Changes in Forest Structure and Fire Behavior on the Messenger Gulch Restoration Project

CFRI-TB-1605

Background

Ponderosa pine (*Pinus ponderosa*) forests within the Pike and San Isabel National Forest, like much of the western United States, have undergone a shift from a historical mosaic pattern of individual trees, clumps, and openings that exhibited a variety of tree sizes to a denser, homogeneous forest structure. These changes have resulted in an increased concern over the potential for altered ecological functions, such as increased potential for crown fires. In response to this shift in forest structure, restoration treatments seeking to enhance structural complexity and mitigate undesirable fire behavior, such as those as part of the Front Range Collaborative Forest Landscape Restoration Project, have started to be implemented. However, due to traditional views of stand management and spatially-inexplicit stand dynamics and fire behavior models the implications of structural complexity are not fully understood or evaluated.

Study Objective

This case study utilized a 10 acre stem-map plot within the Messenger Gulch Restoration Project in order to evaluate the treatment's impact on forest structure and fire behavior. The analysis evaluated pre- and post-treatment changes in traditional forest inventory metrics, forest spatial arrangement, and simulated fire behavior using WFDS, a model that considers the effect of tree spatial arrangement on wind and fire behavior.

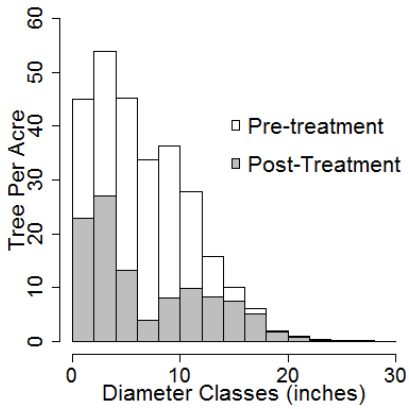
Forest Structure Changes

This site is typical of many xeric middle elevation ponderosa pine stands within the central Rocky Mountains in Colorado with a site index of 50 feet (base age 100). Prior to treatment, the stand was dominated by 2-6" DBH trees, with a moderate stocking level of 277 trees per acre (TPA) and 99 ft^2 of basal area (BA) per acre, but areas that approached 450 TPA. Following treatment, the resulting changes occurred:

- Both TPA and BA per acre were reduced more than 50% by preferentially removing small and midsized trees.
- While there was no change in stands vertical structure, canopy bulk density was reduced 57% while surface fuel loading went up 1 ton $acre^{-1}$.

Table 1. Stand structure and diameter class distribution pre- and post-treatment.

	Pre	Post
TPA	277	109
QMD (in)	8.1	8.8
BA (ft^2/acre)	99	46
Mean - CBH (ft)	11	12
Mean - HT (ft)	28	28
Canopy Bulk Density (lbs/ft^3)	0.014	0.006
Surface load (tons/acre)	1.8	2.8
Species	95% PIPO 5% PSME	97% PIPO 3% PSME



Structure Change Summary

- The Messenger Gulch restoration treatment reduced stem density and basal area by approximately 50%, while favoring larger trees within the distribution of tree sizes.
- The treatment preferentially removed small Douglas-fir trees, favoring ponderosa pine.
- Although there was no change in stand vertical structure, there was a 57% reduction in canopy bulk density.
- The treatment significantly reduced stand continuity by balancing the distribution of cluster sizes and creating larger stand openings.

Fire Behavior Implications

- Reductions in canopy and surface fuel loading resulted in predictions of significant reductions in both canopy consumption and fire line intensity.
- Moderate canopy consumption levels were predicted across both wind scenarios, however fire rate of spread remained high.

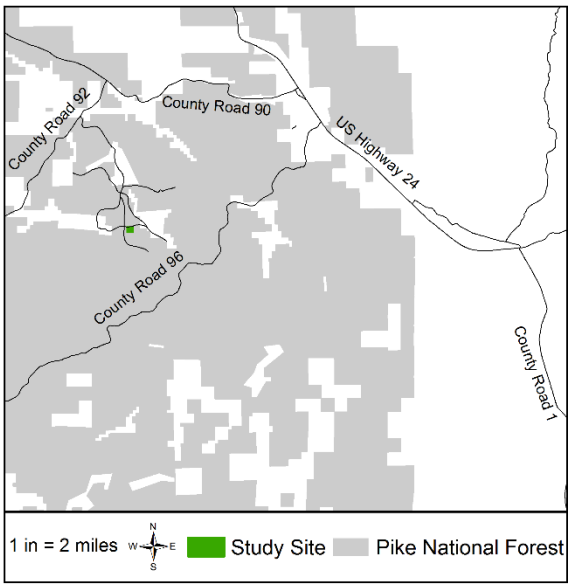


Figure 1. Map of Messenger Gulch 10 acre study site.

