Available online at www.sciencedirect.com
ScienceDirect
Forest Ecology and Management 251 (2007) 195–204
Forest Ecology and Management
www.elsevier.com/locate/foreco

Mechanical fuel treatment effects on fuel loads and indices of crown fire potential in a south central New Mexico dry mixed conifer forest

Glenn J. Mason [a,*], Terrell T. Baker [b], Douglas S. Cram [a], Jon C. Boren [b], Alexander G. Fernald [b], Dawn M. VanLeeuwen [c]

[a] *Cooperative Extension Service, New Mexico State University, PO Box 30003, MSC 3AE, Las Cruces, NM 88003, United States*
[b] *New Mexico State University, PO Box 30003, MSC 3AE, Las Cruces, NM 88003, United States*
[c] *New Mexico State University, PO Box 30003, MSC 3501, Las Cruces, NM 88003, United States*

Received 8 March 2007; received in revised form 5 June 2007; accepted 7 June 2007

Abstract

The ability of mechanical fuel reduction treatments to mitigate severe fire behavior in dry mixed conifer forests is of interest to land managers as well as the public. We compared fuel loads and indices of crown fire potential to test treatment effectiveness following commercial and non-commercial treatments with differing slash prescriptions in mixed conifer stands at three sites on the Lincoln National Forest in south central New Mexico. Surface and canopy fuels were measured and used to develop custom fuel models in NEXUS 2.0 to estimate torching and crowning indices. Results indicated herbaceous fuel loads were unchanged compared to controls 2 years post-non-commercial and 1 year post-commercial harvest treatment. Sound 1000-h fuels were greater in the scatter and commercial treatments compared to control treatments. The commercial treatment resulted in stand structure closer to historical conditions. Canopy base height increased in all treatments except in stands previously treated 20–30 years ago. Commercial harvest was the only treatment to reduce canopy bulk density and the potential for active crown fire, with the exception of one pile treatment. Non-commercial pile treatments increased the TI. However, due to the danger of crown fire initiation from adjacent stands, further overstory removal is needed in non-commercial treatments to lower crowning potential. Prescribed fire may be used to increase treatment effectiveness in all overstory removal treatments by decreasing surface fuels.

Keywords: Crown fire potential; Dry mixed conifer; Fuel loading; Slash prescriptions; Silviculture; Fuels management

1. Introduction

The Healthy Forest Restoration Act of 2003 (White House, 2003) emphasizes high priority projects and reduces the complexity of environmental analysis allowing management agencies a streamlined framework to implement fuel reduction programs. This has the potential to increase the use of mechanical silvicultural treatments in the wildland–urban interface as well as in the backcountry in many forests. Most research in the Western U.S. on the use of silvicultural treatments to alter fire behavior has focused on ponderosa pine (*Pinus ponderosa*) forests (Pollet and Omi, 2002; Cram et al., 2006). An increased understanding of how these treatments affect fuel loading and crown fire potential in mixed conifer forests will allow managers to more effectively implement and develop new silvicultural treatments in a multiple-use management environment.

Prior to logging and fire suppression policies enacted in the early 1900s, ponderosa pine and dry mixed conifer forest types burned frequently at low intensities (Kaye and Swetnam, 1999; Brown et al., 2001), had lower tree densities and were more open than current stands (Kaufmann et al., 1998). However, fire regimes in mixed conifer forests differed from those in ponderosa pine forests. While the high frequency, low-intensity fire regime is classic of historical ponderosa pine forests (Swetnam and Baisan, 1996), some mixed conifer forests are classified as having a mixed-severity fire regime (Fulé et al., 2003). Historically, dry mixed conifer stands were denser than some ponderosa pine stands (Kaufmann et al., 1998), which may be explained by the differences in historical fire regimes.

Mechanical silvicultural treatments have been widely used in the ecological restoration of ponderosa pine stands

* Corresponding author. Tel.: +1 505 646 5121; fax: +1 505 646 5451.
E-mail address: gmason@nmsu.edu (G.J. Mason).

