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Final Project Report

Fire effects for different slash management techniques in lower montane ponderosa pine forests

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Abstract

The need to reduce forest densities and surface fuel loads to reduce fire hazard and reintroduce fire in lower montane ponderosa pine forests has been recognized by Boulder County Parks and Open Space (BCPOS) and other agencies across the western United States. Often mechanical treatments are used to manipulate the forest density to achieve success in reducing crown fire hazard and provide an opportunity to reintroduce prescribed fire. **However, the amount of slash material generated from these activities can increase the surface fuel loadings on site** resulting in increased surface fuel loads available for combustion during subsequent prescribed fire activities. Different methods of slash management produce fuelbeds with unique characteristics (e.g. loading, depth, SAV) which influence fire behavior and effects. For example, masticated fuelbeds typically result in higher surface bulk densities, which is thought to lead to slower rates of spread, and increased fire residence burnout times. In contrast, lop-and-scatter fuelbeds often have lower surface fuel bulk densities but contain large spatial heterogeneity within the fuels complex. In general lop and scatter fuel beds are thought to result in faster rates of spread compared to masticated fuel beds. **Our objective was to compare the impact of mastication versus lop-and-scatter slash management techniques on the key fire effect of soil heating.** A prescribed fire was conducted November 2014 at Heil Valley Ranch northwest of Boulder, Colorado. Twelve 1 m^2 fuelbeds were constructed with three different fuel loadings out of two types of fuel: lop-and-scatter (“slash”) and masticated. Underneath each fuelbed, thermocouples were buried at three different depths to measure the heating front into the soil during the burn.

Overall, **we found that soil heating was low for all fuel type-loading combinations and the heating duration was very short** (only a few minutes). Based on these results, it is expected that soil damage from this prescribed burn was minimal. Future fires that burn in similar fuel types during similar conditions are not expected to cause damage to fine roots or soil nutrient cycling.

1 Introduction

Over the past century, fire exclusion in lower montane ponderosa pine forests has contributed to increased forest densities and surface fuels loads (Kaufmann et al. 2000, Brown and Shepperd 2001, Sherriff and Veblen 2006). Historically, fires that burned in these forests were low-severity surface fires that thinned small trees and reduced surface woody fuels that had accumulated between fire events (Brown et al. 1999). However, the current forest structure and fuel loads are conducive to high-severity fires crown fires (Graham 2003). The need to reduce forest densities and surface fuel loads to reduce fire hazard and reintroduce fire in these forests has been recognized by Boulder County Parks and Open Space (BCPOS) and other agencies across the Colorado Front Range and the western U.S. To successfully achieve this management need, four principles have been identified: 1) reduce surface fuels; 2) increase height to live crown; 3) decrease crown density; and 4) retain large trees of fire-resistant species (Agee and Skinner 2005). In many cases, mechanical treatments are successful in addressing principles related to reducing forest density which often addresses principles 2, 3, and 4. However, the treatment of the surface fuels and the additional surface fuels generated by the management activities is often problematic, especially when there are plans to reintroduce fire into an area.

There are several forest slash management techniques that are currently being implemented with each technique having an economic and ecological tradeoff. For instance, whole-tree harvesting, which removes all the forest slash, reduces surface fuels, but can be economically unfeasible and might have negative impacts on site productivity because it also removes nutrients from the site. Another common option is a slash management technique called lop-and-scatter. This technique, which distributes tree tops across the site, is often times more economically feasible, retains the nutrients stored in the slash on site but increases surface fuel loads. An alternative technique that is recently being implemented is mastication. Mastication shreds and chunks material and deposits it on the forest floor. Similarly to lop and scatter methods mastication retains nutrients on site and results in increase surface fuel loadings, however this method often has economic advantages compared to lop and scatter. Although both mastication and lop-and-scatter result in increased fuel loads and on-site nutrient retention, the orientation and size distribution of the material differs resulting in unique fuels complexes that likely differ in their fire behavior and effects on ecosystems. Masticated fuelbeds typically result in higher surface bulk densities, which is thought to lead to leading to slower rates of spread, and increased fire residence burnout times. In contrast, lop-and-scatter fuelbeds often have lower surface fuel bulk densities but contain large spatial heterogeneity within the fuels complex. In general lop and scatter fuel beds are thought to result in faster rates of spread compared to masticated fuel beds. However due to the large variation in the fuels complex other fire descriptors such as residence time and intensity have not been thoroughly investigated.

