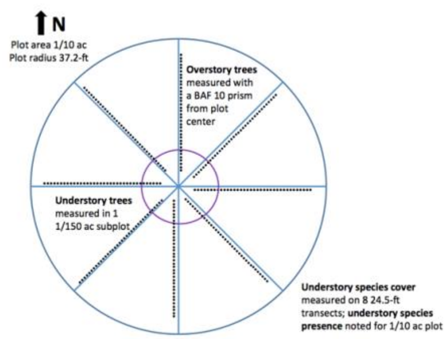
Front Range Roundtable
Collaborative Forest Landscape Restoration Project:
2018 Ecological, Social and Economic Monitoring Plan



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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Front Range Roundtable

2018 Monitoring Plan
Front Range Collaborative Forest Landscape Restoration Project

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Chapter 1. Introduction

The Colorado Front Range Collaborative Forest Landscape Restoration Project (CFLRP) is a 10-year program intended to help reduce the risk of ecologically uncharacteristic and socially undesirable wildfires on 32,000 acres of lower montane, ponderosa pine (*Pinus ponderosa*) dominated National Forest lands administered by the Arapaho and Roosevelt (ARP) and Pike and San Isabel National Forests (PSI). The project is a product of the Front Range Roundtable (FRRT), a multi-stakeholder collaborative advisory group established in 2004, involving federal, state, and local government entities, non-governmental organizations, research institutions, and local communities. The Front Range CFLRP is part of a larger national competitive funding program administered by the USDA Forest Service pursuant to the Federal Landscape Restoration Act of 2009[1]. Under the requirements of this funding, grantees must conduct multi-party ecological, economic, and social monitoring to record the benefits and lessons learned from these restoration efforts using methods collaboratively developed amongst a diverse group of stakeholders. A subgroup of FRRT, the Landscape Restoration Team (LRT), produced an initial CFLRP monitoring plan in 2011 (Clement and Brown 2011). This document represents an update of the original monitoring plan, as of 2017, which synthesizes the activities that have taken place since 2011 and provides guidance for future monitoring activities. This document is envisioned as a "living" document, resulting from collaborative discussions, to be revised by the FRRT as monitoring data are evaluated, synthesized, and incorporated into management plans, and as new information and monitoring methods and approaches are generated over the 10-15 year course of the CFLRP.

Upon completion of the original monitoring plan, the estimated cost to implement monitoring was $40K per year, covering Common Stand Exam (CSE) analysis. In 2014, wildlife and understory plant monitoring programs were ready for implementation (see chapter 3 for details about specific monitoring programs). As a response to additional monitoring needs and further acres treated, the monitoring budget was raised to over $200K per year to cover additional monitoring costs. In addition, during years when excess funds were available due to contract cost savings or the availability of unused contract funds, extra funds were allocated to monitoring and worked into agreements with the Bird Conservancy of the Rockies (BCR) and the Colorado Forest Restoration Institute (CFRI) to fund further monitoring. In an effort to minimize monitoring costs, coupled with the fact that monitoring data for certain programs is not required on a yearly basis, the LRT decided to alternate monitoring funds between understory plant and wildlife monitoring each year. Current monitoring funding is allocated to pre- and post-treatment monitoring and analysis for the following categories (see Table 1 for a yearly budget breakdown for each category, see

[1] For more information on the Federal Landscape Restoration Act of 2009 and the national Collaborative Forest Landscape Restoration Program: https://www.fs.fed.us/restoration/CFLRP/overview.shtml

Appendix A for a breakdown of monitoring activities and studies related to the Front Range CFLRP):

1. CSE Implementation by the USFS.
2. CSE, Spatial Heterogeneity/ Landscape Scale, and Social/ Economic Analysis conducted by CFRI.
3. Wildlife Monitoring and Analysis with BCR.
4. Understory Plant Monitoring and Analysis with CFRI and the Rocky Mountain Research Station (RMRS).
5. Watershed Health (currently being developed).

This monitoring plan is meant to serve as a technical guide for Front Range CFLRP partners on measuring meaningful metrics to help direct management decisions and reduce uncertainty under an adaptive management framework. Collaborative learning and knowledge sharing is a key component to any multi-stakeholder developed monitoring program. By documenting our CFLRP monitoring and adaptive management program over time, we hope that our collective innovations, successes, and challenges will help inform future monitoring programs and improve the adaptive management process for the USFS, other Roundtable entities, and anyone interested in multi-stakeholder developed monitoring and adaptive management programs.

Table 1. Yearly monitoring funding allocation to different monitoring categories from 2015 through 2024.

Year	Understory	Wildlife	CSE	CFRI Analysis	Total Annual Budget
2015	$90k	$0	$60k	$65k	$225k
2016	$0	$100k	$60k	$65k	$225k
2017	$90k	$0	$60k	$65k	$215k
2018	$0 ($45k)*	$100k	$60k	$65k	$270k
2019	$0	$0	$60k	$65k	$125k
2020	$90k ($45k)*	$100k	$60k	$65k	$360k
2021	$0	$0	$60k	$65k	$125k
2022	$0	$100k	$60k	$65k	$225k
2023	$0 ($45k)*	$0	$60k	$65k	$170k
2024	$90	$100k	$60k	$65k	$315k

