Changes in Forest Structure and Fire Behavior on the Red Feather Restoration Project

CFRI-TB-1607

Background

Ponderosa pine (*Pinus ponderosa*) forests within the Arapahoe and Roosevelt National Forest of Colorado, 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 Restoration Program, 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 Unit 17A of the Red Feather I 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 spatial arrangement of trees on wind and fire behavior.

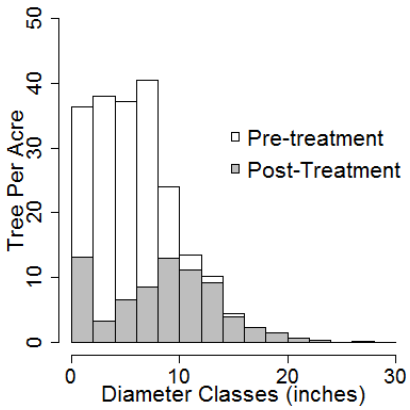
Forest Structure Changes

This site is typical of many xeric mid-elevation ponderosa pine stands within the central Rocky Mountains of Colorado, with a site index of 65 feet (base age 100). Prior to treatment, the stand was dominated by 6-8" DBH trees, with a moderate stocking level of 209 trees per acre (TPA) and 61 ft^2 of basal area (BA) per acre, but areas that approached 600 TPA. Following treatment, the resulting changes occurred:

- Stand density was reduced in terms of TPA (65%) and BA (36%) by preserving the larger trees within the distribution of tree diameters.
- The stand experienced a shift in vertical structure and reductions to surface fuel loading (47%) and canopy bulk density (60%).

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

	Pre	Post
TPA	209	73
QMD (in)	7.4	9.9
BA (ft^2/acre)	61	39
Mean - CBH (ft)	9	11
Mean - HT (ft)	23	30
Canopy Bulk Density (lbs/ft^3)	0.010	0.004
Surface load (tons/acre)	5.2	2.7
Species	95% PIPO 4% PSME	97% PIPO 3% PSME



Structure Change Summary

- The Red Feather restoration treatment reduced both stem density (65%) and basal area (36%).
- Although the change in stand vertical structure was slight, there was a 60% reduction in canopy bulk density and a 47% reduction surface fuel loading.
- While there was only a small change to species composition, the targeted removal of small diameter trees increased the stand QMD.
- By breaking up large clumps of trees stand continuity was reduced and size and number of openings was increased to better resemble the forest's historic condition.

Fire Behavior Implications

- Reductions in canopy and surface fuel loading resulted in predictions of significant reductions to all measure of fire behavior and effects.
- Low to moderate canopy consumption levels were predicted across both wind scenarios following treatment.

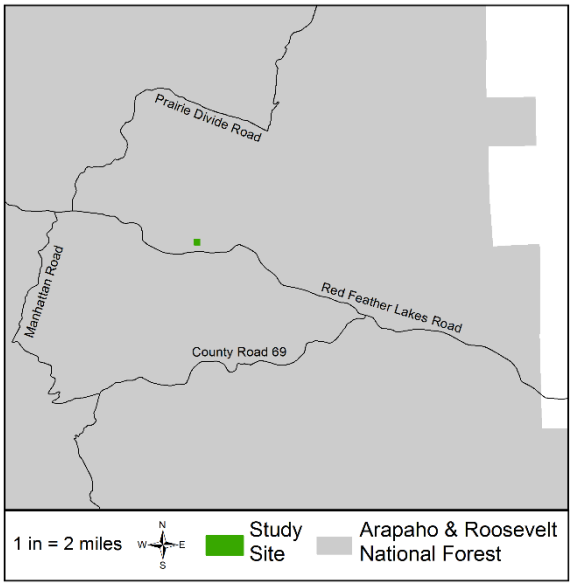


Figure 1. Map of Red Feather 10 acre study site.