Our objective is to compare the impact of mastication versus lop-and-scatter slash management techniques on soil heating. Data derived by this study will provide BCPOS forest and fire managers with information about potential positive and negative effects of prescribed burning in different fuelbeds produced across their lower montane forests.

2 Methods

2.1 Study Site

Two blocks of fuelbeds were established at Heil Valley Ranch, a Boulder County park, in June 2013. Each block is located in a clearing among tree patches, roughly 0.10 ha (0.25 acre) in size and at least 5 m from surrounding trees. Within each block, six 1 m^2 plots were established: three each containing a low, moderate, or high fuel loading of two fuelbed types (lop-and-scatter and masticated). Plots radiated out approximately 10 m from a center point where dataloggers and batteries were located during the burn.

2.2 Plot Establishment

To measure soil temperature during the burn, thermocouples (Type K, Omega Engineering, Omaha, NE) were buried at the center of each plot at 2 cm below the mineral soil surface, 5 cm below the mineral soil surface, and 10 cm below the mineral soil surface. Thermocouples were carefully inserted to ensure maximum contact of thermocouple tip with soil particles, by first inserting a steel rod about 1 mm greater in diameter than the thermocouple horizontally into the soil pit face about 5 cm deep, removing the rod, and gently inserting the thermocouple into the hole created by the insertion rod until resistance was felt, indicating contact between the thermocouple and the soil. Thermocouple wire was then buried 5 cm below the soil surface (to protect the wire from excessive heat) back to the center of each block. At each block center, thermocouples were connected to two CR23X dataloggers (Campbell Scientific, Logan, Utah) which were placed inside datalogger boxes and buried underneath 4 inches of sand to insulate them from high temperatures created by the burn. Dataloggers measured and logged temperature once per minute for several days before and during the burn, including the post-burn cool-down. In addition, one soil moisture probe (EC-5, Decagon Devices, Pullman, WA) was installed at 5 cm deep in each block to monitor soil moisture changes at a frequency of once per hour for several days before and during the burn, including the post-burn cool-down.

After placement of thermocouples, fuelbeds were created to represent unique combinations of fuel type (masticated or lop-and-scatter) and fuel loading (low, moderate, or high). First, all herbaceous fuels and litter were removed from the soil surface to remove variability in these fuels from plot to plot. Litter layers were rebuilt to levels of 4.5 ton acre^{-1} before adding treatments in the form of reconstructed fuelbeds to each plot. Target fuel loadings are: low, 4.5 ton acre^{-1}; moderate, 13.5 ton acre^{-1}; high, 27 ton acre^{-1}. Samples of each fuel class and type (litter, lop-and-scatter or masticated) were brought back to the lab for moisture analysis (weight loss in 60°C oven) for correction of field weights to dry weights.

2.4 Statistical Analysis

The effect of fuel treatment and fuel loading on soil temperature at each depth was analyzed using a two-way analysis of variance, with treatment (lop-and-scatter vs mastication) and loading (low, medium or high) as fixed factors.

3 Results

3.1 Controlled Burn

Around noon on Sunday, November 9th, a light surface fire burned through the fuel beds. The air temperature was between 57°F and 62°F and the relative humidity was between 23% and 27%. Over the entire burned unit, it was estimated that 60% of the ground area was blackened and 60% of the downed woody fuel was burned (Ziegler et al. 2015).

