The effects of prescribed fire and thinning restoration treatments on forest floor fuel loading in warm/dry mixed conifer forests in southwestern Colorado, USA

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Introduction

- Warm/dry mixed conifer forests are dominated by fire-tolerant ponderosa pine (Pinus ponderosa), Douglas-fir (Pseudotsuga menziesii) and mesic species such as white fir (Abies concolor), and aspen (Populus tremuloides).
- Fire suppression over the last century has caused an increase in tree density and a shift towards mesic species moving the forest away from its historical make-up (Korb et al., 2012).
- Fuel-reduction treatments are one of the highest priorities in the management of western United States forests today (Kobziar et al., 2006).
- Fire treatments can lose their effectiveness within 10-20 years if regeneration densities are not controlled (Battaglia et al., 2008).
- Fire may be the best tool available for land managers to fight wild fires, and restore historical fire regimes and forest structure.

Objectives

- Test the effects of forest restoration treatments on forest floor fuel loading in a warm/dry mixed conifer forest stand in southwestern Colorado.
- Quantify the differences among untreated controls and areas treated with thinning/prescribed fire and prescribed fire only seven years following prescribed fire treatments.
- Compare pre-treatment 2003 data with 2015 post-treatment data for control, thin/burn and burn only treatments.

Study Site

- The plots were established in 2002, thinned in 2004, and the prescribed fires took place in 2007 and 2008.
- Treatments included: (1) control, (2) thin/burn, and (3) burn only.
- There are 4 replicates of each treatment (4 x 3 = 12 treatment units). Within each unit, 20 plots were established on a 60 m systematic grid.

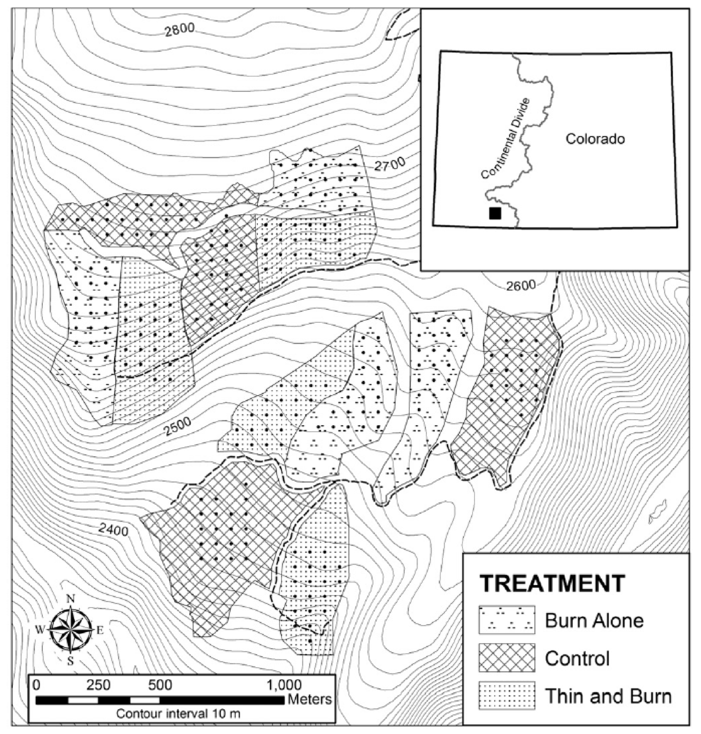

Figure 1: Topographical map of study site with treatment blocks, units and plots.

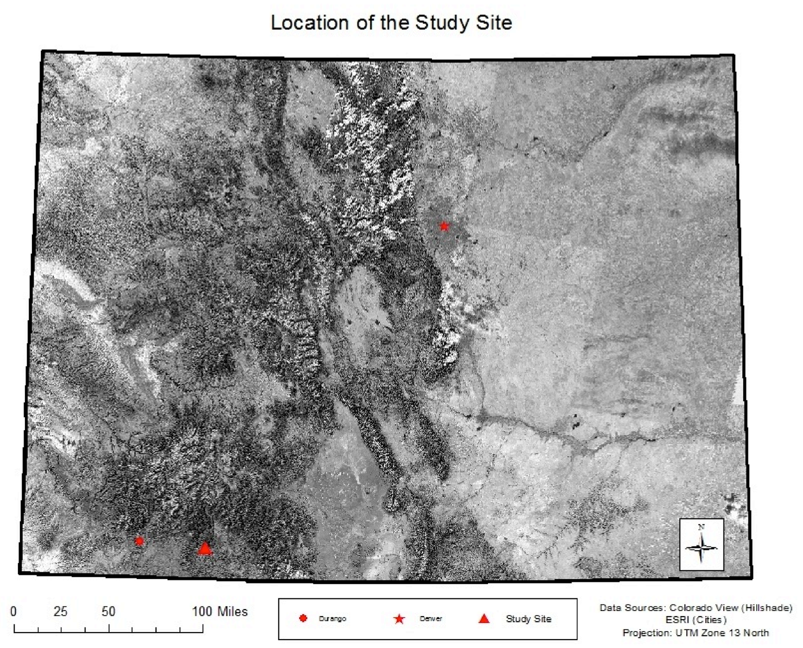

Figure 2: Satellite view of study site location.

