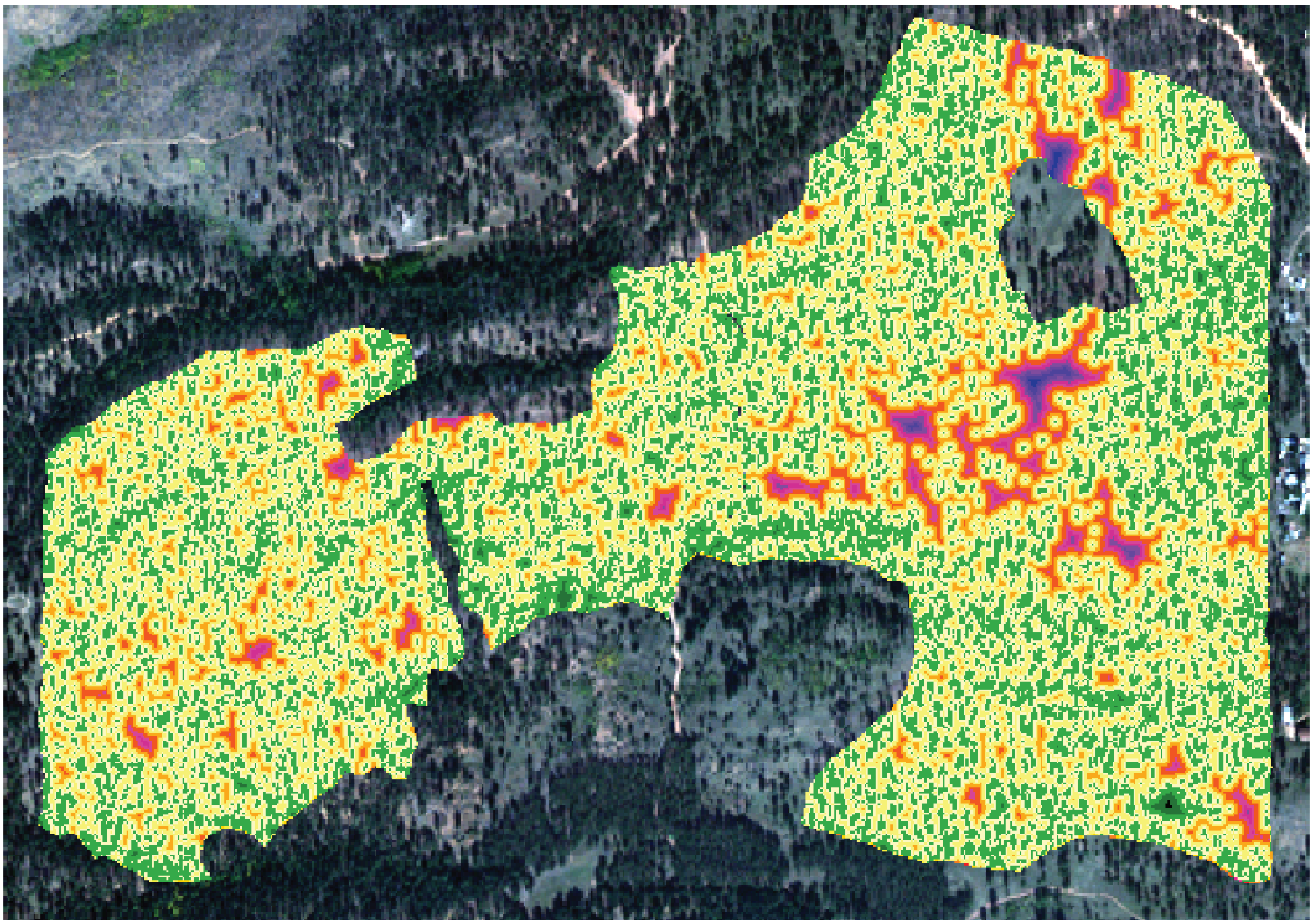
2016 Front Range CFLRI Monitoring: Progress, Outcomes, and Recommendations



Prepared by the Colorado Forest Restoration Institute at Colorado State University on behalf of the Front Range Roundtable Landscape Restoration Team

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CFRI-TB-1601
September 2016

COLORADO FOREST RESTORATION INSTITUTE
Colorado State University

Front Range Fuels Treatment Partnership Roundtable

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Executive Summary and Recommendations

In May 2016, members of the Landscape Restoration (LR) Team met to consider summary results from monitoring and research, advance recommendations for improving future treatments, and strategize about future monitoring and research needs pertaining to the Front Range Collaborative Forest Landscape Restoration Initiative (CFLRI). The CFLRI is in the sixth year of implementing its program of work. The focus of the meeting was to determine whether current monitoring protocols and analyses were sufficient to make recommendations to improve future restoration treatments of the Front Range CFLRI. Progress toward framing recommendations for improving future treatments was made through in-depth analysis of two CFLRI project areas and comparison of these projects to recently collected data representing reconstructed historical forest structure in areas near the recent treatments.