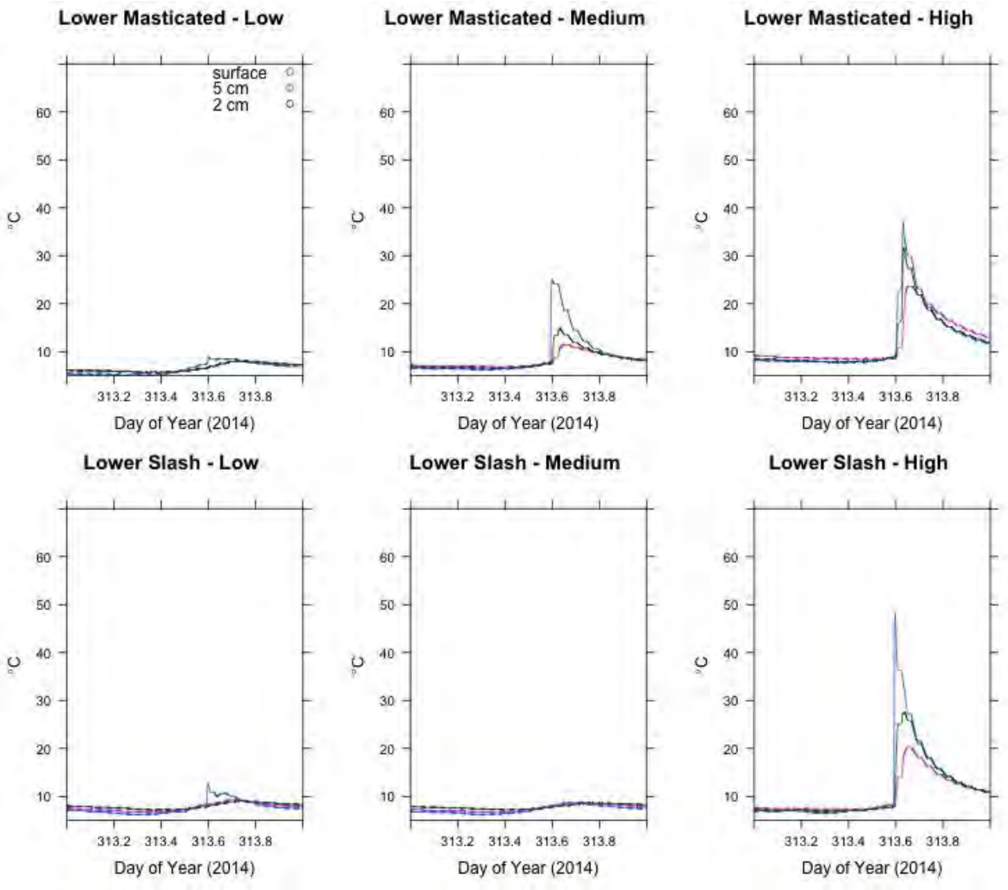


Figure 1. Time series of soil temperatures during the day of the burn from the lower plot cluster.