Our study area is within the San Juan National forest in southwest Colorado about 18 km northwest of Pagosa Springs, Colorado at N 37.296, W 107.228 (Fulé et al., 2009). The elevation ranges from 2438 to 2743 m at about a 15-30% slope on south-facing aspects (Korb et al., 2012). This area has temperatures ranging from a maximum of 25.7° C in July to a minimum of -17°C in January (Korb et al., 2012). Vegetation in this area includes ponderosa pine, Douglas-fir, white fir, aspen, gambel oak, snowberry, and service berry (Korb et al., 2012).

Experimental Design and Methods

- The field methods used in this study were based on the Brown method for inventorying downed woody material (Brown, 1974).
- The planar intersect technique was used to estimate weights and volumes of downed wood materials, litter and duff depth.
- We used the same fuel transects established in 2003 prior to forest restoration treatments.
- Within each site, five random plots were sampled, for a total of 60 plots (5 plots x 12 units).
- Non-parametric Kruskal Wallis tests were used to quantify differences between the three treatment sites, followed by a post-hoc Bonferroni test. Repeated measures ANOVA tests quantified changes across time (2003 to 2015 data) and (2009 and 2015 data).

Results

Table 1: Mean (± SEM) forest stand characteristics by treatment. N=4. Different letters indicate significance at ≤ 0.05 using one-way ANOVA. Data from Stoddard et al. 2015.

	2009 Tree Canopy (% Cover)	2013 Tree Basal Area (m^2 ha^{-1})	2013 Tree Density (trees ha^{-1})	2013 Seedling ha^{-1} (<40 cm height)	2013 Sapling ha^{-1} (>40.1 cm height and > 2.5 cm DBH)	2013 Shrub Density (stem ha^{-1})	2015 Shrub Density (stem ha^{-1})
Control	49.06 (1.8) **a**	26.8 (1.3) **a**	540.6 (49.8) **a**	276.3 (51.2) **a**	911.3 (246.5) **a**	30302.5 (3347.0) **a**	17807.89 (1659.22) **a**
Thin/Burn	30.78 (1.8) **b**	11.3 (1.2) **b**	117.2 (34.5) **b**	87.5 (36.0) **b**	2982.5 (817.6) **a**	43916.3 (2720.8) **b**	42721.62 (13744.19) **b**
Burn Only	40.31 (0.6) **c**	20.5 (0.7) **c**	316.6 (20.9) **c**	253.8 (53.9) **ab**	983.8 (520.5) **a**	28188.8 (3500.3) **a**	26400.04 (5486.00) **a**

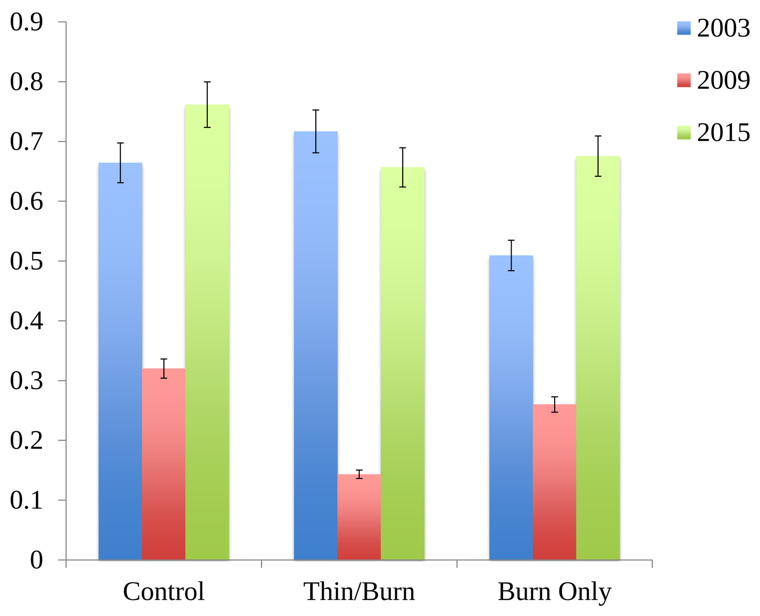

Figure 3: Average forest floor litter depths (cm) among three forest restoration treatment for three time periods (2003 pre-treatment), (2009 one year post-treatment), (2015 seven years post-treatment). There were significant differences between 2003 and 2009 litter depths using an ANCOVA test (F=4.3, p=0.04) for thin/burn treatments. There were no significant differences (p=0.38) between 2003 and 2015 litter depths using an ANCOVA test for any treatments. There were no significant differences among treatments in 2015 using a one way ANOVA (p=0.51).

