# Treatment effects on structure and fire behavior in the Uncompahgre Mesas Forest Restoration Project – March 2014

Ponderosa pine (*Pinus ponderosa*) forests within the Uncompahgre National Forest, like much of the western United States, have undergone a shift from a mosaic pattern consisting of individual trees, patches and openings that exhibited a variety of tree sizes to a more dense, 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 concern, restoration treatments, such as those a part of Uncompahgre Plateau Collaborative Forest Landscape Restoration Project, seek to enhance structural complexity, and mitigate undesirable fire behavior. 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 evaluated.

**Study objectives**

This study utilized field-collected data, spatial-statistical methods and three dimensional physics based fire behavior models to investigate restoration treatment effects on 1) vertical and horizontal structural complexity at both the stand-level and patch-level , and 2) fire behavior, across a range of wind speeds.

**Approach**

During the summer 2012, we established a single 200 m x 200 m plot (~10 acres) within unit #1 of the Unc Mesa restoration project (Fig. 1) and stem-mapped, and measured all stumps and trees (≥ 4.5 ft tall (Fig. 2)). Pre-treatment forest structure was recreated using a combination of linear regression methods and additional field sampling in adjacent stands. Structural complexity in both the horizontal and vertical dimensions was evaluated at both the stand and patch levels using common spatially-explicit methodologies (Fig. 3).

Potential fire behavior was simulated by populating the Wildland-urban interface Fire Dynamics Simulator (WFDS) with our field collected data for the pre- and post-treatment forests. WFDS is a physics-based fire model, developed by the National Institute of Standards and Technology, designed to simulate the spatially- and temporally- dynamic


***Summary***

- We found the restoration treatment in the Unc Mesa restoration project reduced horizontal and vertical structural complexity, though post-treatment structure was still far from homogeneous.
- The treatment was effective at reducing fire behavior; effectiveness increased with higher open wind speeds, despite greater within-canopy wind speeds post-treatment.


***Recommendations***

- Consider tradeoffs of fire hazard and structural complexity objectives.
- Adopt metrics of complexity to enable adaptive management
- Define target ranges of complexity to steer treatments away from shifts towards homogeneity
- Reduce surface fuel loads to leverage gains made already by thinning.

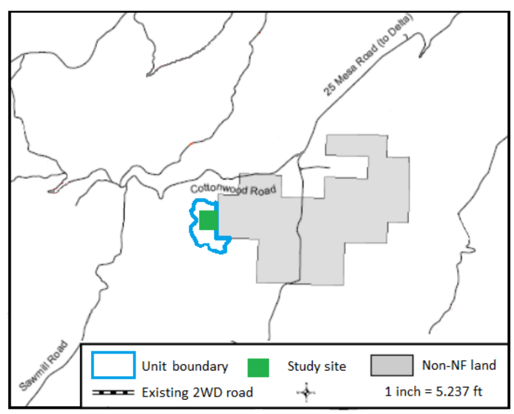


Figure 1. Map of Unc Mesa unit #1 and study site

interactions between fire, vegetation and wind flow. We simulated fire behavior pre- and post-treatment under four open wind scenarios (5, 9, 20, and 30 mph) with typical mid-summer dead and live fuel moistures. For each simulation, we estimated the mean rate of spread, mean fireline intensity, and percent of canopy consumed.

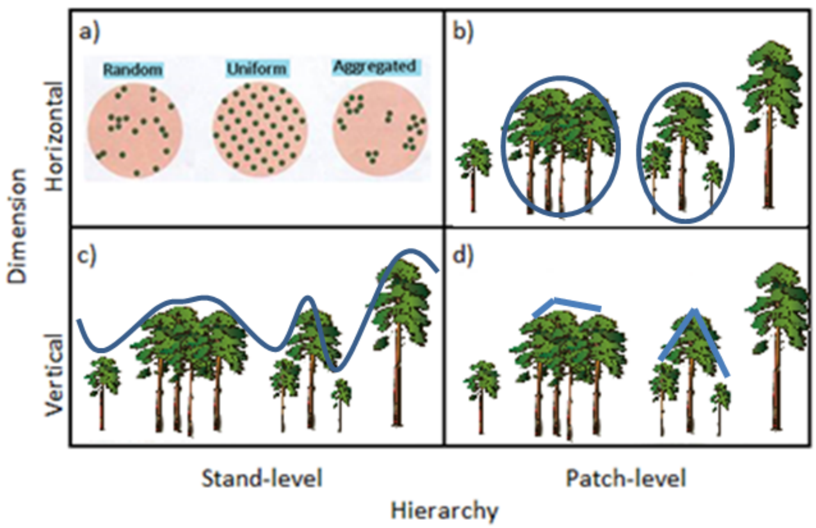


Figure 3. Framework of structural complexity used in this analysis: a) the spatial patterning of trees at the stand-level; b) changes in patch size distribution; c) canopy roughness; and d) the variation in trees heights among patches.