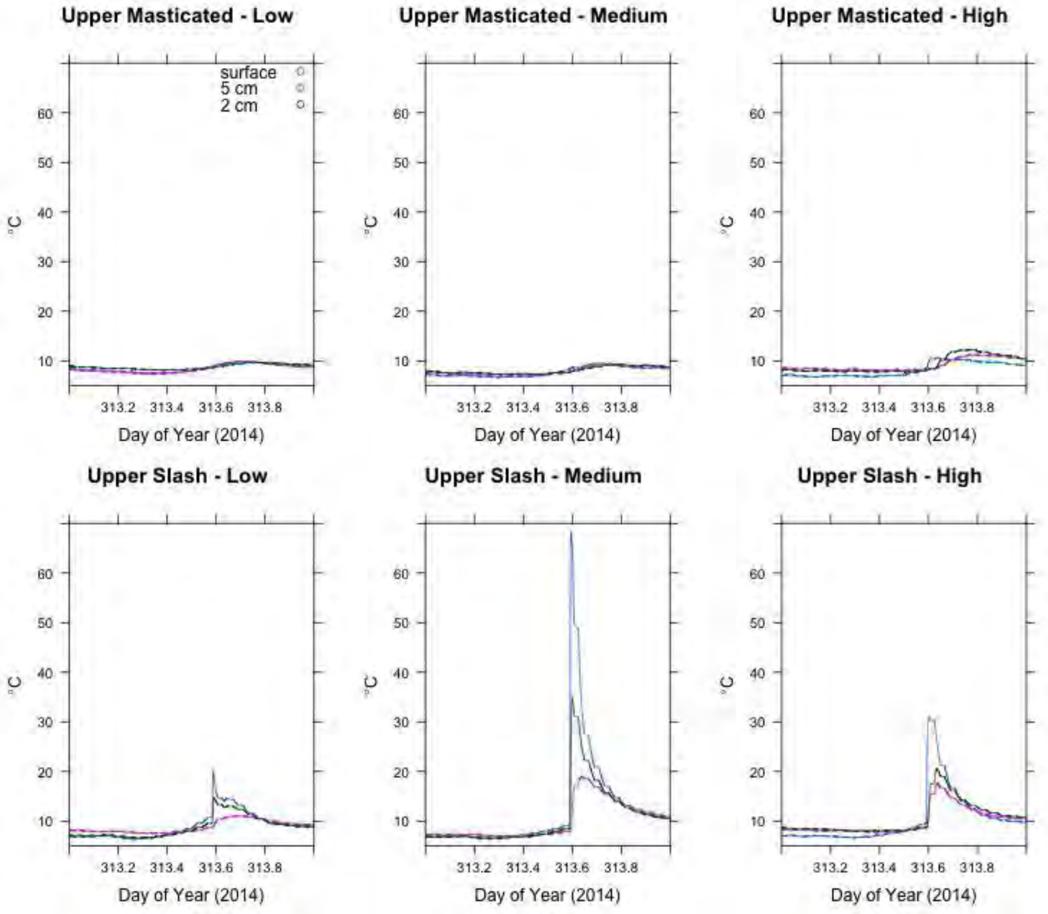


Figure 2. Time series of soil temperatures during the day of the burn from the upper plot cluster.

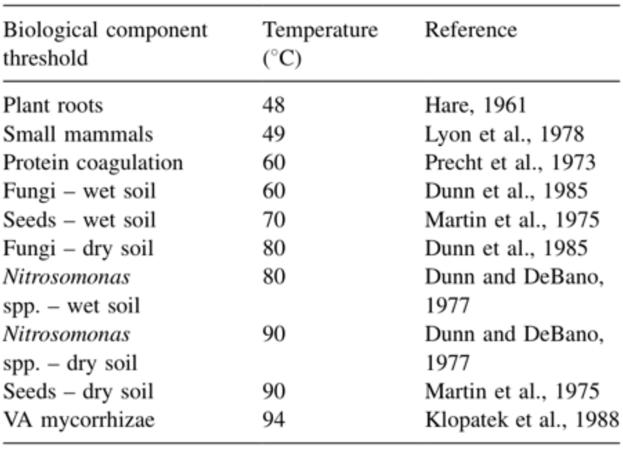
3.1 Soil Temperatures

We aimed to answer the questions:

1. Did burning these two fuel types result in lethal temperatures for fine roots, seedbank and soil microorganisms?
   Result: No.
2. At similar fuel loadings, does mastication result in higher prescribed burn soil temperatures than lop-and-scatter treatments?
   Result: No.

Overall we found low soil temperatures for all fuel type and loading combinations. At one of the slash plots with medium fuel loading, the surface thermocouple (i.e., on top of the soil surface within the fuel bed) recorded temperatures exceeding the threshold of root death (Neary, 1999), but this did not exceed 1 minute of exposure. The short duration of high temperatures suggests that fine root death would have been low in this plot. With that one exception, none of the surface nor deeper soil temperatures exceeded the threshold reported for biological disruption in soils (Table 1).

Table 1. Neary (2009) summary of threshold temperatures for biological disruptions in soils (see Neary (2009) for references).

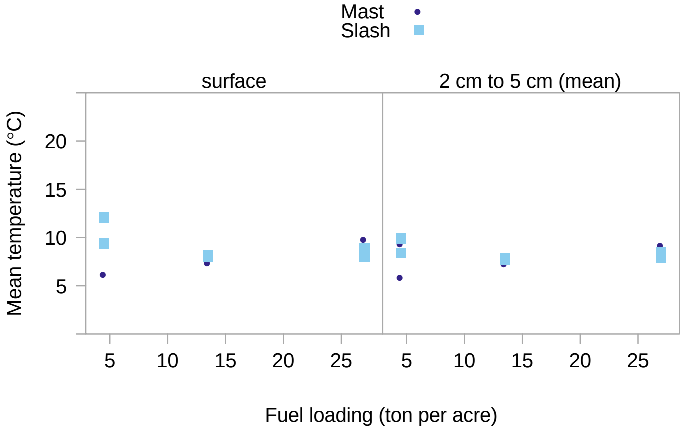


Biological component threshold	Temperature (°C)	Reference
Plant roots	48	Hare, 1961
Small mammals	49	Lyon et al., 1978
Protein coagulation	60	Precht et al., 1973
Fungi – wet soil	60	Dunn et al., 1985
Seeds – wet soil	70	Martin et al., 1975
Fungi – dry soil	80	Dunn et al., 1985
Nitrosomonas spp. – wet soil	80	Dunn and DeBano, 1977
Nitrosomonas spp. – dry soil	90	Dunn and DeBano, 1977
Seeds – dry soil	90	Martin et al., 1975
VA mycorrhizae	94	Klopatek et al., 1988