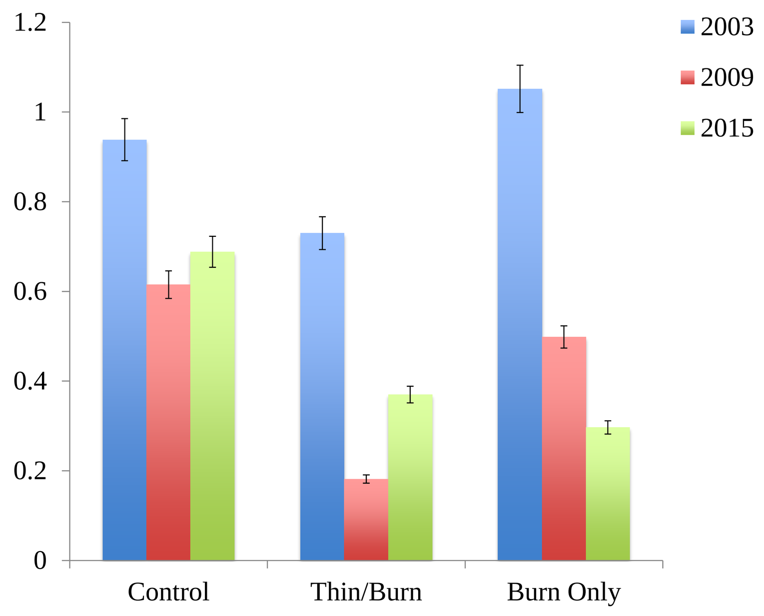

Figure 4: Average forest floor duff (cm) among three forest restoration treatment for three time periods (2003 pre-treatment), (2009 one year post-treatment), (2015 seven years post-treatment). There were significant differences between 2003 and 2009 litter depths using an ANCOVA test (0.035) for thin/burn treatments. There were no significant differences (p=0.15) between 2003 and 2015 duff depths using an ANCOVA test. There were no significant differences among treatments in 2015 using a one way ANOVA (p=0.23).

Table 2: Mean (± SEM) woody debris characteristics for the three treatment sites for pre-treatment (2003), one year post-treatment (2009), and seven years post-treatment (2015). There were no significant differences among treatments in 2015 using a one way ANOVA for fine woody debris (p=0.24) or coarse woody debris (p=0.79). There were significant differences between 2003 and 2009 fine woody debris using an ANCOVA test (F=7.3, p=0.01) for thin/burn treatments. There were no significant differences between 2003 and 2015 for fine woody debris (p=0.44) or coarse woody debris (p=0.92) and between 2003 and 2009 for coarse woody debris (p=0.1) using an ANCOVA test for any treatments.

	2003		2009		2015	
	Fine Woody Debris	Coarse Woody Debris	Fine Woody Debris	Coarse Woody Debris	Fine Woody Debris	Coarse Woody Debris
Control	2.32 (0.24)	25.40 (8.17)	1.71 (0.38)	19.52 (5.67)	1.84 (0.66)	7.55 (4.04)
Thin/Burn	2.23 (0.15)	16.58 (4.65)	1.22 (0.20)	24.51 (4.75)	0.84 (0.53)	9.88 (2.43)
Burn Only	2.65 (0.58)	27.20 (9.42)	2.53 (0.57)	15.15 (6.30)	0.62 (0.25)	7.08 (2.23)

Major Findings/Conclusion

- Litter and duff fuel depth were significantly different one year post-prescribed fire in comparison to pre-treatment data for only thin/burn treatments. Seven years post-prescribed fire, litter and duff fuel depth were not significantly different in comparison to pre-treatment data for any treatments. This illustrates that reductions in forest litter and duff depth seven years post-treatment are short lived.

- Fine woody debris fuel loading was not significantly different among treatments in 2015 using a one way ANOVA. Fine woody debris fuel loading was significantly different between pre-treatment (2003) and one year (2009) following prescribed burn treatments for thin/burn and burn only treatments. Fine woody debris fuel loading was not significantly different between pre-treatment (2003) and seven years post prescribed fire (2015) for control, thin/burn or burn only treatments.

- Coarse woody debris was not significantly different among treatments in 2015 using a one way ANOVA. Coarse woody debris fuel loading was not significantly different between pre-treatment (2003) and one year (2009) following prescribed burn treatments or between pre-treatment (2003) and seven years (2015) following prescribed burn treatments for control, thin/burn or burn only treatments.

- Our findings illustrate that changes in forest fuel depths and fine woody debris loading are generally short-lived following prescribed fire treatments. Land managers wanting to decrease forest fuel depths and fine and coarse woody debris loading will need to consider more frequent prescribed burning treatments and balance the desire to decrease fuel loads with other ecological responses to prescribed fire treatments such as changes in soil nutrients, wildlife habitat and understory vegetation productivity.

Figure 5: Photos of representative stands for control, thin/burn, and burn only sites respectively.

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