*Round 2 inventory funding needed

Chapter 2. Adaptive Management and Monitoring

This chapter outlines the adaptive management (AM) model (see Aplet et al. 2014) intended to assess the success of CFLRP treatments for a minimum of 15 years after project implementation, and to guide future treatments through an adaptive management framework (Holling 1978; see section 2.2). Monitoring results will be used both to evaluate the rate and extent of achievement of individual project goals, and to incorporate data into analyses of cumulative effects at the landscape level. The monitoring protocols outlined in the following chapters are designed to address specific desired conditions. Desired conditions are short descriptions of broad ecosystem goals that are to be achieved through the CFLRP project. These conditions are intended to form a focus for the restoration strategy and to provide a basis for developing treatment objectives and priorities that will be assessed during the monitoring program. Desired conditions developed by the FRRT are as follows (see Clement and Brown (2011) and Dickinson and SHSFR (2014) for further discussion regarding these desired conditions):

1. Establish a more favorable species composition favoring lower montane species over other conifers.
2. Establish a more characteristic fire regime.
3. Increase coverage of native understory plant communities.
4. Increase the occurrence of wildlife species that would be expected in a restored lower montane forest.
5. Reduced potential for damaging post-fire erosion and sedimentation to municipal water supplies.
6. Establish a complex mosaic of forest density, size and age (at stand and landscape scales).

2.1. Types of Monitoring

DeLuca et al. (2010) describe two fundamental types of monitoring: implementation and effectiveness monitoring. *Implementation monitoring* can be described as compliance monitoring, which assesses whether or not a management action has taken place as prescribed. This type of monitoring can be achieved relatively quickly, and is used to evaluate if treatments meet baseline objectives such as shifts in basal area, fuel loading, and quadratic mean diameter. To better understand if a management prescription ultimately achieved intended results, *effectiveness monitoring* must be implemented. Hutto and Belote (2013) further break down effectiveness monitoring into *surveillance monitoring*, which establishes a baseline set of ecological conditions, and *effects monitoring*, which evaluates whether or not management activities have unexpected consequences on the ecosystem. Effectiveness monitoring may require longer timeframes (e.g. understory response to a treatment after several years), or involve complex skillsets to incorporate various models (e.g., fire behavior modeling) or aerial imagery analysis. For this reason, effectiveness monitoring may be implemented periodically rather than annually, to assess how management activities influence larger processes such as fire behavior, watershed health, or spatial dynamics in the system. Another crucial part of an AM model includes the *adaptive monitoring* of monitoring guidelines themselves (Lindenmayer and Likens 2009), which encourages monitoring activities to evolve as new information becomes available (this document is an example of this type of monitoring). The AM model adopted by the Front Range CFLRP (Aplet et al. 2014) includes all of the above types of monitoring to provide forest managers with the best available information. Under this model, implementation monitoring will be executed most frequently, likely within a year of treatment. Effectiveness monitoring will be executed less frequently, as larger datasets and skillsets are required for analysis. Adaptive monitoring will be continuous, as monitoring activities are always subject to review as new information, methods, and funding become available.

2.2. Adaptive Management Model

Two essential concepts of a monitoring program are that ecosystems are dynamic at multiple scales in space and time, and there is often uncertainty surrounding attempts to define rates or magnitudes of ecosystem changes that may take place (Holling 1978). Ecosystems are inherently dynamic and changes occur across spatial scales ranging from individual plants to landscapes and time scales ranging from days to centuries. Uncertainty arises because we do not know precisely how ecosystem components interact at these multiple scales to produce the rich variety of behavior that is present in natural systems. A current example of uncertainty is caused by anthropogenic climate change, in which forecast changes in temperature or precipitation regimes may lead to unexpected and unpredictable ecosystem changes. Another example is from disturbance magnitude. Colorado's forests experienced a mountain pine beetle (*Dendroctonus pondersae*) epidemic from 1996 to 2013 that first established in higher elevation forests but also affected lower montane forests. Although the epidemic is now considered to be concluded (CSFS 2015), how to effectively manage for resiliency given the interaction of climate, beetles, and mortality has posed another set of uncertainties for the FRRT (Romme et al. 2007).

Variability and uncertainty in ecosystem dynamics mean that management actions must be flexible and adaptable to new data and theories as they become available. The basis for an adaptive management approach is that we do not always know what will happen when we apply a treatment to an area, therefore we must monitor ecosystem response and assess whether desired conditions were met, or if unforeseen circumstances altered the expected response. Each management action can be seen as an experiment, with outcomes that are assessed and used to guide future treatments. Data from the monitoring program will be used to objectively assess both structural and functional characteristics, and provide more refined directions for future management actions. Furthermore, new methods for monitoring and additional data describing Front Range montane forest ecological patterns and processes will likely be developed through the life of the CFLRP project, and therefore the monitoring process must be able to adapt to these new inputs.

The FRRT adaptive management (AM) model (Figure 1) acts as a framework for monitoring and aims to reduce project uncertainties through time. The AM model includes the three types of post-treatment monitoring described above (implementation, effectiveness, and adaptive) as well as during-project monitoring. During-project monitoring is a sub-loop of implementation monitoring, intended to evaluate if a treatment was implemented the way it was intended, and is typically conducted by the USFS. All monitoring loops are designed to feed back into the specific steps in the AM process, which are described below (see Aplet et al. 2014 for a more detailed explanation of each step):