In general, the analysis suggested that the treatments shifted forest structure to more closely resemble historical forest structure. However, a few apparent differences between post-treatment forest structure relative to historical stand structure were noted including (1) a higher relative abundance of Douglas-fir, (2) an apparent reduction in structural variability across productivity gradients, (3) a possible under-representation of larger canopy openings, and (4) a possible under-representation of small to medium groups of trees (2–15 trees). It should be noted that before formal recommendations by the LR Team can be made regarding these discrepancies, analyses from a broader range of CFLRI sites should be examined, and consensus on the relationship between post-treatment and historical conditions should be reached within the group. Nevertheless, this preliminary comparison between post-treatment and historical stand conditions allowed the LR Team to begin development of an analytical framework for evaluating the outcomes of CFLRI treatments and making future recommendations.

In addition, the LR team agreed that (1) current monitoring protocols and analytical frameworks were adequate to begin the formalization of recommendations for future monitoring and analysis of CFLRI projects and recommended (2) continued use of simple metrics to measure forest spatial characteristics, (3) further development of landscape-scale analyses to improve the planning and placement of future treatments, and (4) further development of methodologies to relate CFLRI treatments to reference (historical) conditions. The LR team discussed research on additional topics including the effects of restoration treatments on (1) expected fire behavior, (2) wildlife species and community assemblages, and (3) understory plant communities. More detailed discussion of outcomes, recommendations, and research presentations from the meeting are outlined below.

Introduction & Approach

On May 23, 2016 members of the Front Range Round Table (FRRT) Landscape Restoration (LR) Team[1] met for an annual monitoring discussion. The goal of this session was to determine whether current data and analyses allow for recommendations to be made so that future CFLRI restoration treatments will more closely resemble the desired stand conditions of the FRRT (Clement and Brown 2011; Dickinson et al., 2014). The LR Team achieved this goal through presentations and discussion of monitoring data from two previously implemented CFLRI treatments. The areas discussed included Ryan Quinlan and Phantom Creek (Teller County, CO) project areas. In previous monitoring discussions, available data was used to determine whether treatments were shifting forest conditions in the direction of desired conditions, but specific desired targets for forest conditions were not evaluated. Recent availability of data documenting historical reconstructed (1860) forest stand conditions from the Front Range Forest Reconstruction Network (FRFRNet; Brown et al. 2015, Battaglia et al. in prep.) allowed comparison of pre- and post-treatment conditions from these project areas to the estimated historical conditions, allowing the LR team to determine how closely restoration treatments mirrored conditions of historical forest structure. The scope of the discussion was limited to two project areas for which full datasets were available, to allow greater depth of analysis and consideration.

The approach and organization of the discussion was to compare forest structural data (e.g., density, basal area, composition, tree group size, and canopy and openings) in pre- and post- treatment stands to reference conditions from 1860 documented by the FRFRNet at sites within 30 mi (48 km) of the treatments. Such comparisons allowed the LR team to evaluate how closely post-treatment conditions resembled historical stand structure. Although mimicking historical forest structure in one selected year is a simplification of the more nuanced desired stand conditions of the FRRT, comparisons of post-treatment conditions to historical forest structure allowed a framework for determining whether these data were sufficient to make future recommendations. Consideration of current data on forest structure and comparison to historical conditions led the attendees to develop a list of potential recommendations for future CFRLI projects to consider formalizing and/or adopting, pending further analyses.

Below, we outline the major comparisons between post-treatment and historical stand conditions, highlighting areas of apparent congruence and discrepancy. In addition, we summarize recommendations to improve future monitoring efforts and analysis. Lastly, we summarize the major progress, findings, and discussion of the LR team, including current research on (1) historical conditions of the Front Range, and restoration effects on (2) forest structure and composition, (3) fine-scale spatial structure, (4) fire behavior, (5) wildlife, and (6) understory plant communities.

Outcomes & Analysis of Restoration Treatments

The LR team discussed data on several aspects of forest structure in pre- and post-treatment stands and compared this data to historical reference conditions. Data was summarized by aspect (north vs. south) to infer how forest structure changed along productivity gradients. Results from these comparisons of forest structure led to the identification of four possible discrepancies between post-treatment and historical stand conditions.

(1) LR Team attendees included Rob Addington (The Nature Conservancy), Greg Aplet (The Wilderness Society), Kevin Barrett (Colorado Forest Restoration Institute, Colorado State University), Hannah Bergemann (Colorado Forest Restoration Institute, Colorado State University), Jenny Briggs (US Geological Survey), Jeffery Cannon (Colorado Forest Restoration Institute, Colorado State University), Joan Carlson (US Forest Service, Region 2), Marin Chambers (Colorado Forest Restoration Institute, Colorado State University), Tony Cheng (Colorado Forest Restoration Institute, Colorado State University), Casey Cooley (Colorado Parks and Wildlife), Jonas Feinstein (Natural Resource Conservation Service), Paula Fornwalt (USDA Forest Service, Rocky Mountain Research Station), Ben Gannon (Colorado Forest Restoration Institute, Colorado State University), Mark Martin (USDA Forest Service, Arapaho-Roosevelt National Forest/Pawnee National Grasslands), Mike McHugh (Aurora Water), Steve Sanchez (USDA Forest Service, Pike-San Isabel National Forest/Cimarron and Comanche National Grasslands), Nick Stremmel (Boulder County Parks and Open Space), Chris Wanner (Boulder County Parks and Open Space), Brett Wolk (Colorado Forest Restoration Institute, Colorado State University), Justin Ziegler (Dept. of Forest and Rangeland Stewardship, Colorado State University). Facilitation by Heather Bergman and Katie Waller (Peak Facilitation).

