

INTRODUCTION

- Management actions from land-use changes such as fire suppression, livestock grazing have caused changes in forest structure and composition in many dry conifer forests
- Pre 1800 stand densities in ponderosa pine forests range from <200 trees ha⁻¹ before 1800 to >2400 trees ha⁻¹ currently, making forests vulnerable to large, severe wildfires
- The Front Range CFLRP is a large-scale restoration initiative aimed at reducing fire hazard in ponderosa pine forests in the Front Range and emphasizing restoration of historical fine-scale spatial patterns such as openings and groups of trees.



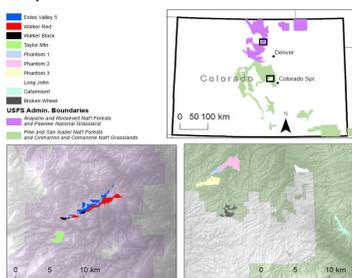
COMPLEX SPATIAL PATTERN



- Pre-settlement forests were characterized by mosaic of openings, individuals trees, and tree groups
- The irregular pattern of trees and openings creates variation in surface fuels inhibiting the spread of crown fire
- Heterogeneous stand structure slows the insect outbreaks and the spread of some pathogens, and allows for periodic tree regeneration following disturbance events

RESEARCH QUESTIONS

- Do CFLRP restoration treatments alter spatial patterns in such a way that they increase heterogeneity of forest spatial patterns?
- Does the adaptive management approach used by the Front Range CFLRP effectively alter treatment outcomes over time?



- 14 restoration treatments of the Colorado Front Range CFLRP
- Pike San Isabel National Forest
 - 9 treatments
- Arapahoe Roosevelt National Forest
 - 5 treatments
- Spanning 2010-2014

METHODS

- Supervised Maximum likelihood of satellite imagery was used to quantify changes in spatial patterns due to CFLRP treatments in pre- and post-treatment forests
- Source imagery was obtained from Woldview2 and GeoEye1 satellites before and after CFLRP treatments (4-band or 8-band/ NDVI, simple ratio, red to green ratio)
- 1. Maximum likelihood Supervised classification (canopy, opening, shadow)
- 2. Grey level thresholding (Using NDVI-values)



Statistical Analysis

Gap Delineation

- We used a gap delineation algorithm identifying all areas with < 5% canopy over 0.045 ha as 'gaps'
- Gaps of 0.045 were chosen as this scale is relevant to resource availability and tree growth.
- Gap delineation was completed in R.

Spatial variables examined

To examine restoration outcomes, we compared pre- and post-treatment:

- Residual canopy cover (%)
- Gap cover (%)
- Gap size variation (CV)

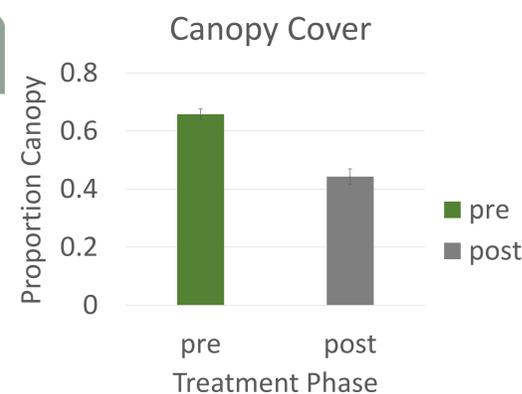
Linear Regression

- Examined change in post-treatment outcomes of each variable over time

RESULTS: TREATMENT OUTCOMES

Overall, CFLRP treatments altered spatial patterns by:

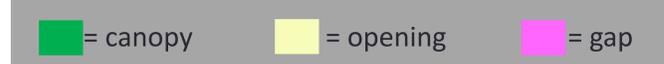
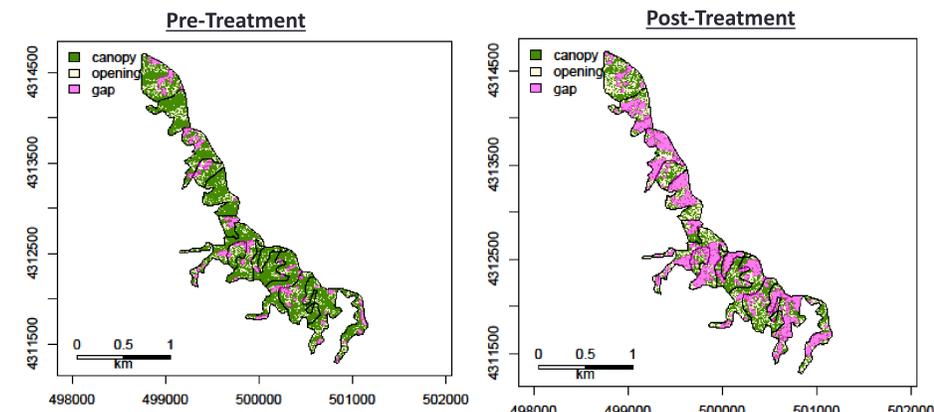
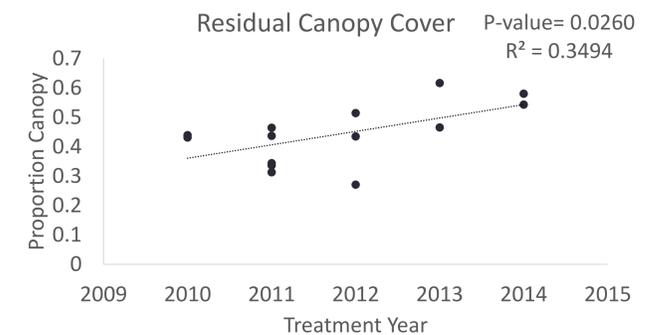
- ❖ Reducing canopy cover by 20 percentage points
- ❖ Increasing gap cover by 18 percentage points
- ❖ Created more variable gap sizes



RESULTS: ADAPTIVE MANAGEMENT

We found little evidence that CFLRP treatments substantially altered spatial patterns of restoration treatments over time:

- ❖ With an adaptive management approach, we expected decreased residual canopy cover and increased variability in spatial patterns over the course of the program.
- ❖ Our data suggests that treatments have greater residual canopy cover as the year of completion advances, and exhibited no significant changes in spatial patterns



CONCLUSIONS

- CFLRP treatments are achieving multiple restoration goals including reducing forest cover, increasing large gaps, increasing spatial heterogeneity
- Our analysis did not detect significant changes in spatial outcomes over time as may be expected using an adaptive management approach

Management Recommendation

- Implementing the Individuals, gaps and openings (ICO) method described in Churchill et al. (2013) may lead to increased spatial heterogeneity at fine-scales
- Using Landscape scale planning methods described in Kashian et al. (2017) may serve as a guide for planning and implementing spatially complex treatments at multiple scales
 - High resolution imagery in reference forests can be used to quantify natural spatial heterogeneity to guide implementation in restoration projects
 - Such analyses allow for specific spatial metrics to be determined and used as benchmarks restoration treatments