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, ~87% of trees and basal area in the plot were contained in very large clumps of >15 trees. Following treatment, the resulting changes occurred:

- The area occupied by clumps was reduced by 12% and redistributed to both single trees and openings, reducing stand horizontal continuity and increasing the size and number of openings.
- The variation in stand-level forest structures increased, achieving a balance across the range of fine-scale stand structures desired in restored ponderosa pine forest systems.

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

	Pre-treatment		Post-treatment	
Aerial cover (%)				
Single tree	4.8		8.3	
Clumps	23.7		11.2	
Openings	71.5		80.5	
Clump Size Composition	**% TPA**	**% BA acre^{-1}**	**% TPA**	**% BA acre^{-1}**
Single Tree	1.9	3.1	12.0	16.6
Small (2-4 trees)	3.2	3.7	19.5	23.8
Medium (5-9 trees)	3.7	5.7	20.7	24.3
Large (10-15 trees)	2.7	2.6	13.4	8.7
Very large (15+ trees)	88.5	84.9	34.4	26.6

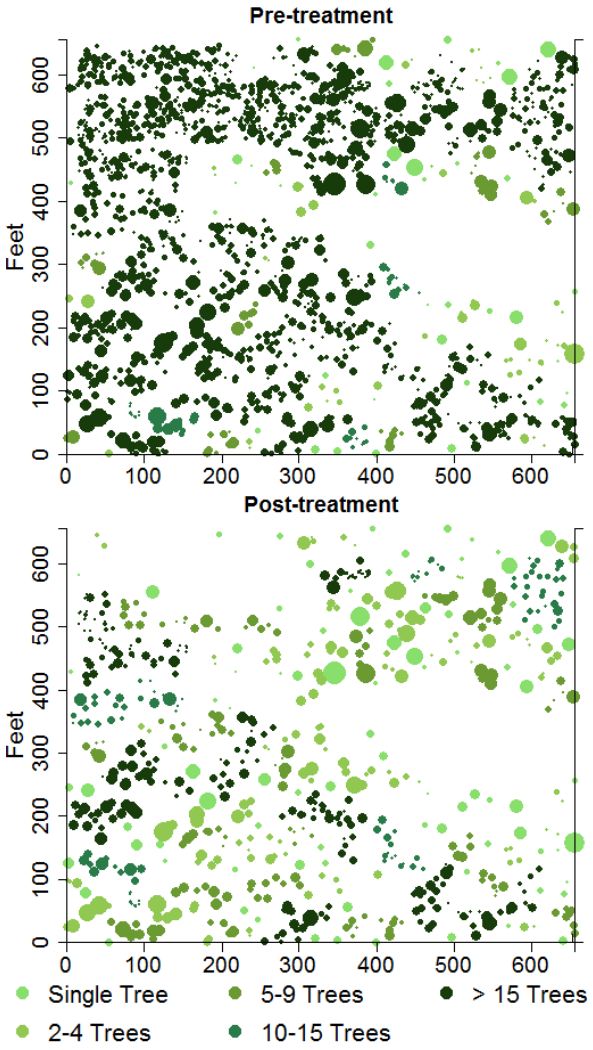


Figure 2. Stem-map of sampled area. Trees sized to represent crown area.

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 canopy consumption, fireline intensities, and rates of spread consistent with extreme fire behavior. Following treatment, all metrics of fire behavior simulated were reduced our both wind scenario. The extreme wind scenario tested found reductions in canopy consumption (63%), fire rate of spread (31%), and fireline intensity (77%).The moderate wind scenario found reductions to rate of fire spread (6%), canopy consumption (62%), and fireline intensity (66%) following treatment. Overall, the treatment reduced potential fire severity and behavior, with low to moderate levels of canopy consumption predicted for both wind speeds following treatment. However, based on the rate of spread and fireline intensity there remains considerable potential for extreme fire behavior that may limit fire operations.

Table 3. Pre- and post-treatment fire behavior predictions from Wildland-Urban Interface Fire Dynamics Simulator model runs under high and moderate 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	147	138	20,486	6,970	80.5	30.6
30	259	178	35,054	8,056	85.1	31.5

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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