It should be noted that these discrepancies were found using initial analyses of two project areas [Ryan Quinlan and Phantom Creek, 358 and 696 acres (145 and 282 ha), respectively] and should be viewed as preliminary. These discrepancies are noted here so that they can be explored more fully in a larger range of CFLRI project areas, and—pending further discussion—may be formalized into recommendations for future treatments.

> 1. Although basal area in post-treatment stands was similar to historical conditions, Douglas-fir was over-represented in post-treatment stands, while ponderosa pine was under-represented relative to reference conditions in the areas examined.
>
> 2. North aspects were thinned heavily, resulting in similar basal area on both north and south aspects. Generally, basal area on northern aspects was lower than expected relative to reference conditions. This indicates that marking protocols may be invariant across variable topography, which may lead to homogenization of stand structure rather than increased or maintained heterogeneity. A greater focus on incorporating topographic and productivity gradients in treatment prescriptions and marking protocols may reduce this homogenization effect.

In addition to discussion of forest structure, the LR Team also discussed new data and analyses on spatial aspects of forest structure (e.g., percent cover, percent large openings, canopy patch size, etc.) derived from satellite imagery of pre- and post-treatment stands and compared this data to historical reference conditions. These analyses focused on categorizing openings into two separate classes: (1) "edges" (narrow openings <6 m from tree canopy) and (2) large openings or "meadows" (openings with radius > 6 m from canopy). Additional analyses measured the percentage of canopy in large, medium, or small patches, reflecting different numbers of trees in groups with interlocking crowns, and isolated trees. Based on analysis of spatial aspects of forest structure the LR Team identified areas of apparent discrepancy between post-treatment and historical stand spatial structure:

> 3. Although percent canopy cover in post-treatment stands was similar to reference conditions, large openings or meadows were under-represented following treatment. Correspondingly, openings classified as canopy edge were over-represented.
>
> 4. Relative to reference conditions, large groups of trees (16+ trees) and single trees were over-represented in post-treatment stands. Correspondingly, small to medium groups of trees (2–16 trees) were underrepresented relative to reference conditions.

Together, these results suggest that these treatments may produce stands with many single trees with relatively uniform spacing, in addition to retaining large patches of interconnected groups of trees from the pre-treatment forest conditions and fostering extensive edge habitat rather than large openings. Both of these spatial discrepancies from reference conditions could be mitigated by producing a greater diversity of tree group sizes while simultaneously creating larger canopy openings.

Outcomes & Recommendations for Future Monitoring

Through the process of analyzing and interpreting data with an explicit goal of working toward advancing management recommendations, the LR Team made four conclusions and recommendations relevant to monitoring and analysis of future CFLRI projects:

> 1. Unanimously, the LR team agreed that the type and extent of monitoring data currently being collected is adequate to evaluate treatments and make recommendations for future treatments. However, further development of additional analyses (e.g., opening size distribution, analysis of distribution of structural metrics) and further consideration of the relevance of reference conditions in identifying targets for future restoration treatments may be important next steps to improve monitoring analyses.

2. The LR team concluded that simple spatial metrics are preferred for evaluating spatial components of desired metrics over more complex metrics. Presentations in this monitoring discussion used metrics such as percent openings in edge versus large open ings, which were easier to interpret than more complex spatial heterogeneity metrics used previously (e.g., FragStats). However, some complex spatial heterogeneity metrics (e.g., those related to connectivity) may prove useful for monitoring changes in potential wildlife habitat.

3. Although the LR team agreed that project-level data was adequate to address project-level evaluation of treatments, the group felt that landscape-scale analyses are still necessary to address the larger-scale questions about landscape-scale heterogeneity and for use in future treatment planning.

4. The LR team felt that consideration of reference conditions allowed progress toward making more concrete recommendations for future treatments. However, refinement of how reference conditions are framed and evaluated may be necessary. Specifically, the group is interested in further consideration of the role of past disturbance history in shaping reference conditions. Much of the FRFRNet data reflects forest structure in 1860, so the degree to which the reference sites were influenced by the widespread regional fires in 1851 should be carefully evaluated.