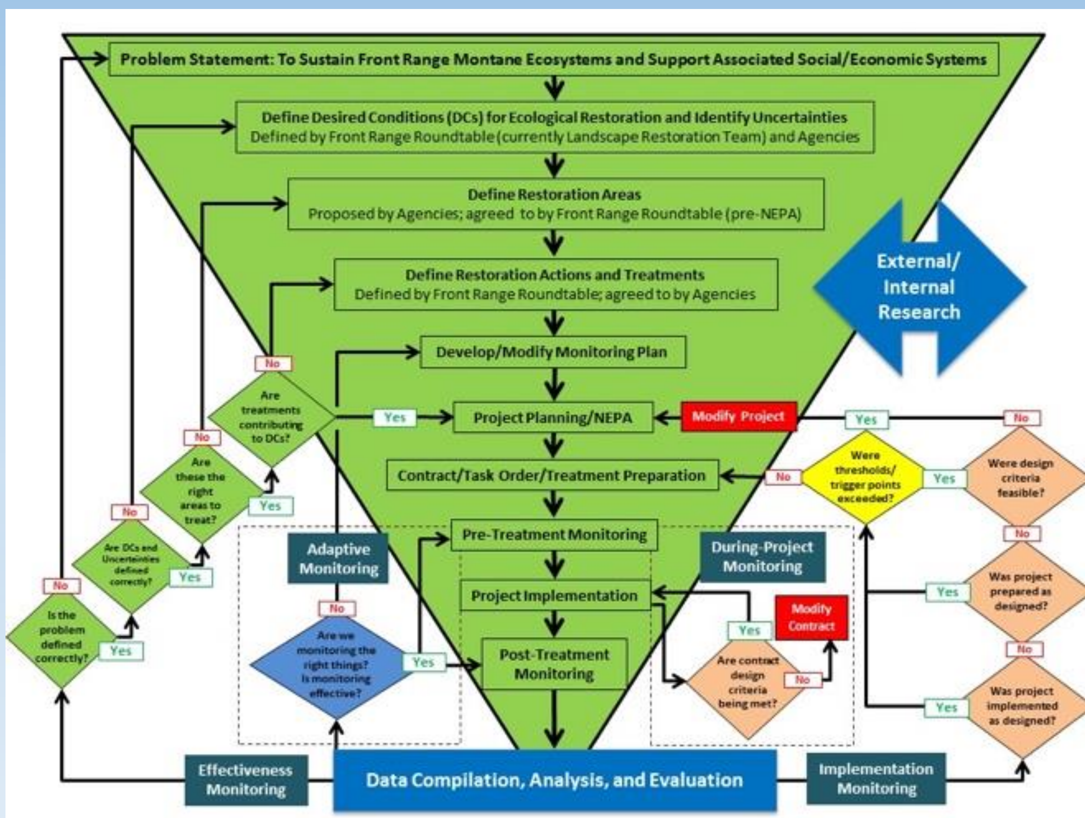


Figure 1. Adaptive management model for the Front Range CFLRP. For a more detailed description of the steps outlined by the model, refer to Aplet et al. (2014).

2.2.1. Goal Setting and Desired Conditions

It is important that all members of the collaborative are in agreement on defining the goals of the project. The broad goal of the FRRT, as described in Aplet et al. (2014), "is to bring the dry montane forests of the Front Range into a condition that can sustain desired ecosystem values in the presence of inevitable wildfire." More explicitly, stakeholders of the collaborative should also describe the desired conditions of the forests (outlined on page 2), or the kind of forest they would like to see in the future, including undesirable conditions they would like to avoid. Desired conditions reflect our understanding of how ecosystems function, and how their composition and structure will respond over time given dynamic landscape conditions. Inevitably, our understanding of the system will change as monitoring results and new research become available. The AM model acknowledges that our understanding of ecosystem dynamics is always changing and has built-in feedbacks that allow us to change goals and desired conditions if necessary as our understanding of the system evolves.

2.2.2. Define Restoration Areas

An essential step to the AM model is prioritizing areas to be treated. Given the limited resources available to address such an extensive landscape, it is imperative to focus on areas that will have a maximum return on investment. The FRRT has identified approximately 400,000 acres that could be treated that would enhance community safety and health of lower montane forests. Under the AM model, the approach used to prioritize treatments should constantly be reevaluated and refined with monitoring data and collaborative discussion to more efficiently hone in on target areas that will maximize investment.

2.2.3. Define Restoration Actions and Treatments

Given a prioritization of areas to treat, a plan outlining the approach used to achieve restoration must be developed. This plan should describe silvicultural and operational tools and constraints considered to meet objectives, budgets (including monitoring), stakeholder responsibilities, and provide a rough framework for restoration that informs the public about the project and helps guide monitoring activities. This step provides the quintessential question for effectiveness monitoring: Does forest restoration as described by the plan achieve agreed upon desired conditions without causing undesired effects? This step in the AM model allows us to refine treatment activities through time to apply the best available treatments to meet project goals.

2.2.4. Develop/Modify Monitoring Plan

The monitoring plan should be developed to determine if treatments are achieving desired conditions without causing undesired effects, and address who will be implementing monitoring. The monitoring plan should involve both pre-treatment and post-treatment monitoring such that pre- and post-treatment conditions can be directly compared to assess treatment effectiveness. It is important to note that monitoring in itself is adaptive, in which stakeholders in the collaborative periodically assess whether or not the monitoring plan continues to be effective. This provides the opportunity to amend the monitoring plan to better assess treatment effectiveness. If changes are made to the monitoring plan, caution should be used in data comparison, as only datasets collected with the same methods are suitable for statistical analysis.

Chapter 3. The Ecological Monitoring Program

This chapter includes specific guidelines that will be used for ecological monitoring during implementation of the Colorado Front Range CFLRP project. Because we utilize an adaptive monitoring process, we expect this to be a living document that is subject to constant revision by the FRRT. For instance, the original monitoring plan (Clement and Brown 2011) primarily outlined a series of specific measurements that are collected in individual plots, largely based on existing USFS Common Stand Exam (CSE) protocols that are part of standard inventory procedures. These methods mainly fall under the implementation monitoring umbrella (such as shifts in basal area and species composition) at the stand scale, but largely ignored effectiveness monitoring at larger scales. Throughout the collaborative process, the LRT identified several gaps in trying to translate individual CSE plot data to the landscape scale. For example, one of our desired conditions is to "establish a complex mosaic of forest density, size, and age." The LRT felt strongly that this desired condition should include some sort of spatial metric to define and assess that mosaic condition beyond simple averages and distributions of the identified monitoring variables as measured in field based plots. To address this problem, The LRT created the Spatial Heterogeneity Subgroup of the Front Range (SHSFR), and considerable progress has been made on arguably one of the more difficult conditions to monitor (see Dickinson and SHSFR (2014)). Similarly, a Wildlife Working Team and Understory Plant Monitoring Team were created within the LRT in order to develop monitoring programs related to specific topics that needed more specialized expertise and were deemed a high priority to monitor. The monitoring products created by these subgroups largely fall within the effectiveness monitoring umbrella, addressing broader concerns involving the consequences of restoration activities on various components of ecosystem functioning.