0378-1127/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.foreco.2007.06.006

(Covington et al., 1997) and are increasingly being applied in mixed conifer forests. The ability of mechanical silvicultural treatments to reduce fire severity has been indicated using various fire behavior models (Stephens, 1998; Scott and Reinhardt, 2001; Keyes and O'Hara, 2002; Stratton, 2004; Stephens and Moghaddas, 2005) and has been documented in observational studies (Omi and Kalabokidis, 1991; Agee et al., 2000; Omi and Martinson, 2002; Cram et al., 2006). Agee and Skinner (2005) recommended four basic principles to increase fire resistance in dry forest types: (1) control surface fire behavior; (2) increase canopy base height (CBH); (3) reduce canopy bulk density (CBD); and (4) retain large fire-resistant trees. More specifically, treatments that reduce CBD less than 0.1 kg ha^{-1} significantly decrease the potential for active crown fire (Agee, 1996; Graham et al., 1999; Scott and Reinhardt, 2001; Cram et al., 2006). However, in some mixed conifer systems it has been argued that climate and weather may be more important in determining fire severity than fuel loads, thus rendering fuel reduction treatments ineffective (Schoennagel et al., 2004). While it has been shown that mechanical silvicultural treatments in ponderosa pine forests can be effective at reducing fire severity (Cram et al., 2006), it is unclear how applicable these same treatments are in mixed conifer forests (Schoennagel et al., 2004).

The effects of thinning treatments on surface fuel loads are often unknown. In most instances canopy fuels are measured, however surface fuels are often estimated based on pictures (Anderson, 1982; Battaglia et al., 2005; Scott and Burgan, 2005). While canopy fuels are of particular interest and importance due to their role in supporting an active crown fire, the role surface fuels play in initiating crown fire should not be overlooked. Depending on circumstances, treatments failing to treat surface fuels may decrease fire severity relative to control stands (Stephens and Moghaddas, 2005; Cram et al., 2006). However, fire severity has been shown to be greater in stands that do not treat surface fuels as compared to those that treat surface fuels through prescribed fire or other means (Stephens and Moghaddas, 2005; Cram et al., 2006) and in one case greater than control treatments (Stephens, 1998).

The objectives of this study were to evaluate the effect of three commonly applied silvicultural treatments on fuel loads by fuel class and potential fire behavior in mixed conifer forests of the Sacramento Ranger District Lincoln National Forest, New Mexico. The three treatments were (1) non-commercial thin with slash piled, (2) non-commercial thin with slash scattered, and (3) commercial harvest up to 61-cm diameter at breast height (DBH) with slash removed. We hypothesized that (1) herbaceous and live woody fuels would increase the most over time in the commercial harvest treatments followed by non-commercial scatter, non-commercial pile, and untreated controls; (2) non-commercial scatter treatments would lead to the largest increases in dead and down surface fuels followed by non-commercial pile, commercial, and control treatments; (3) commercial harvest would increase canopy base height and decrease canopy bulk density more than the non-commercial and untreated control treatments; and (4) indices of crown fire potential would be highest (i.e. showing less potential for crown fire behavior) in the commercial harvest, followed by the non-commercial pile, non-commercial scatter, and control treatments. This research sought to provide managers with the information needed to help choose the treatment that best matches their objectives.

2. Methods

2.1. Study area

Three study areas, Bailey Canyon (Bailey), Cox Canyon (Cox), and Sleepy Grass Campground (Sleepy) were located in the Lincoln National Forest, approximately 3.2–16 km from Cloudcroft, NM within the Sacramento Ranger District. Elevation ranged from 2560 m to 2773 m. Average annual rainfall for Cloudcroft, NM is 704 mm with 50% falling in July–September (World Climate, 2006). Average maximum and minimum temperatures are 14.0 °C and 0.8 °C, respectively (World Climate, 2006). Vegetation type was mixed coniferous forest classified as a *Psuedotsuga menziesii* series and *Quercus gambelii* typic phase (Alexander et al., 1984).

The three study areas differed in historic treatments and current treatments being applied (Table 1). The Bailey and Sleepy areas were similar in that neither had been commercially logged in the last 60–100 years, while the Cox site was commercially logged 20–30 years ago (Mickey Mauter,

Table 1
Site-treatment combinations, treatment history, and plot aspect of sites studied in the Lincoln National Forest, NM

Site-treatment combinations (*n* = 3)	Year treated	Years sampled	Historic treatments	Years since historic treatment	Aspect
Bailey pile[a]	2003	2004–2005	Commercial harvest	60–80	South
Bailey scatter	2003	2004–2005			North
Bailey control	na	2004–2005			South
Cox pile	2003	2004–2005	Commercial harvest	20–30	South
Cox scatter	2003	2004–2005			South
Cox control	na	2004–2005			South
Sleepy pile	2002	2004	Commercial harvest	60–80	South
Sleepy commercial[b]	2004	2005			South
Sleepy control	na	2004–2005			South

[a] Experimental units were ≥1.3 ha.
[b] Sleepy pile was commercially harvested after sampling in 2004 to make Sleepy commercial.