Changes in Forest Structure and Fire Behavior on the Lookout Canyon Long-term Vegetation Plot

CFRI-TB-1603

Background

Ponderosa pine (*Pinus ponderosa*) forests within the Kaibab National Forest of Arizona, 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 Rocky Mountain Research Station Long-term Vegetation Plots (LVP), 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 LVP 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.

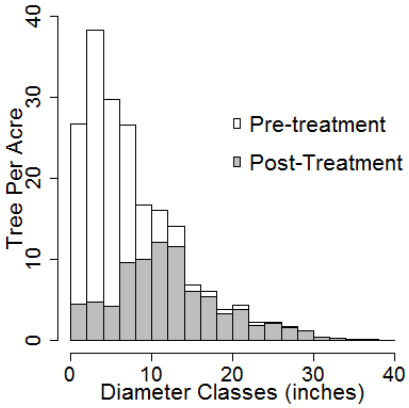
Forest Structure Changes

This site is typical of many ponderosa pine stands within the Colorado Plateau in Arizona with a site index of 95 feet (base age 100). Prior to treatment, the stand was dominated by 2-8" DBH trees, with a moderate stocking level of 197 trees per acre (TPA) and 112 ft^2 of basal area (BA) per acre, but areas that approached 400 TPA. Following treatment, the resulting changes occurred:

- Stand density was reduced in terms of TPA (58%) and BA (23%) by preserving the larger trees within the distribution of tree diameters.
- There was a large shift in vertical stand structure, and reductions to surface fuel loading (19%) and canopy bulk density (48%).

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

	Pre	Post
TPA	197	82
QMD (in)	10.2	13.9
BA (ft^2/acre)	112	86
Mean - CBH (ft)	16	22
Mean - HT (ft)	38	52
Canopy Bulk Density (lbs/ft^3)	0.012	0.006
Surface load (tons/acre)	1.6	1.3
Species	100% PIPO	100% PIPO



Structure Change Summary

- The Kaibab restoration treatment reduced both stem density (58%) and basal area (23%).
- There was a substantial shift in stand vertical structure, and there was a 48% reduction in canopy bulk density and a 19% reduction surface fuel loading.
- The targeted removal of trees less than 8" in diameter significantly 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

- Both before and after the treatment the stand exhibited canopy consumption indicative of low severity fires.
- Reductions in canopy and surface fuel loading resulted served to limit the potential of extreme fire behavior under high wind speeds.

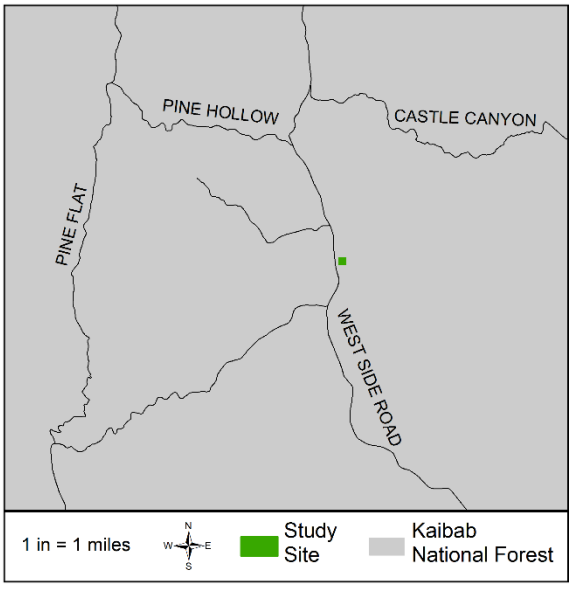


Figure 1. Map of Lookout Canyon 10 acre study site.

Forest Spatial Arrangement Changes

Most forest restoration projects within ponderosa pine 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, 83% of trees and 63% of 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 10% and redistributed mostly to openings, this reduced the stand's 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 forest structures indicative of historic forest patterns.

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

	Pre-treatment		Post-treatment	
Aerial cover (%)				
Single tree	5.0		6.7	
Clumps	34.9		25.0	
Openings	60.0		68.3	
Clump Size Composition	**% TPA**	**% BA acre^{-1}**	**% TPA**	**% BA acre^{-1}**
Single Tree	2.2	7.5	9.2	15.9
Small (2-4 trees)	4.0	9.6	17.7	29.4
Medium (5-9 trees)	4.9	10.4	21.6	23.1
Large (10-15 trees)	6.0	9.4	13.5	9.6
Very large (15+ trees)	83.0	63.1	37.9	22.0

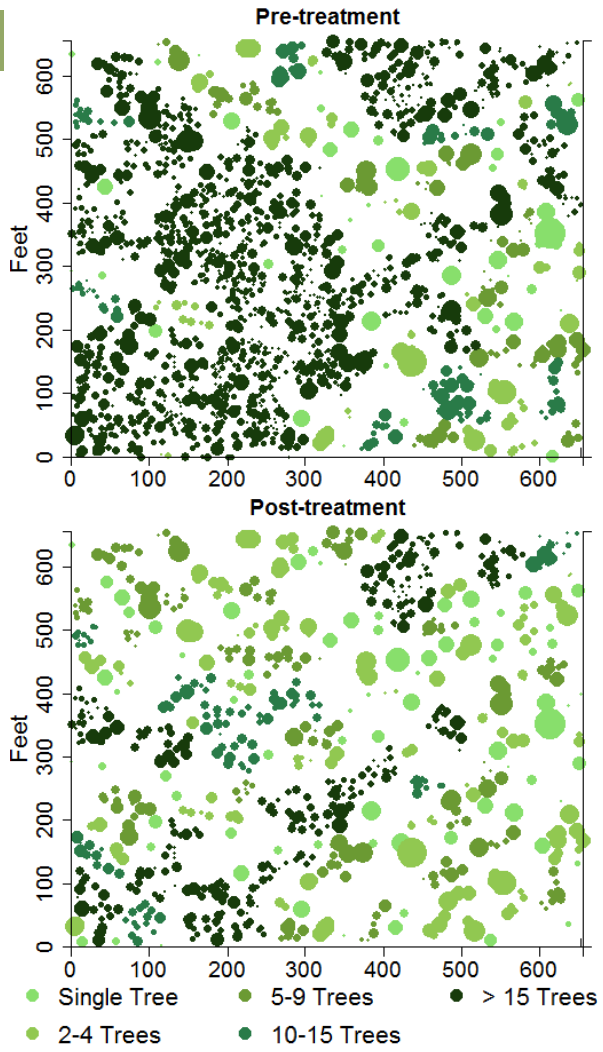


Figure 2. Stem-map of sampled area. Trees sized to represent crown area.

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, the fire behavior metrics had sorted responses. The extreme wind scenario tested found only a slight reduction in canopy consumption due to the low level of pretreatment consumption, but a substantial reduction in fireline intensity (85%) was predicted. The moderate wind scenario found no effect of treatment on canopy consumption or fireline intensity. Overall, the treatments removal of small trees and reduction to canopy fuels resulted in increased surface winds and therefore increased rates of spread (~20%), but removal of these ladder fuels significantly reduced the threat of extreme fire behavior under high wind scenarios.

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	84	109	1,485	1,545	0.9	0.3
30	125	138	17,229	2,514	2.4	1.0

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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