Our ecological monitoring framework is presented in Sections 3.1, and 3.2. Section 3.1 describes specific methods used to evaluate the Desired Conditions laid out by the FRRT. Section 3.2 provides monitoring guidelines for Front Range CFLR projects.

3.1. Methods used in Ecological Monitoring Model

The original monitoring plan from 2011 presented a basic plot design, based on CSE methods, to compare pre- and post-treatment conditions and assess desired conditions. The evolution of the Ecological Monitoring Model since 2011 has led to some modifications of traditional CSE plots, and several new approaches such as an understory specific protocol, the use of satellite imagery in assessing forest structural heterogeneity, and other specific approaches to assess desired conditions on the Front Range. Although several modifications to the original protocols have occurred, variables measured should all be scalable to a per acre basis, allowing pre- and post-treatment data to be compared. Many of the desired conditions can be assessed using more than one method, and appropriate methods to use are outlined in Table 4.

3.1.1. Modified Common Stand Exam

Common Stand Exam plots are standard inventory procedures conducted by the USFS prior to silvicultural management of a stand, thus they provide an excellent opportunity to obtain pre-treatment information by leveraging existing data. Repeated measures at CSE plots provide valuable insight to pre- and post-treatment compositional and structural stand characteristics. When using Modified CSE plots for all new monitoring activities, we recommend stratifying treatments by cover type, treatment type, and aspect, with at least 3 plots in each stratified area with accompanying control plots. Additionally, we recommend including 1 *overstory subplot*, 2 *Brown's transects*, 3 *regeneration subplots*, and 5 *understory subplots* (see Figure 2 and further explanation below). It is important to note that not all CSE plots follow these recommendations, and appropriate considerations must be made to ensure data are comparable pre- and post-treatment (e.g., same basal area factor (BAF) used for variable radius plots pre- and post-treatment). Throughout the lifetime of the Front Range CFLRP, several modifications have been made to monitoring guidelines to improve efficiency, statistical rigor, and to better capture and describe the Desired Conditions of the FRRT. Please refer to Table 2 for a summary of changes that have occurred to the monitoring framework between its original design in 2011 until now. Depending on monitoring objectives and past monitoring strategies, some subplots may be ommitted or modified to meet monitoring needs.

Plot Type	Original Monitoring Recommendations	Updated Monitoring Recommendations
Overstory	Variable radius plots *commonly* measured with *20 BAF* prism	Variable radius plots measured with a *10 BAF* prism
Overstory	Include trees greater than *2.5 inches* DBH in variable radius plots	Include trees greater than *5 inches* DBH in variable radius plots
Seedlings/Saplings	Plot size: *1/200th* acre	Plot size: *1/250th* acre
Seedlings/Saplings	*1* Seedling/Sapling Plot	*3* Seedling/Sapling Plots
Seedlings/Saplings	Count seedlings/saplings less than *2.5 inches* DBH	Count seedlings/saplings less than *5 inches* DBH
Understory	Measured on three *50-foot point intersect transects*	Measured in *five 1 square meter quadrats* – or see *3.1.2.* if more detail is desired given monitoring objectives
Sampling Intensity	Not defined	At least 3 plots per stand, stratified by cover type, treatment, and aspect
Surface fuels	2 Brown's transects, alternating E/W, N/S in plots	2 Brown's transects with no *pre-determined orientation, but separated by 90 degrees*

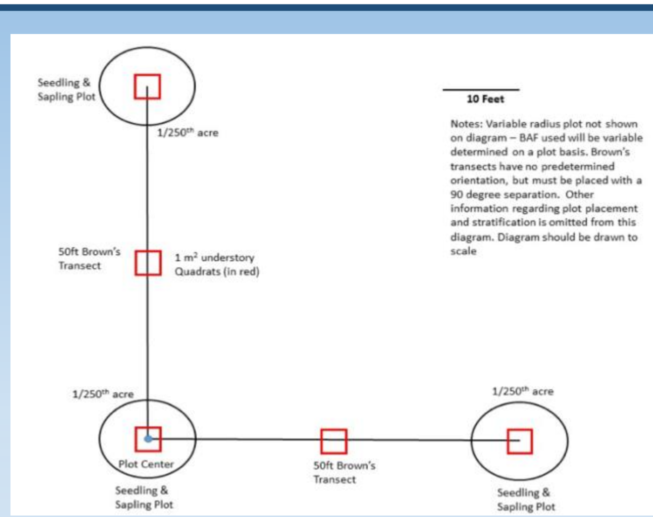


Table 2. (Left) Summary of recommended changes that have occurred to CSE plots throughout the lifetime of the Front Range CFLRP.

Figure 2. (Right) Diagram of Modified Common Stand Exam Plots.