Presentation Summaries

Historical Stand Conditions of the Front Range

Benjamin Gannon[2] presented a summary of the Front Range Forest Reconstruction Network (FRFRNet; Brown et al. 2015, Battaglia et al. in prep) which was developed to better understand Front Range forest ecology and to provide reference conditions for restoration. The FRFRNet

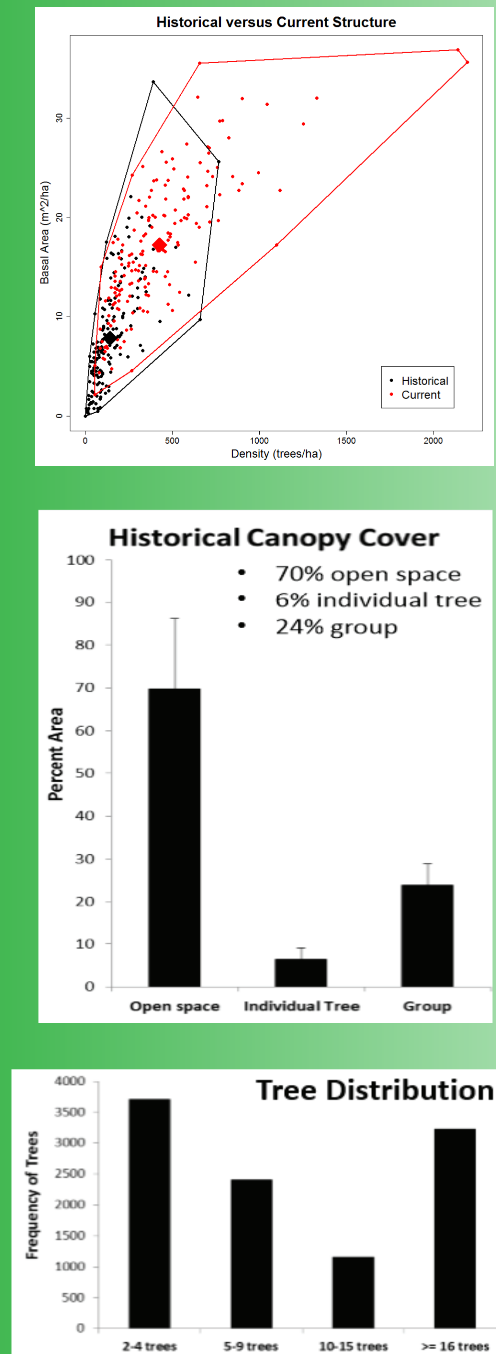

Figure 1. (a) Current and historical distribution of density and basal area for plots included in the FRFRNet indicating general increase in density and basal area. (b) Distribution of stand area in openings, isolated trees, and tree groups. (c) Frequency of trees in groups of various tree group size.

(2) Research Associate, Colorado Forest Restoration Institute, Colorado State University

provides data on historical (ca. 1860) forest structure (e.g., density, basal area, composition, tree age and size distributions, etc.), and is currently being analyzed to provide data on fine-scale forest spatial structure (e.g., size of tree groups and openings). Current forests are denser and have higher basal areas than they did historically, but forest structure was and is quite diverse across the Front Range due to disturbance and topography (Figure 1A). Open space made up the majority of historical stands, most canopy cover was produced by trees in groups (Figure 1B), and approximately one-third of trees in groups were in large groups of 16 or more (Figure 1C). In addition to providing insight to historical ecological processes across the Front Range, results from the FRFRNet can serve as reference points to evaluate CFLRI restoration treatments.

Restoration Effects on Forest Structure

Kevin Barrett[3] presented forest structural data from Ryan Quinlan and Phantom Creek project areas to compare basal area, stand density, tree size, and stand composition with historical reference conditions from FRFRNet. Pre- and post-treatment data was available for Phantom Creek, while only post-treatment data was available for comparison from Ryan Quinlan. Reference conditions obtained from FRFRNet were drawn from plots located within a 30-mile radius of Ryan Quinlan, however only the plots that fell within the upper quartile in elevation were compared for Phantom Creek as the site is at a relatively high elevation (9000 ft, 2740 m). Results suggested that restoration generally shifted forest structure toward historical conditions, however, some aspects of forest structure differed from historical conditions. For example, treatment at Phantom Creek increased the ratio of ponderosa pine to Douglas-fir. However, post-treatment conditions exhibited considerably more Douglas-fir and less ponderosa pine than were historically present (Figure 2A).

Additionally, while basal area at Phantom Creek reflects historical conditions (67 ft^2/acre post-treatment, compared to 63 ft^2/acre historically), tree density remained considerably higher post-treatment compared to reference conditions (147 trees per acre post-treatment compared to 104 trees per acre historically). Quadratic mean diameter increased from 9.75 to 10.68 inches as a result of the treatment, but was still about 0.75 inches smaller than reference conditions. Residual basal area on both north and south aspects were similar, indicating that similar tree marking protocols were used across productivity gradients, thus homogenizing stand structure across varying topographies. In addition, comparing post-treatment basal area with reference conditions shows a higher basal area on northern aspects historically than what is seen currently at Phantom Creek (Figure 2B).