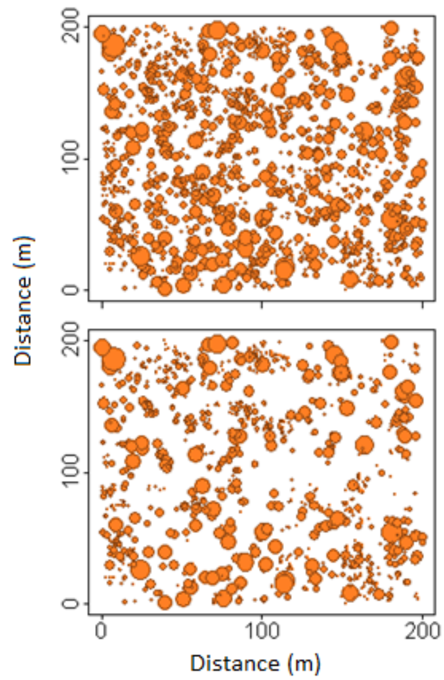


Figure 2. Stem-map of trees pre-treatment (above) and post-treatment (below), leveld to measured crown radii in Unc Mesas unit #1 plot

Table 1. Analyses of structural complexity

| | Pre | Post |
|---|---|---|
| ***a) Stand-level horizontal complexity*** | | |
| Pattern (random, agg., unif.) | Agg. | Agg.* |
| ***b) Patch-level horizontal complexity*** | | |
| *Aerial cover (%)* | | |
| Individual tree | 4 | 4 |
| Patches | 39 | 24 |
| Openings | 57 | 72 |
| *Patch metrics* | | |
| Patch size composition | | |
| Small (1-5 trees) | 22 | 44 |
| Medium (6-10 trees) | 13 | 21 |
| Large (11-20 trees) | 31 | 17 |
| Very large (20+ trees) | 34 | 18 |
| ***c) Stand-level vertical complexity*** | | |
| TH index | 0.57 | 0.54 |
| ***d) Patch-level vertical complexity*** | | |
| $CV_{HT}$ | 0.41 | 0.36 |

* Post-treatment was more uniform than pre-treatment

Agg., aggregated; unif., uniform; $CV_{HT}$ , median coefficient of variation in tree heights within a patch

## Findings and discussion

Following treatment, structural complexity was decreased as measured by a shift towards more uniformity of tree pattern at the stand-level, reduction in stand-level canopy roughness and the tree height diversity within a patch (Table 1). This suggests that the treatment resulted in an overall decrease in structural complexity within 3 of our 4 measures. However, the treatment did result in a reduction in the average patch size and a decrease in the total canopy cover of patches, indicating a reduction in the number of large patches thus favoring the creation of a matrix of individual trees, patches and openings. Although the treatment did largely result in simplification of structural complexity, the post-treatment structure still maintained some degree of heterogeneity across all measures.

We suggest managers adopt feasible and qualitative or quantitative methods to assess complexity. Aside from enabling setting and evaluating of structural restorative goals, this provides a means to consider the trade-offs of meeting multiple treatment objectives when marking or removing trees. For example, we postulate the reduction in structural complexity is due to a conflict in implementation between ecological restoration and fuels hazard mitigation. The increases in tree height and canopy base height (Table 2) suggest removal of ladder fuels, which would result in decreased aggregation and tree height diversity.

Following treatment, fire behavior was reduced across all wind scenarios tested (Table 4). Treatment effectiveness also increased with higher open wind speeds, despite higher within-canopy wind speeds following treatment (Fig. 3). The reduction of canopy biomass and surface fuels diminishes crown fire activity as seen in Figure 4, thus lowering rate of spread and fireline intensity. It should be noted that projected fire behavior may still be greater than desired. This study extends to 6 other sites across the Rocky Mountains and Colorado Plateau; simulations across sites suggest reducing surface fuels is the most effective method at reducing fire behavior.

Table 2. Summary of non-spatial stand structure pre- and post-treatment in Unc Mesa Unit #1

| | Treatment status | |
|---|---|---|
| | Pre | Post |
| TPA | 203 | 126 |
| QMD (in) | 10.8 | 10.5 |
| BA ($ft^2$/acre) | 135 | 77 |
| CBH (ft) | 20 | 22.3 |
| HT (ft) | 64.6 | 83.7 |
| Surface load (tons/acre) | 5.4 | 4.7 |
| Species comp. | 87% PIPO, 6% POTR, 7% PIPU, 1% QUGA | 87% PIPO, 7% POTR, 6% PIPU, 1% QUGA |

TPA, trees per acre; QMD, quadratic mean diameter at breast height; BA, basal area; CBH, mean canopy base height, HT, 90$^{th}$%ile tree height; species codes follow NRCS PLANTS nomenclature

## Acknowledgements

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Table 3. Results of fire simulated by WFDS in Unc Mesa unit#1 pre- and post-treatment across four wind scenarios.

| Open wind speed (mph) | Rate of spread (ch/hr) | | Fireline intensity (kW/m) | | Canopy consumed (%) | |
|---|---|---|---|---|---|---|
| | pre | post | pre | post | pre | post |
| 5 | 107 | 88 | 21081 | 12726 | 69.7 | 51.2 |
| 9 | 157 | 154 | 35335 | 19256 | 67.3 | 46.5 |
| 20 | 289 | 221 | 70800 | 29934 | 78.1 | 51.6 |
| 30 | 320 | 251 | 108460 | 37118 | 80.3 | 52.9 |