The *overstory subplot* is a variable radius subplot (10 BAF) around plot center used to tally trees >5 inches diameter at breast height (DBH). If the plot was previously measured using a different BAF, be sure to match BAF that was previously used. Data for each tally tree includes: species, DBH, height, crown base height, live crown ratio, canopy position, and signs of animal damage. Table 3 outlines proper definitions and methods to use when collecting these data. Additionally, an ocular estimate of age (old/young/transitional; refer to Huckaby et al. 2003a and Huckaby et al. 2003b) should be recorded if an increment core sample cannot be obtained.

Brown's transects (Brown 1974) are 50 feet long, and separated by 90 degrees. These are standard Brown's transects, measuring 1 hr (<0.25 inches in diameter), 10 hr (0.25-1 inch in diameter), 100 hr (1 – 3 inches in diameter), and 1000 (>3 inches in diameter) hr fuels and litter/duff depths at regular intervals. Typically, 1 and 10 hour fuels are measured along 6 feet of the transect, 100 hour fuels are measured along 10 feet of the transect, and 1000 hour fuels are measured along the entire transect. Duff measurements are typically measured at 2 points (6 and 10 feet along the transect), and litter measurements at 3 points (15, 30, and 45 feet along the transect). Refer to USDAFS (2015), particularly Chapter 4, "Downed Woody Material Method 2" for additional information regarding the implementation of Brown's transects on CSE plots.

Regeneration subplots are fixed area, 1/250th acre (7.45 foot radius) subplots used to identify and tally seedlings and saplings <5 inches DBH by species. Seedlings are defined as <4.5 feet tall, and saplings are defined as 0-5 inches DBH. One regeneration plot is centered on the variable radius plots, and the other 2 are centered 50 feet from plot center at the end of each Brown's transect.

Table 3. Methods used when measuring forest characteristics, as outlined by the USFS Field Sampled Vegetation (FSVeg) User guide (USDAFS 2015, available from: http://www.fs.fed.us/nrm/fsveg/index.shtml). Refer to Chapter 4 – Collecting and Recording Data of the user guide for additional information, specifically pages 4-66 through 4-95 for addressing common scenarios that may be encountered in the field. This information should be used to compliment, not replace, recommendations outlined in this document.

Metric	Definition/Method
Species	Species code obtained from USDA Plants Database.
DBH	Diameter at 4.5 feet above ground level on uphill side of tree.
Height	Tree height from ground level on the uphill side of the tip of the tree leader.
Crown Base Height (Height to Crown)	Crown height on uphill side of tree, from ground level to base of live crown (lowest branch whorl with live branches that are continuous with live crown)
Live Crown Ratio	Crown ratio, in percent, as the length of the live crown divided by tree height. Length of the live crown is defined as the length from the uppermost live leader or branch to the lowest live branch.
Canopy Position (Crown Class)	1. Open Grown [OG] – Full light from above and all sides. 2. Dominant [DO] – Full light from above and partial light from sides. 3. Codominant [CO] – Full light from above, comparatively little from the sides. 4. Intermediate [IN] – Crown occupies subordinate position. Little direct light from above, none from sides 5. Overtopped [OT] – No direct light, entirely below general crown level of stand 6. Remnant [RE] – Trees remaining from previous management

Understory subplots are used to calculate the average percent cover by functional group (grass, forb, shrub, litter, rock, and bare ground). Each subplot is $1m^2$, and percent cover by functional group is recorded into the following cover classes: 0-1%, >1-5%, >5-25%, >25-50%, >50-75%, >75-95%, and >95%. One subplot is centered on the variable radius plot, 2 are centered at the end of each Brown's transect, and 2 are centered in the middle of each Brown's transect. If more detail is desired on understory abundance and composition, consider using plots described in 3.1.2.

3.1.2. Understory Plots

After several years of attempting to measure the understory plant response to restoration treatments, the LRT concluded that the metrics being collected were not sufficient to evaluate the effects of management on the understory plant community, and development of a more robust approach was warranted. Between 2010 and 2014, data collection methods changed nearly annually and were not consistent between the ARP and PSI, making comparisons across CFLR projects difficult. The plan composed by Clement and Brown (2011) focused primarily on quantifying overstory trees, tree regeneration, and fuels, while understory plant monitoring was primarily conducted by personnel with limited botany knowledge. This greatly inhibited the ability to develop a robust data collection protocol to describe the understory plant community. A pilot study in 2011-2013 by several members of the LRT (Briggs et al. 2017) used and evaluated several more time-intensive, detailed protocols to measure species richness and percent cover at a subset of CFLR treatment sites and paired untreated areas. At the request of the LRT, the Understory Plant Monitoring Team was formed in January 2014 to develop focused metrics of success related to understory plants and a more in depth protocol for measuring understory plant responses to forest restoration management activities. The team developed a set of desired criteria, and a protocol to more intensively monitor understory conditions and answer the following questions:

1. Have treatments increased or maintained total native plant cover and diversity?
2. Have treatments increased or maintained the cover and diversity of native graminoids, forbs, and shrubs?
3. Have treatments increased the cover and diversity of native early successional species?
4. How have treatments increased or maintained the cover of key native plants (to be defined by ARPF/PSI personnel)?
5. Have treatments increased the spatial heterogeneity of understory plant communities at the landscape scale over the long term?
6. Have treatments minimized increases in total exotic plant cover or diversity?
7. Have treatments minimized increases in the cover of exotic species of concern (e.g., noxious weeds)?

The LRT has an agreement with RMRS and CFRI to monitor understory plots. Understory plots collect much of the same data as CSE plots, but also collect more detailed information on understory plant communities. Given the focus of collecting high-quality understory plant data under this approach, we recommend a trained botanist be responsible for implementing these protocols, rather than combining this data collection with CSE plots. Under this monitoring approach, plots will consist of 1 *overstory subplot*, 1 *regeneration subplot*, 8 *understory species cover transects*, *1 live tree cover transect*, and 1 *understory species presence* subplot (see Figure 3 and Table 4). Refer to Wolk et al. (2015) for full protocol.