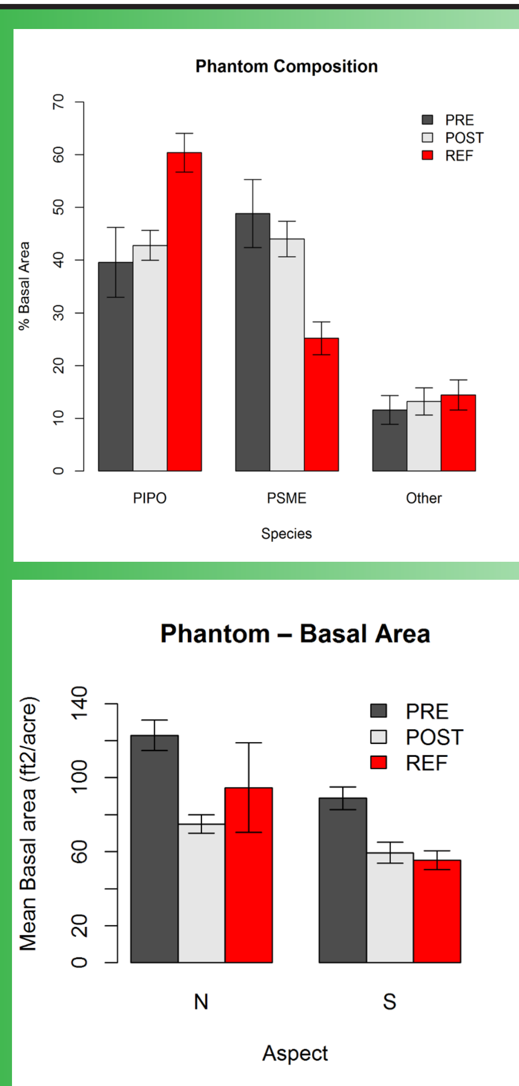

Figure 2. (a) Relative abundances for ponderosa pine (PIPO), Douglas-fir (PSME), and other species, for pre- and post-treatment, and historical reference conditions at Phantom Creek. (b) Basal area summarized by aspect for pre and post-treatment, and historical reference conditions at Phantom Creek.

(3) Research Associate, Colorado Forest Restoration Institute, Colorado State University

The LR team discussed how to best use reference conditions to evaluate post-treatment forest structure, and two main points of concern arose as a result of this discussion. One concern was that further assessment of how to use reference conditions to evaluate project-scale results may be needed. By using reference sites within 30 miles surrounding a site we may be combining data from a range of different site conditions to assess the success of a single site with a more narrow range of site conditions. An additional concern arose about the influence of the 1851 fire year on reference condition data, which describes the forest structure of ca. 1860. Much of FRFRnet was conducted in areas that were disturbed during the fire year, and the group wanted to avoid making recommendations to restore sites to reflect a recent post-disturbance landscape. Both of these concerns will be addressed during the next monitoring discussion. In addition, staff at the Colorado Forest Restoration Institute will explore proxies for productivity such as total wetness index for future analyses.

Restoration Effects on Fine-scale Spatial Structure

Jeffery Cannon[4] presented preliminary data from current research that utilizes satellite imagery to evaluate how CFLRI treatments across the Front Range alter fine-scale spatial structure (Figure 3A). The work refines previous work on this topic by addressing problematic issues with shadows in aerial imagery, (2) presenting new analyses that directly address desired conditions using simpler metrics related to canopy openings and tree group size distribution, and (3) making direct comparisons of spatial structure to historical conditions from the FRFRNet. Major results presented from Ryan Quinlan and Phantom Creek project areas indicate that treatments are creating appropriate levels of canopy openness, however, more of these openings occur in close proximity to canopy edge rather than as part of larger openings relative to historical conditions (Figure 3B). In addition, treatments are altering tree group size to better reflect reference conditions, however isolated trees and very large groups (>15 trees) are over-represented, while moderate sized groups (2–15 trees) are under-represented relative to historical conditions (Figure 3C). Local spatial statistics such as distribution of tree group size may be more intuitive and more readily incorporated into treatment prescriptions and marking protocols compared to previous metrics of heterogeneity (e.g., FragStats-based metrics). In general, these results indicate that a greater focus on creating small- to medium-sized tree groups rather than isolated trees during tree marking could lead to post-treatment spatial patterns that are more congruent with historical stand conditions.