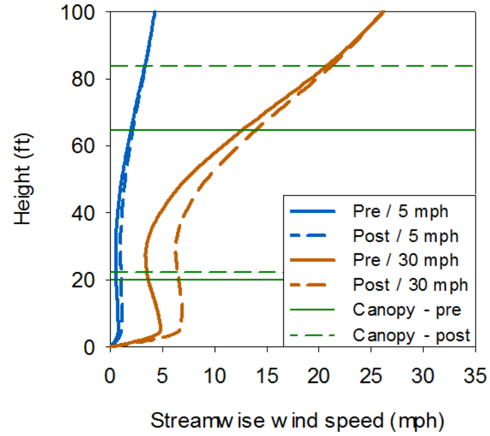


Figure 3. Wind speed profiles for two open winds (5 and 30 mph) pre- and post-treatment in Unc Mesa unit #1, simulated using WFDS.

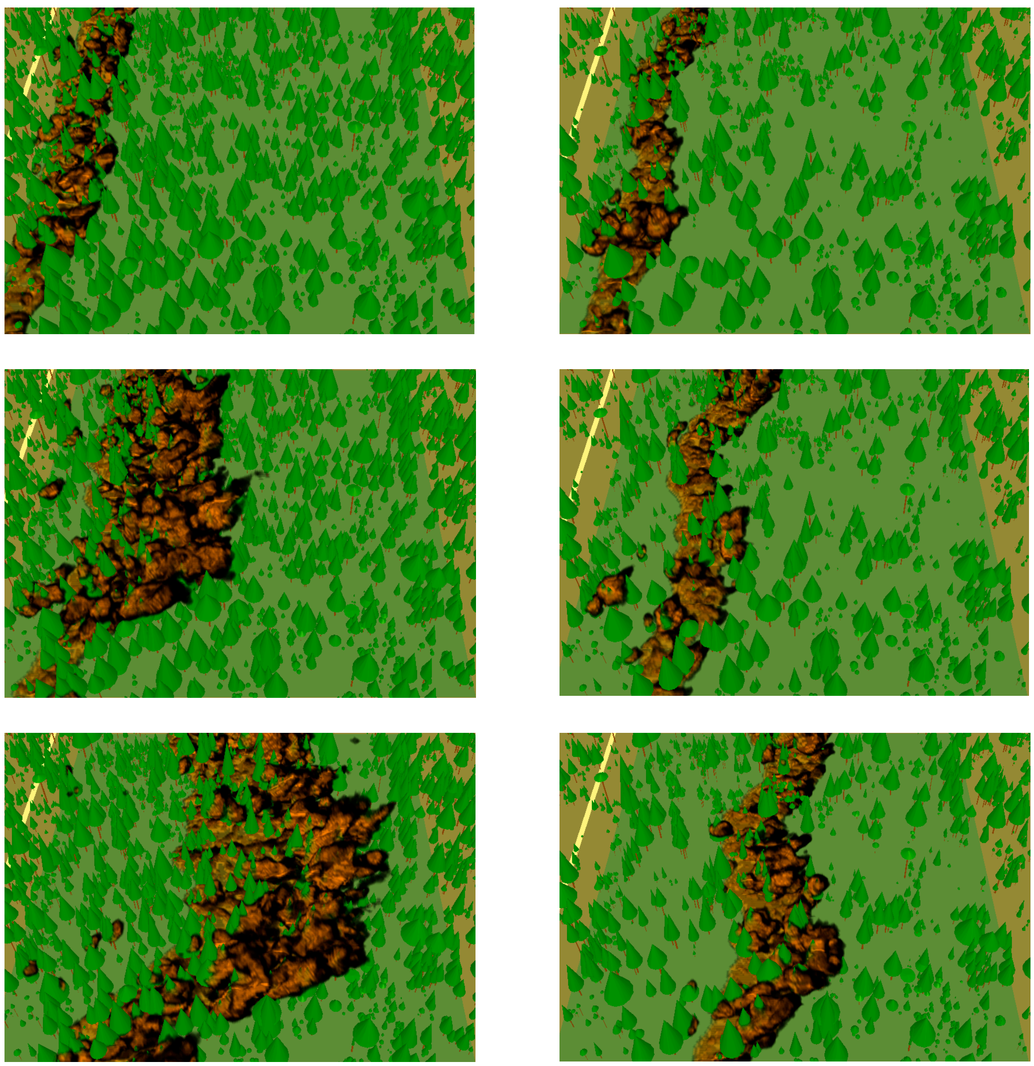

Figure 4. Time series of WFDS simulated wildfire in the highest wind scenario (30mph open) for the Unc Mesa unit #1 before (left) and after (right) treatment.

This summary is produced from a study spanning 7 study sites across the Rocky Mountains and Colorado Plateau conducted by:

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