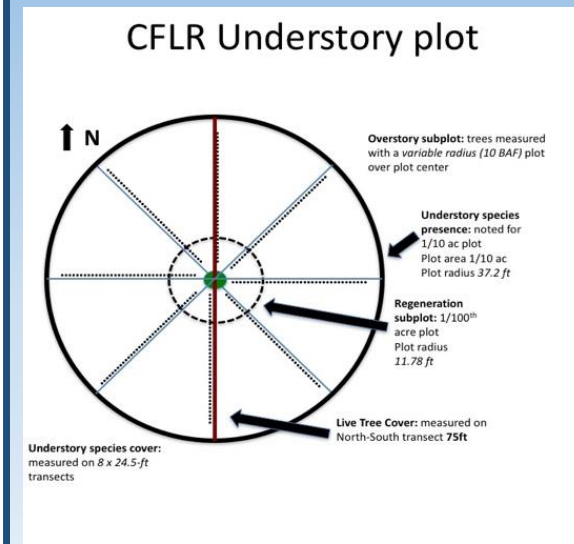


Figure 3. Plot layout for Understory Plots.

Table 4. Summary of subplots and measurements taken for understory plots.

Subplot Type	Subplot Size	Measurements	Notes

Overstory (Trees > DBH)	• Variable radius
	• 10 BAF
		• Species
		• DBH
		• Condition (live/dead)
		• Decay class for snags
		  o 1A = Needles present
		  o 1B = No needles
		  o 2 = Coarse branches and bark present
		  o 3 = Rotten, very few remaining branches	

Regeneration (Trees < DBH)	• 1/100th acre (11.78 ft. radius)
	• Centered at plot origin
		• Species
		• Height Class
		  o 1 = 0-4 inches
		  o 2 = 4.1-18 inches
		  o 3 = 18.1-30 inches
		  o 4 = 30.1-54 inches
			• Plots were originally 1/150th acre
			• If regeneration data was previously collected, be sure to use proper plot size to ensure comparable data

Understory Species Cover	• 8, 25 ft. long transects
	• Cardinal and ordinal directions from plot origin
	• Measured every foot from 6 to 30 feet along transect tape
		• Species (if present)
		• Substrate presence
		  o Litter/duff
		  o Soil/gravel
		  o Rock > 0.5 inches
		  o Fine fuels (0.1 – 2.9 inches)
		  o Coarse fuels (3+ inches)
		  o Moss/lichen
		  o Woody basal
		  o Herbaceous basal
		• Litter and duff depth at 10, 20, and 30 feet	

Live Tree Cover	• 75 ft. long transect
	• North-South through plot origin
	• Measured every foot
		• Canopy Cover (yes/no)
		• Tree group size for section of transect classified as "cover"
		  o Class 1 = 1 tree
		  o Class 2 = 2-4 trees
		  o Class 3 = 5-9 trees
		  o Class 4 = 10-15 trees
		  o Class 5 = 16+ trees
			• Tree group size first implemented 2016
			• Tree group defined as trees with interlocking crowns < 5 feet apart

Understory Species Presence	• 1/10th acre (37.2 ft. radius)
	• Centered at plot origin
		• Species present not accounted for on understory transects
		• Exotic species cover
		  o Rare = 0-1%
		  o Common = 2-10%
		  o Abundant = 11-50%
		  o Very Abundant = >51%	

3.1.3. Spatial Heterogeneity

Desired Condition Number 6 (Chapter 2), which is to "establish a complex mosaic of forest density, size and age (at stand and landscape scales)," is one in which the FRRT has struggled to define in terms of quantitative metrics. Because of this difficulty, the FRRT established the Spatial Heterogeneity Subgroup of the Front Range (SHSFR) to further refine these desired conditions and develop methods for monitoring forest structure at the stand and landscape scales. Since the formation of this subgroup, considerable progress has been made on refining this desired condition (see Dickinson and SHSFR 2014), and developing a more intensive approach to assess within stand and landscape scale forest structures. Previous approaches involved using a combination of remotely-sensed imagery and spatial statistics (Pelz and Dickinson 2014), which provided an alternative to labor-intensive stem mapping techniques to quantify forest canopy cover and spatial aggregation of canopy patches. Briefly, these approaches used remotely sensed National Agriculture Imagery Program (NAIP) imagery to classify restoration treatments into forested canopy or openings. Classified maps were then analyzed using spatial statistics software (e.g., FRAGSTATS, McGarigal et al. 2012; see Appendix B for desired conditions and spatial metrics used for this approach). Similar to monitoring and analysis of data and stand structure, the methodology for monitoring spatial structure has evolved and will likely continue to be refined.

The initial approaches described above for monitoring changes in spatial heterogeneity have since been refined to address problems associated with the use of NAIP imagery, and to develop simpler metrics to evaluate whether treatments are altering stands toward desired conditions. First, imagery for monitoring spatial heterogeneity is now obtained from satellite imagery (e.g., WorldView-2). Although the spatial resolution of imagery is typically lower for satellite sources (approx. 2.5 m) relative to NAIP imagery (approx. 1 m), the greater spectral resolution (8-spectral bands) and greater temporal availability (approximately every 3 months) may allow more accurate and rapid assessment of treatments. In addition, recent developments include the use of NDVI (Normalized Difference Vegetation Index) to classify shadowed portions of images as canopy or openings allowing more comprehensive assessment of treatments. Additional use of other technologies, such as Lidar, also may be possible in certain places and for some treatments, and allow for more detailed spatial analyses and metrics to be developed.