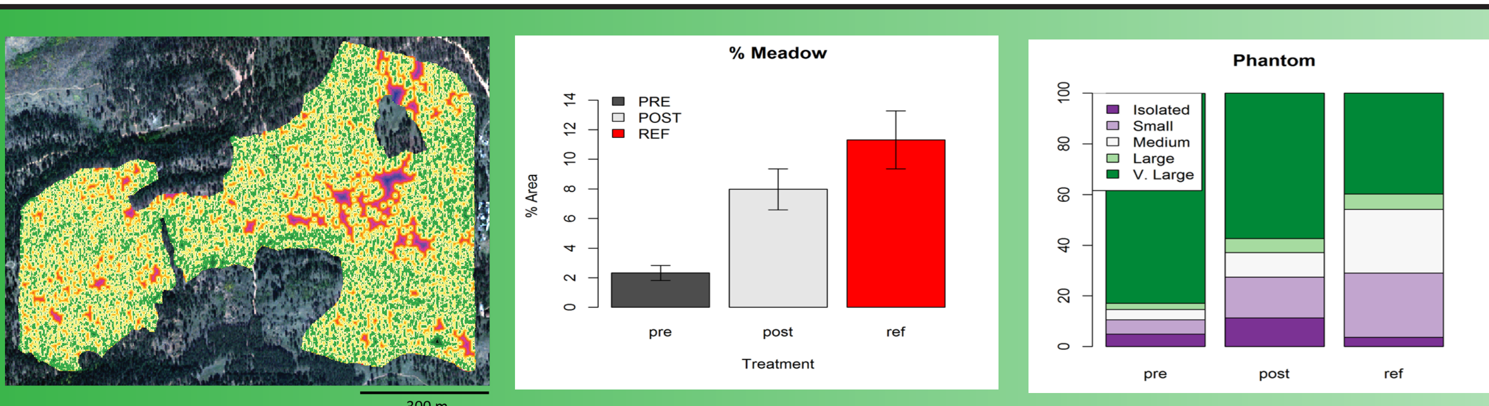

Figure 3: (a) Classification of a post-treatment imagery for a portion of the Ryan Quinlan project area (Teller Co.). Green indicates canopy patches, yellow indicates openings near canopy edge, and pink-purple colors indicate large interior openings. (b) Proportion of treatment area in large openings at Ryan Quinlan and (c) proportion of tree cover in various group sizes in pre- and post-treatment stands in Phantom Creek compared to historical reference.

4) Research Associate, Colorado Forest Restoration Institute, Colorado State University

The LR team agreed that the simpler spatial metrics presented here (proportion of stand in canopy, edge openings, large openings, and tree group size) may be more useful for monitoring changes in stand-scale heterogeneity and should be further pursued across the Front Range. Additional work to produce visual maps of forests with varying proportions of canopy openings and group size may aid in translating desired conditions into improved treatment prescriptions and tree marking prior to treatments. Lastly, the members of the LR team suggested that the language of desired conditions related to spatial heterogeneity may be too vague and could be refined to include more specificity regarding fine-scale tree patterns.

Restoration Effects on Fire Behavior

One of the goals of the LR team is to better understand how restoration treatments may impact fire behavior. Justin Ziegler[5] presented a summary of research describing how seven forest restoration thinnings in CO, AZ, and NM altered stand heterogeneity and modeled fire behavior using a 3D fire model, Wildland-urban interface Fire Dynamics Simulator (WFDS). Two of the sites included in Justin's analyses were part of the Front Range CFLRI—including Phantom Creek and Messenger Gulch. For most sites, trees were aggregated before thinning and remained aggregated after thinning, though thinnings had inconsistent effects on the degree of tree aggregation (Table 1). This inconsistency can be ecologically appropriate according to reference conditions. Most importantly, no thinning created tree uniformity. Modeled fire line intensity and rate of spread decreased following treatment, and this effect was more pronounced at higher wind speeds (Figure 4). Rearrangement of fuels into heterogeneous arrangements had an effect on fire behavior, but it was relatively modest compared to the prominent effect of reducing canopy fuels. Details can be found in Ziegler (2014).

Restoration Effects on Wildlife Communities

Jenny Briggs[6] , Casey Cooley[7] , and the Wildlife Working Team are currently investigating the effects of restoration treatments on wildlife communities. They presented the process used to select wildlife species to monitor and provided preliminary results for Abert's squirrel monitoring. Priority (tier 1) species to monitor were chosen systematically by starting with over 300 species found in Front Range lower montane forests and filtering based on political prudence, economic/social importance, and ecological significance. The process resulted in seven avian species, the Abert's squirrel, and pine squirrel, which are sampled biennially beginning in 2014 by the Bird Conservancy of the Rockies (BCR). The sampling strategy used by BCR

Site	Pattern, pre-thin	Pattern, post-thin	Δ degree of aggregation
HB	**Uniform**	Agg	**More**
LC	Agg	Agg	Less
MG	Agg	Agg	**More**
PC	Agg	Agg	**More**
DL	Agg	Agg	**More**
UM	Agg	Agg	Less
BW	Agg	Agg	No change

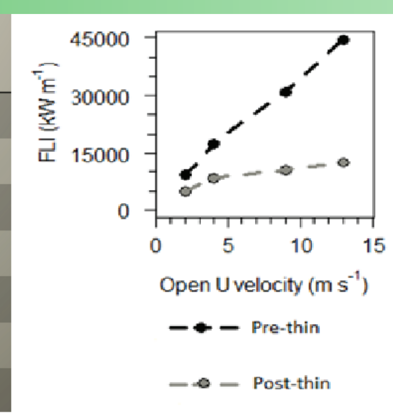

Table 1: (Left) Change in tree aggregation in pre- and post-treatment stands. PC and MG refer to CFLRI treatments Phantom Creek and Messenger Gulch respectively. Agg = aggregated.

