Changes in Forest Structure and Fire Behavior on the Phantom Creek Restoration Project

CFRI-TB-1606

Background

Dry-mixed conifer 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, continuous, and homogeneous forest structure. These changes have resulted in an increased concern over the potential for altered ecological functions, such as increased probabilities 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 Phantom Creek 1 of the Phantom Creek 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 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.

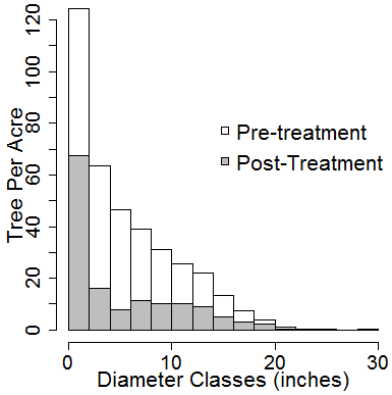
Forest Structure Changes

This site is typical of many productive mixed conifer stands within the Central Rocky Mountains of Colorado with a site index of 85 feet (base age 100). Prior to treatment, the stand was dominated by 2-4" DBH trees, with a high stocking level 378 trees per acre (TPA) and 111 ft^2 of basal area (BA) per acre, but areas that exceeded 800 TPA. Following treatment, the resulting changes occurred:

- Both TPA and BA per acre were reduced by ~60%, with trees being proportionally removed from each of the tree diameter classes.
- Although there was no detectable change in surface fuel loading, canopy bulk density was reduced by 65%.

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

	Pre	Post
TPA	378	143
QMD (in)	7.2	7.3
BA (ft^2/acre)	108	41
Mean - CBH (ft)	10	12
Mean - HT (ft)	22	25
Canopy Bulk Density (lbs/ft^3)	0.017	0.006
Surface load (tons/acre)	5.9	5.9
Species	54% PSME 20% PIPO	41% PSME 32% PIPO



Structure Change Summary

- The Phantom Creek restoration treatment project reduced stem density and basal area by approximately 60%.
- Trees were proportionally removed from each diameter size class leading to a small shift in quadratic mean diameter.
- The stand composition shifted towards being more balanced between Douglas-fir and ponderosa pine.
- Along with a vertical shift up in mean tree height and canopy base height, there was a 65% reduction in canopy bulk density.
- Stand continuity was reduced and the variability in forest structures was increased by breaking up large clumps of trees.

Fire Behavior Implications

- Disruptions in stand continuity and alterations to the fuels complex resulted in predicted reductions in all measures of fire behavior tested.
- Moderate canopy consumption levels were predicted for both wind scenarios, however active crown fire behavior is still expected.

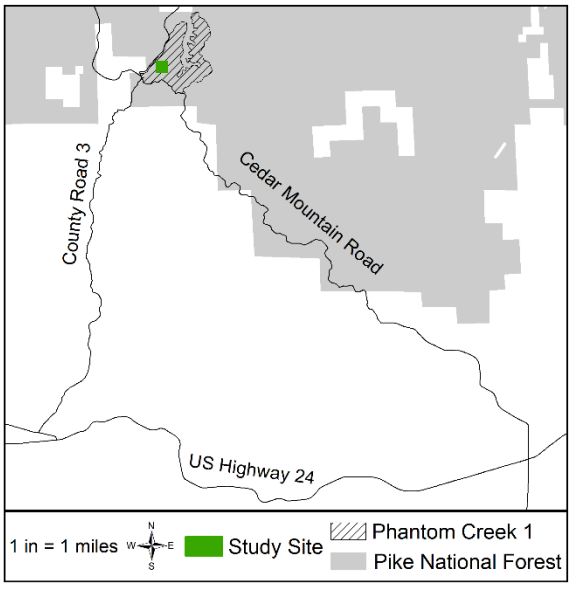


Figure 1. Map of Phantom Creek 10 acre study site.

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, 99% of trees were contained in clumps of >15 trees which accounted for more than 41% of the stand area. Following treatment, the resulting changes occurred:

- The area occupied by clumps was reduced by 25% and redistributed mostly to openings, reducing stand continuity and increasing the size of openings.
- The variation in stand-level forest structures was increased by breaking up clumps of >15 trees and redistributing them into each of the small clump sizes.

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

	Pre-treatment		Post-treatment	
Aerial cover (%)				
Single tree	4.0		7.8	
Clumps	40.7		15.4	
Openings	55.3		76.9	
Clump Size Composition	**% TPA**	**% BA acre^{-1}**	**% TPA**	**% BA acre^{-1}**
Single Tree	0.2	0.5	5.4	14.8
Small (2-4 trees)	0.3	0.7	9.5	17.7
Medium (5-9 trees)	0.2	0.5	7.2	10.7
Large (10-15 trees)	0.0	0.0	10.5	9.8
Very large (15+ trees)	99.3	98.3	67.4	47.0

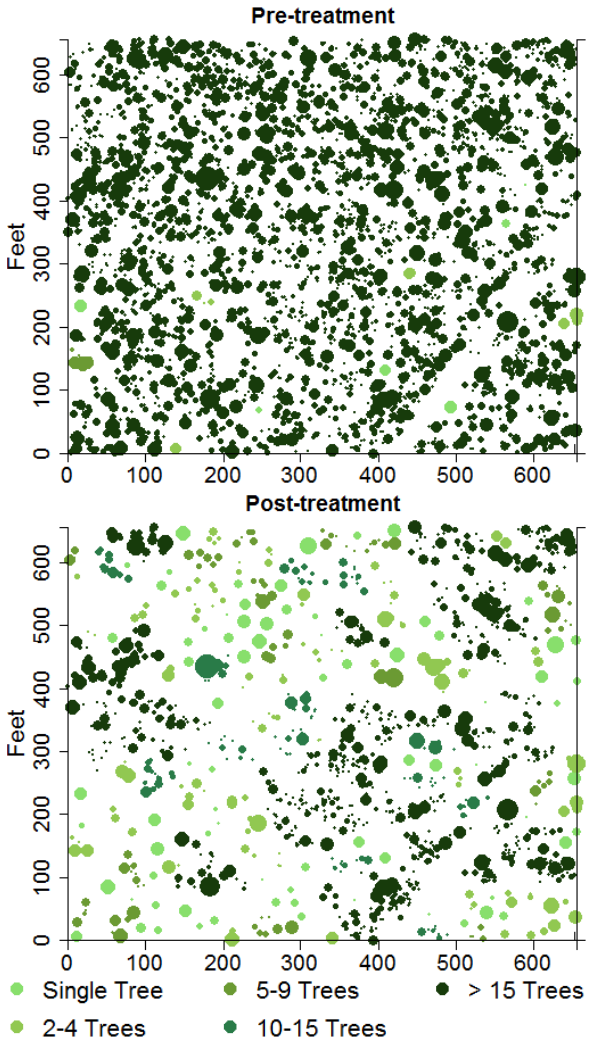


Figure 2. Stem-map of sampled area. Trees sized to represent crown area.

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 with the exception of fire rate of spread under our lower wind scenario. The extreme wind scenario tested found reductions in canopy consumption (35%), fire rate of spread (52%), and fireline intensity (81%). The moderate wind scenario saw slightly reduced benefits to canopy consumption (28%), fire rate of spread (21%), and fireline intensity (61%). Overall, the treatment reduced potential fire severity and behavior, with 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	181	142	47,702	18,710	91.2	66.0
30	350	169	117,254	22,189	91.1	59.0

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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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