The main effect of fuel treatments on soil temperatures was with the fuel loading, rather than fuel type (Figure 3; Table 2). Soil temperatures in the lowest fuel loading, 4.5 tons acre^{-1}, were mostly indistinguishable from normal soil temperatures during that time of day. In contrast, soil temperatures in the highest fuel loading, 27 tons acre^{-1}, were about 5 degrees C higher than normal temperatures.

These results indicate that under the weather and burning conditions of these prescribed fires, little soil heating occurred. One aspect of fire effects that we noted was a lack of fuel consumption on our plots which limited the potential heat flux received at the soil surface. The lack of fuel consumption places some limitations on extrapolating our findings to larger areas or to cases where greater fuel consumption occurs. Therefore, while this study provided a unique opportunity to investigate soil heating under different slash treatments and fuel loadings our results are only indicative of what occurred during this burning event within our measurement areas. Logically if a larger proportion of fuel is consumed we would expect greater soil heating than measured here. Although not seen in our study this tradeoff could also have implications for attempting to simultaneously meet slash hazard reduction goals and limiting the effects of prescribed fire on soil organisms. Further work that quantifies the effects of different slash management practices and fuel loading in similar soil types as those located on BCPOS lands which is conducted under a wide range of fuel consumption scenarios could help guide best management practices.

1 d prior to burn



During burn

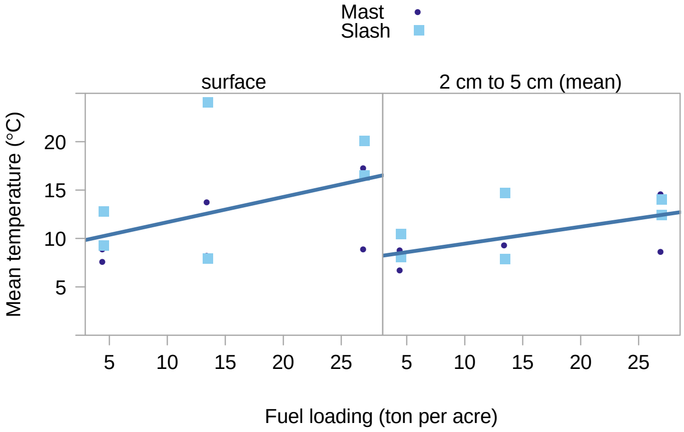


Figure 3. Average temperatures from 12:00 PM through 5:00 PM on the day prior to and the day of the burn, November 9, 2015. With both fuel types, temperatures increased at higher fuel loading during the burn, a trend not seen the day before during that same time window. Temperatures at low fuel loading were not significantly elevated during the burn compared to the day

4 Summary of Conclusions

- Burning either slash or masticated fuel at fuel loadings of up to 27 tons per acre did not cause soil temperatures to exceed thresholds of soil biological damage.
- There was no difference in soil heating between masticated and slash fuels.
- Fuel loading did have a small but significant effect on soil heating, suggesting that if the burn had exhibited more extreme fire behavior due to weather, the highest fuel loading may have resulting in damaging soil temperatures.

Table 2. Linear model results for the mean 2 cm to 5 cm soil temperature response to burning, showing a significant increase in the burn effect by fuel loading, but no difference in effect by fuel type.

Estimate	Std.	Error	t	P value	Sig < 0.05
(Intercept)	-1.09944	1.39737	-0.787	0.452	
TrtSlash	1.52167	1.2986	1.172	0.271	
Loading	0.16629	0.07022	2.368	0.042	*
Residual	standard	error:	2.249 on 9 degrees of freedom		
Multiple	R-squared:	0.4368,	Adjusted	R-squared:	0.3117
F-statistic:	3.491	On 2 and 9 DF, p-value: 0.07548			

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