Figure 4: (Right) Relationship between wind speed and modelled fire line intensity for pre- and post-treatment stands.

(5) Research Associate, Colorado State University, PI: Dr. Chad Hoffman

(6) Research Ecologist, United States Geological Survey

(7)Forest Habitat Coordinator, Colorado Parks and Wildlife employs spatially balanced grids in which bird counts are conducted to provide density and occupancy estimates. Because much of this strategy relies on auditory calls from birds, detection probability of Abert's squirrel is low as they are typically less vocal. Due to the difficulties in monitoring Abert's squirrel, much of the recent work by the Wildlife Working Team has focused on a pilot study, looking at the efficacy of using camera traps baited with peanut butter (Figure 5A) compared to the use of four transects at four points within the bird grid (Figure 5B) to record signs of Abert's squirrel activity—primarily needle clippings and "cone cobs."

While the data has not yet been evaluated for the squirrel sign portion of the study, camera traps estimated occupancy consistently for 2014 and 2015 (Figure 5C). As monitoring data continues to be collected, occupancy estimates will be more meaningful as changes in occupancy can be better attributed to factors beyond natural population cycles for a given species. This year, the wildlife team plans to collect data at bird grids, evaluate the squirrel sign study, and make a decision on sampling methodology for Abert's squirrel monitoring.

Restoration Effects on Understory Plant Communities

Brett Wolk[8] and Paula Fornwalt[9] presented an update on progress toward evaluating how CFLRI treatments impact understory plant communities. Progress toward this goal includes refining the desired conditions related to understory plants into seven testable monitoring hypotheses. Currently, they are collecting pre-treatment data in a variety of treatment areas to assess how treatments alter the abundance and diversity of (1) native species, (2) functional groups, (3) early seral species, (4) exotic plants, (5) key native species (i.e., threatened/endangered), (6) noxious weeds, and (7) spatial heterogeneity of herb communities (i.e., beta diversity). In addition, Brett presented an update on the seven treatment areas that have been established where pre-treatment herbaceous surveys have been completed. The seven treatment areas span the Front Range and include a total of 18 treatment and control pairs and three different treatment types (mechanical thinning, hand thinning, and prescribed

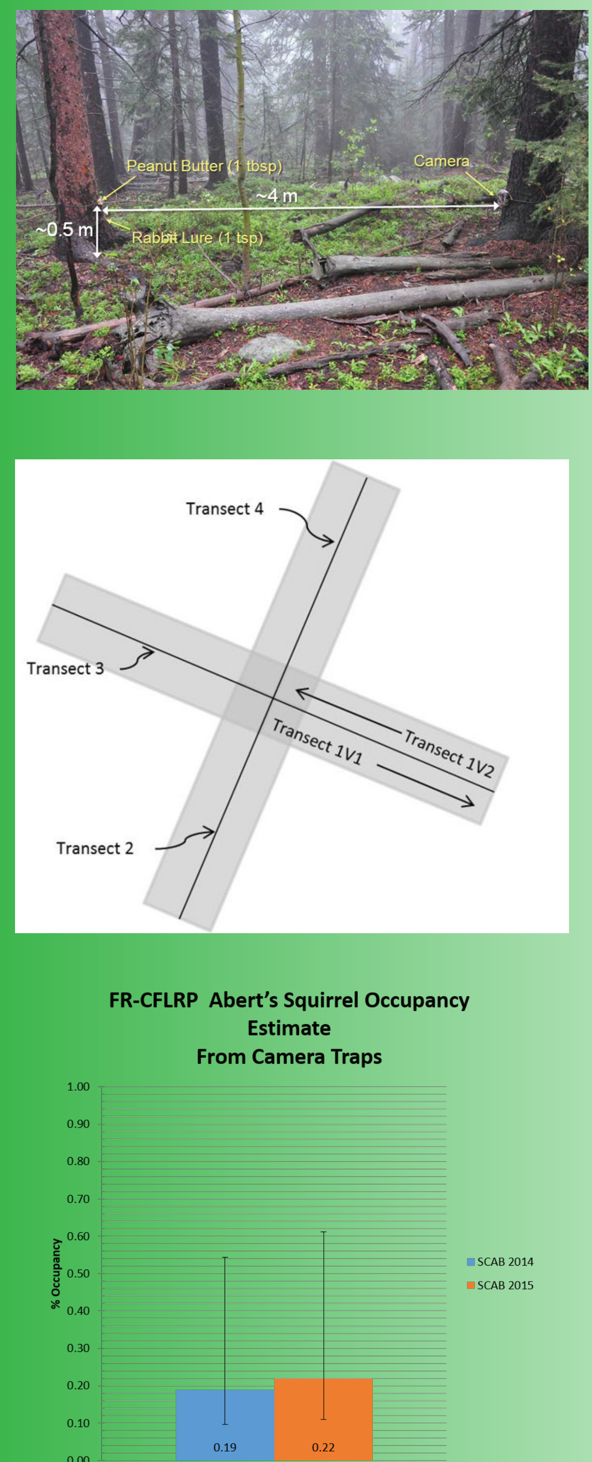

Figure 5. (a) Plot design for baited camera traps. (b) Plot design for Abert's squirrel sign survey transects, repeated at 4 points per bird grid. (c) Occupancy estimates for Abert's squirrel obtained from camera traps for 2014 (blue) and 2015 (orange).