In addition to changes in methods, the LRT has made refinements to the analysis of classified imagery to more clearly evaluate how changes in spatial heterogeneity in treated stands relates to the Desired Conditions of the CFLRP related to spatial structure (Dickinson and SHSFR 2014). For example, in previous analyses of fine-scale spatial heterogeneity, metrics such as edge density, patch size distribution, and largest patch index were reported (See Appendix B). However, articulating expected and desired conditions based on these metrics proved difficult. Thus, the adoption of simpler spatial metrics more closely related to the expressed desired conditions was recommended by the LRT (Cannon and Barrett 2016).

Current analyses of fine-scale spatial heterogeneity focus on estimating the proportion of "large openings" (greater than a certain distance from canopy patches) versus "interstitial openings" which are closer to canopy patches. In addition, a focus on the proportion of canopy area in small, medium, and large patches in current analyses helps address the extent to which canopy is distributed among various group sizes. These analyses are more closely linked to the Individuals, Clumps, and Openings (ICO) framework outlined by Churchill et al. (2013), which advocates the use of simple spatial metrics that more comprehensively describe spatial structure and can be readily incorporated into tree marking protocols. A more comprehensive report detailing methods and results is currently in preparation, but see Cannon and Barrett (2016) for examples and details.

3.1.4. Wildlife

Developing a wildlife monitoring plan for the Front Range CFLRP has been a complex process involving several phases of work. Clement and Brown (2011) contained suggestions regarding the most informative species and taxa to monitor, and recommended an initial focus on recording wildlife sign on CSE plots before and after treatment. However, neither funding nor consensus on the desired conditions for wildlife were readily available for a full wildlife monitoring effort during the early years of CLFR work. With a supplemental grant from the Southern Rockies Landscape Conservation Cooperative, a small group from the LRT initiated wildlife sign surveys on CSE plots in a subset of treated and untreated areas in 2011-13 to evaluate general patterns of wildlife use (Briggs et al. 2017); this pilot study found no significant differences in fresh sign from ungulates or tree squirrels on treated vs. untreated plots one year post-treatment, but concluded that these methods did not provide enough detail on patterns of habitat use or population status and trends to merit adoption for a diverse suite of species or longer time frames.

In 2013, a group of specialists from several agencies was convened by the LRT to evaluate wildlife monitoring options in greater depth and provide recommendations for a full monitoring program. This "Wildlife Working Team" (WWT) met monthly for over a year, and quarterly thereafter, adopting a process, methods, and recommendations that are fully described in WWT report to the LRT (Truex et al. (in preparation)).

The first step in the WWT planning process was to develop a comprehensive list of vertebrate species and invertebrate family/genera/species that occur in Front Range montane forests. This was compiled from existing information sources such as the Colorado Natural Heritage Program database, agency "watch lists" (e.g. federally listed species, Management Indicator Species (MIS) of the USFS, and USFS Sensitive Species), field guides, and more general species distribution information. More than 300 species were included on this initial list. In the second step, the list was filtered to select species that had the majority of their distribution in the CFLRP landscape footprint, defined as encompassing elevations between 6000 – 10000 feet, from the Colorado/Wyoming border to the city of Colorado Springs, including all habitat associations. This filter narrowed the list to 145 species/groups by removing all those that had only marginal or seasonal overlap with the focal landscape, or were known to have been extirpated there.

In the third step, the 145 species were categorized and scored according to 3 criteria developed by the WWT (described in more detail in Truex et al. (in preparation)). The criteria included (i) the degree to which each species was "ecologically informative" of the condition of ponderosa pine-dominated forest and had key ecological functions in this ecosystem (Marcot and Vander Heyden 2001); (ii) the "political prudence" of monitoring the species (e.g. status as federally listed under the ESA or a USFS Sensitive Species) and (iii) the "socio-economic" importance of the species (e.g. game species or popular watchable wildlife). The scores for each species for the 3 criteria were developed based on published literature, agency reports, expert opinion, and extensive discussion among WWT members, resulting in 64 species/groups with high consensus scores. In the fourth and final step, the WWT evaluated the feasibility and desirability of monitoring each of these species/groups, considering factors such as scale and population parameters for measurement; the existence of tested and effective protocols; costs and logistics; and representation of diverse trophic levels. Based on this evaluation, the WWT recommended 12 species/groups to the LRT for full monitoring efforts at either a primary or secondary level. Primary species ("Tier 1") were four passerine songbirds (mountain bluebird, golden-crowned kinglet, olive-sided flycatcher, and pygmy nuthatch), two woodpeckers (Williamson's sapsucker and hairy woodpecker), the northern goshawk, and two tree squirrels (Abert's squirrel and pine squirrel). Secondary species/groups ("Tier 2") were the flammulated owl, seven bats (big brown bat, hoary bat, little brown bat, long-legged myotis, silver-haired bat, western long-eared myotis and western small-footed myotis), and carabid beetles.

After consideration of these recommendations in early 2014, the LRT approved the initiation of an agreement between USFS and the Bird Conservancy of the Rockies (BCR) to monitor most of the Tier 1 species (songbirds, woodpeckers, and tree squirrels as feasible) every other year beginning in summer 2014. BCR follows a well-established protocol for Integrated Monitoring in Bird Conservation Regions (IMBCR; White et al. 2015) that uses point counts to generate estimates of species' occupancy (percent of sites occupied) and density (number of individuals). For the Front Range CFLR landscape, the IMBCR approach was tailored to represent a spatially balanced design with 60, 1 km^2 grids sampled each season in each of the two Front Range NFs, divided equally among forested areas between 6000 and 9500 feet that were a) slated for CFLR treatment and b) not slated for treatment, respectively. Each grid contains 16 locations for point count surveys, generating a total of 1920 points sampled in each monitoring season (see White et al. 2015 and Truex et al. (in preparation) for more details).

