increased ability to manage fire when needed (Stephens et al., 2009). The second most important fuel stratum in terms of fire hazard reduction is commonly ladder fuels which can provide vertical continuity to move fire from the surface to the forest overstory. Retaining and growing larger trees is also an important aspect of fire hazards reduction treatments since these trees have a higher survival probability because of thicker bark and elevated crowns (Agee and Skinner, 2005; Fulé et al., 2007; Hurteau and North, 2009).

Several papers have analyzed the change in potential fire behavior resulting from initial fuels treatments using empirical field studies (Kilgore and Sando, 1975; Covington et al., 1997; Omi and Martinson, 2004; North et al., 2007; Stephens et al., 2009; Fiedler et al., 2010) or simulations with or without the aid of field data (Keane et al., 1990; van Wagtendonk, 1996; Stephens, 1998). Far fewer studies have investigated how forests that have received fuel treatments change over time (Peterson et al., 1994; Sackett and Haase, 1998; Fulé et al., 2005, 2007; Fajardo et al., 2007) and most of these studies have occurred in relatively xeric Rocky Mountain ponderosa pine (*Pinus ponderosa*) forests.

Understanding the longevity of fuel treatments in terms of their ability to maintain fire behavior and effects within a desired range is an important management question. Initial treatment effects such as reduced surface and ladder fuels will diminish over time (van Wagtendonk, 1985; Kiefer et al., 2006) and information from longer-term studies can assist managers in providing important information to aid in deciding how to allocate finite resources, e.g., maintenance of existing fuel treatment versus implementation of new fuel treatments. The objective of this study was to determine how fuels, forest structure, and predicted fire behavior have changed 7-years after initial fuel treatments in mixed conifer forests in the northern Sierra Nevada. The null hypothesis

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investigated is there will be no differences in forest structure and predicted fire behavior 1-year post-treatment (Stephens and Moghaddas, 2005a) as compared to similar measurement and analysis 7-years post-treatment.

2. Methods

2.1. Study area and treatments

This study was performed at the University of California Blodgett Forest Research Station (Blodgett Forest), approximately 20 km east of Georgetown, California. Blodgett Forest is located in the mixed conifer zone of the north-central Sierra Nevada at latitude 38°54′45″N, longitude 120°39′27″W, between 1100 and 1410 m above sea level, and encompasses an area of 1780 ha (Fig. 1). Tree species in this area include sugar pine (*Pinus lambertiana*), ponderosa pine, white fir (*Abies concolor*), incense-cedar (*Calocedrus decurrens*), Douglas-fir (*Pseudotsuga menziesii*) Franco, California black oak (*Quercus kelloggii*), tanoak (*Lithocarpus densiflorus*), bush chinkapin (*Chrysolepis sempervirens*), and Pacific madrone (*Arbutus menziezii*).

Soils at Blodgett Forest are well-developed, well-drained Haploxeralfs (Alfisols), derived from either andesitic mudflow or granitic/granodiorite parent materials (Moghaddas and Stephens, 2007). Cohasset, Bighill, Holland, and Musick are common soil series. Soils are deep, weathered, sandy-loams overlain by an organic forest floor horizon. Common soil depths range from 85–115 cm. Slopes across Blodgett Forest average less than 30%.

Climate at Blodgett Forest is Mediterranean with a summer drought period that extends into the fall. Winter and spring receive the majority of precipitation which averages 160 cm (Stephens and Collins, 2004). Average temperatures in January range between 0 °C and 8 °C. Summer months are mild with average August temperatures between 10 °C and 29 °C, with infrequent summer precipitation from thunderstorms (averaging 4 cm over the summer months from 1960 to 2000) (Stephens and Collins, 2004).