(8)Assistant Director, Colorado Forest Restoration Institute

(9)Research Ecologist, US Forest Service, Rocky Mountain Research Station fire). Because several treatments have not yet been implemented (and was one canceled), Brett and Paula are exploring ways to make other inferences from the data such as relating overstory and understory data while remaining treatments are completed.

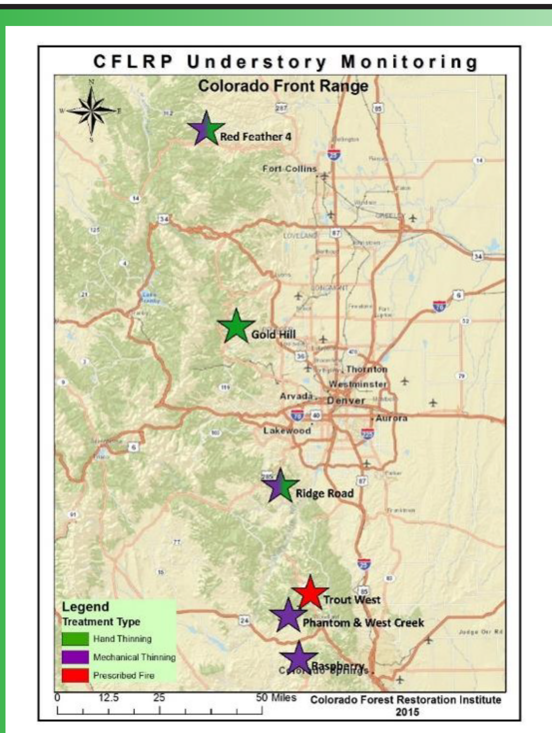

Figure 6. Project areas included in the CFLRI Understory monitoring project. Together, these include 18 paired treatment and control sites and a total of 207 plots with pre-treatment data.

Next Steps

After consideration of analyses of monitoring data on forest structure and fine-scale stand spatial structure, the LR team agreed that current monitoring protocols are collecting sufficient data to allow the group to make recommendations to adjust future restoration treatments. However, it is currently unclear what form such recommendations may take (i.e., presentation, formal report, etc.), and future LR team meetings may focus on development of formal recommendations. One potential direction is to further explore whether the apparent discrepancies outlined here are consistent across CFLRI project areas.

Although the LR-team agreed that current monitoring data collection is sufficient to make recommendations, they agreed that additional analyses of the currently collected monitoring data will allow more concrete recommendations. One recommendation was to explore productivity gradients besides slope aspect (e.g., topographic wetness index) to inform how treatments vary across these gradients and relate to historical conditions. Additionally, the development of simpler metrics to analyze spatial metrics allowed evaluation of spatial structure, but additional analysis that delineate opening could further advance this understanding. Spatial analyses that quantify the number and size of large openings (such as the use of a patch detection algorithm) can help inform how treatments alter gap size distribution and relate to historical expectations (e.g., Dickinson 2014).

Inclusion of new analyses comparing pre- and post-treatment forest structure to reference conditions was an important step toward making formal recommendations to improve future CFLPR treatments. However, the LR team identified that further refinement of how reference conditions are framed and compared to pre- and post-treatment conditions may be necessary. Development of a framework for comparing post-treatment conditions to historical reference conditions along with continued evaluation of CFLRI treatment effects on forest structure and fine-scale spatial patterns is an important step toward developing concrete recommendations to further the adaptive management process for the Front Range CFLRI.

References

Brown PM, Battaglia MA, Fornwalt PJ, Gannon BM, Huckaby LS, Julian C, Cheng AS (2015) Historical (1860) forest structure in ponderosa pine forests of the northern Front Range, Colorado. 1473:1–19.

Clement J, Brown P (2011) Front Range Roundtable Collaborative Forest Landscape Restoration Project 2011 Ecological, Social and Economic Monitoring Plan. Colorado Forest Restoration Institute.

Dickinson Y (2014) Landscape restoration of a forest with a historically mixed-severity fire regime: What was the historical landscape pattern of forest and openings? For Ecol Manage 331:264–271.

Dickinson YL, Spatial Heterogeneity Subgroup of the Front Range Roundtable (2014) Desirable Forest Structures for a Restored Front Range. Colorado Forest Restoration Institute. CFRI-TB-1402.

Ziegler J (2014) Impacts of treatments on forest structure and fire behavior in dry western forests. Master's Thesis, Department of Forest and Rangeland Stewardship. Colorado State University.