Forest Spatial Arrangement Changes

Most forest restoration projects within dry mixed conifer systems seek to enhance the variation in stand-level forest structures. Here forest structure is described as the allocation of aerial cover to single trees, clumps of trees, and openings and the distribution of tree clump sizes from single trees to clumps containing more than 15 trees. Prior to treatment, ~93% of trees and basal area in the plot were contained in clumps of >15 trees. Following treatment, the resulting changes occurred:

- The area occupied by clumps was reduced by 20% and redistributed mostly to openings, while slightly increasing the presence of single trees.
- By breaking up large clumps stand continuity was greatly reduced and the quantity and size of openings was increased.
- The distribution of stand-level forest structures achieved a balanced representation across the range of clump sizes.

Table 2. Analysis of forest spatial arrangement, changes in cover and clumping.

	Pre-treatment		Post-treatment	
Aerial cover (%)				
Single tree	4.5		7.0	
Clumps	33.8		13.6	
Openings	61.6		79.3	
Clump Size Composition	**% TPA**	**% BA acre^{-1}**	**% TPA**	**% BA acre^{-1}**
Single Tree	0.6	2.4	7.0	17.2
Small (2-4 trees)	1.4	3.5	15.8	23.9
Medium (5-9 trees)	1.4	2.8	14.9	14.6
Large (10-15 trees)	0.8	1.3	18.3	16.7
Very large (15+ trees)	95.7	90.0	44.1	27.5

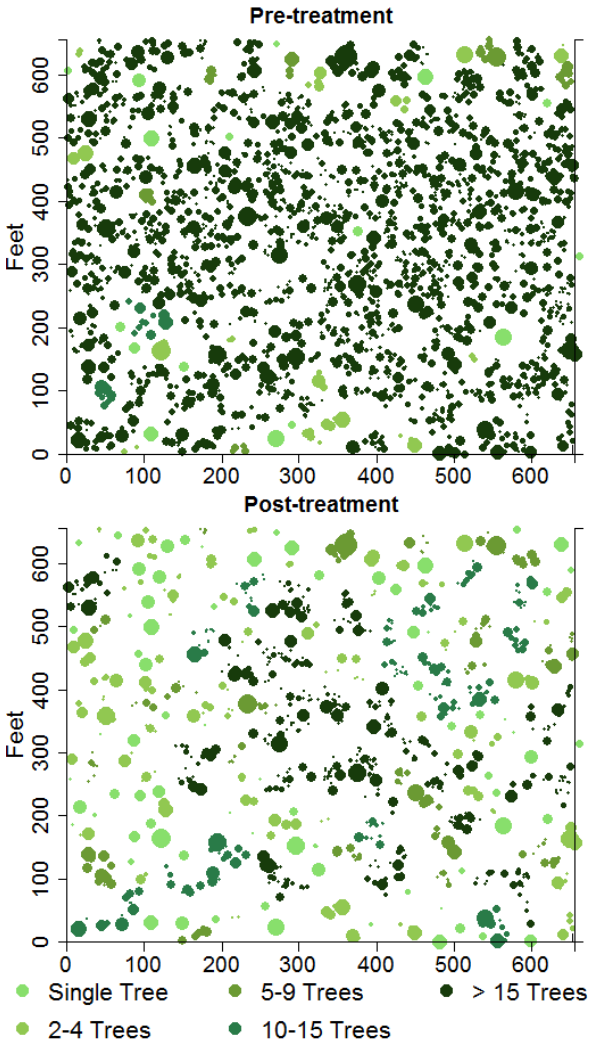


Figure 2. Stem-map of sampled area, were trees are sized to represent crown area.

Fire Behavior Changes

Beyond increasing stand-level forest structural variability, often forest restoration treatments seek to reduce fire behavior and effects. Prior to treatment, under the high wind speed the stand exhibited rates of spread consistent with extreme fire behavior. Following treatment, all metrics of fire behavior simulated were reduced. The extreme wind scenario tested found canopy consumption cut in half and reductions to fire rate of spread (41%) and fireline intensity (39%). The moderate wind scenario saw similar reductions canopy consumption (55%), rate of spread (42%), and fireline intensity (31%) following the treatment. Overall, the removal of small trees during the treatment reduced both fireline intensity and rate of spread to be within the range of fire behaviors conducive to a range of fire management options.

Table 3. Pre- and post-treatment fire behavior predictions from Wildland-Urban Interface Fire Dynamics Simulator model runs under moderate and high wind speed scenarios.

Open Wind Speed (mph)	Rate of Spread (ch/hr)		Fireline Intensity (kW/m)		Canopy Consumption (%)	
	Pre	Post	Pre	Post	Pre	Post
9	100	58	2,614	1,812	6.5	2.9
30	137	81	4,351	2,636	11.6	4.9

This is part of a broader project funded by the Joint Fire Sciences Program project 13-1-04-53 and USDA National Fire Plan, spanning 8 study sites across the Southern Rocky Mountains and Colorado Plateau. Additional study methods, details, summaries and videos of pre- and post-treatment fire behavior can be found at (cfri.colostate.edu). Project conducted by:

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