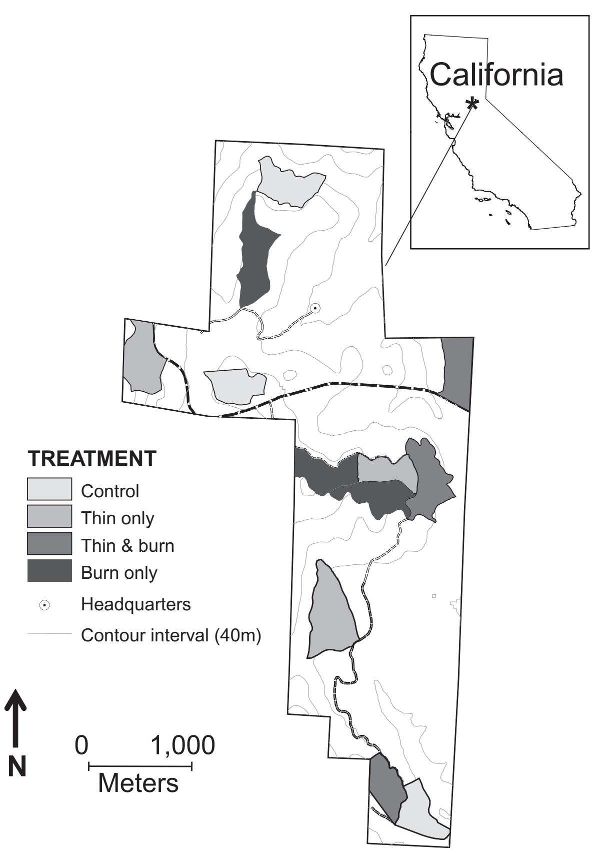

Fig. 1. Experimental units (three replicates per treatment type) within Blodgett Forest, California, USA.

Fire was a common ecosystem process in the mixed conifer forests of Blodgett Forest before the policy of fire suppression began early in the 20th century. Between 1750 and 1900, median composite fire intervals at the 9–15 ha spatial scale were 4.7 years with a fire interval range of 4–28 years (Stephens and Collins, 2004). Forested areas at Blodgett Forest have been repeatedly harvested and subjected to fire suppression for the last 100 years reflecting a management history common to many forests in California and elsewhere in the Western US (Graham et al., 2004).

2.1.1. Fuel treatments

The primary objective of the treatments was to modify stand structure such that 80% of the dominant and co-dominant trees in the post-treatment stand would survive a wildfire modeled under 80th percentile weather conditions (McIver et al., 2009). The secondary objective was to create a stand structure that maintained or restored several forest attributes and processes including, but not limited to, snag and coarse woody debris recruitment, floral and faunal species diversity, nutrient cycling, and seedling establishment. To meet these objectives, three different treatments: mechanical only, mechanical plus fire, and prescribed fire only, as well as untreated control, were each randomly applied (complete randomized design) to 3 of 12 experimental units that varied in size from 14 to 29 ha. Total area for the 12 experimental units was 225 hectares. To reduce edge effects from adjoining areas, data collection was restricted to a 10 ha core area in the center of each experimental unit (Stephens and Moghaddas, 2005a).

Control units received no treatment during the study period (2000–2012). Mechanical only treatment units had a two-stage prescription; in 2001 stands were crown thinned followed by thinning from below to maximize crown spacing while retaining 28–34 m^2 ha^{-1} of basal area with the goal to produce an even species mix of residual conifers (Stephens and Moghaddas, 2005a). Individual trees were cut using a chainsaw and removed with either a rubber tired or track laying skidder. During harvests, some hardwoods, primarily California black oak, were coppiced to facilitate their regeneration. All residual trees were well spaced with little overlap of live crowns in dominant and co-dominant trees. Following the harvest, approximately 90% of understory conifers and hardwoods up to 25 cm diameter at breast height (DBH) were masticated in place using an excavator mounted rotary masticator. Mastication shreds and chips standing small diameter live and dead trees in place and this material was not removed from the experimental units. The remaining un-masticated understory trees were left in scattered clumps of 0.04–0.20 ha in size.

Mechanical plus fire experimental units underwent the same treatment as mechanical only units, but in addition, they were prescribed burned using a backing fire. Fire only units were burned with no pre-treatment using strip head-fires. All initial prescribed burning was conducted during a short period (10/23/2002 to 11/6/2002; the fire only units were burned a 2nd time in fall 2009 but this study will not include the results of these fires) with the majority of burning being done at night because relative humidity, temperature, wind speed, and fuel moistures were within predetermined levels to produce the desired fire effects (Kobziar et al., 2007). Prescribed fire prescription parameters for temperature, relative humidity, and wind speed were 0–10 °C, >35%, and 0.0–5 km h^{-1}, respectively. Desired ten-hour fuel stick moisture content was 7–10%.

2.1.2. Vegetation measurements

Overstory and understory vegetation was measured in twenty 0.04 ha circular plots, installed in each of the 12 experimental units