In addition to this primary monitoring program, several additional species-specific monitoring steps or decisions were taken. Because the IMBCR protocols involve aural detections of species such as songbirds, woodpeckers, and the pine squirrel, which may not be as effective for less vocal species like the Abert's squirrel, the WWT evaluated additional methods to monitor Abert's squirrel. A pilot study was conducted by Colorado Parks and Wildlife (CPW) and USFS in 2014 and 2015 using camera traps and Abert's squirrel feeding sign surveys at a subset of the IMBCR grids. The camera traps detected a total of 23 wildlife species at 10 grids in treatment areas and 10 in untreated areas on each of the 2 NFs. To monitor the Northern Goshawk, a USFS-designated Sensitive Species, the WWT recommended that existing USFS protocols be followed in 2017 and every 5 years thereafter. Despite this recommendation, the WWT has decided to forego Northern Goshawk due to competing monitoring interests. For the "Tier 2" wildlife, the WWT recommended that monitoring be undertaken by partner agencies or institutions, rather than funded and conducted under the CFLRP work plan, given the specialized methods or expertise needed to effectively monitor the status of these species/groups. In summary, as of spring 2017, two full seasons of monitoring Tier 1 wildlife have been completed by BCR via a USFS contract at 120 sites across the CFLR landscape (2014 and 2016) and two pilot seasons of camera trapping have been completed by CPW and USFS personnel at a subset of 40 sites (2014 and 2015).

3.1.5. Watershed Health

A major impetus for forest management across the Colorado Front Range, including the CFLRP, is to protect water quality. The LRT has identified reduced potential for damaging post-fire erosion and sedimentation to municipal water supplies as a desired condition for the CFLRP. Although we have established a desired condition, creating and implementing a monitoring protocol has been slower to develop. The complexities of monitoring effects at the stand or landscape scale of CFLR treatments, which impact a very small percentage of the landscape, has proven challenging. The expertise and time commitment needed to run complicated fire behavior and hydrological models has been a major obstacle in developing useful watershed health metrics. The importance of monitoring impacts of forest management on water quality remains a priority, and in 2016 the LRT convened a sub-team to develop monitoring metrics to assess watershed health. Results from this sub-team will be included in a future version of the monitoring plan.

3.1.6. Fire Behavior and Severity

Another key desired condition of the Front Range CFLRP is to restore a more characteristic, mixed severity fire regime. The LRT has identified broadcast burning as a key component to restore this process to the Front Range lower montane forests and accomplish restoration objectives. Implementing prescribed burning as part of the CFLRP has been challenging for a myriad of social, political, economic, and logistical reasons, thus severely limiting the use of fire as a management tool across the ARP and PSI in the initial years of the program. As the impetus and ability for the USFS to implement broadcast burning has been increasing, the LRT initiated the formation of a sub-team to develop desired conditions and protocols for monitoring fire effects. As of 2018, protocols have been developed to monitor first order fire effects on vegetation and fuels, but no monitoring on fire behavior has been adopted.

Comprehensive monitoring of fire effects can be accomplished using the Understory Plot Layout (section 3.1.2), however, a more rapid assessment can be accomplished by supplementing the Modified CSE Plot (section 3.1.1) by taking additional measurements along one of the Brown's Transects. Although Understory Plots yield the most comprehensive set of data, implementing them requires more skilled technicians and added sampling time due to the detailed understory data collected. Monitoring methods should be chosen based on crew training, funding, and monitoring objectives. In addition, monitoring should be implemented using the same methods that were implemented pre-treatment. For example, if Modified CSE Plots with Brown's Transects were implemented prior to the burn, post-treatment monitoring should also be done with CSE plots and Brown's Transects. This section will outline the metrics associated with Understory Plots, and describe additional measurements that may be used to augment Modified CSE Plots (Table 5).

Fuel treatment effectiveness plots should be installed prior to burning, and sampled following Modified CSE (Section 3.1.1) or Understory Plot (Section 3.1.2) protocols. Although we recommend implementing Understory Plots for the most comprehensive dataset, modified CSE plots may be used prior to treatment. Unlike other monitoring protocols, all measured trees should be tagged prior to the burn with a steel tag to allow tree-level monitoring after the burn. In addition, litter/duff pins should be installed prior to the burn to accurately measure litter and duff consumption. This is done by hammering a large nail into the ground, such that the top is flush with the litter layer. After units are burned, plots require immediate postburn observations to determine effects on substrate and vegetation burn severity, tree mortality, and fuels reduction. Monitoring should be conducted within 2-3 weeks, or up to 2 months after fire has interacted with sampling plots. Table 5 outlines specific protocols for implementing monitoring of postburn effects on vegetation and fuels for both Understory Plot and Modified CSE Plot types. For more detailed descriptions of monitoring plots, please refer to the full fire effects monitoring protocols found on the CFRI website: https://cfri.colostate.edu/wp-content/uploads/sites/22/2018/10/ImmediatePostburnProtocol_Mothership_2018.pdf .

Table 5. Protocols used for monitoring first order fire effects on vegetation and fuels using Understory Plots and Modified CSE Plot Types.

	Understory Plot	**Modified CSE Plot, with additional measurements taken along a randomly chosen Brown's Transect**
Photo point	**4 photos.** - North towards the ground, eye-level, and canopy - South eye-level. Capture plot name, date, and treatment status in frame.	**4 photos.** - Facing the end of the transect (50 ft), towards ground, eye-level, and canopy. - Facing the beginning of transect (0ft), eye level. Capture plot name, date, and treatment status in frame.
Overstory and Sapling Condition	**Match plot size/BAF used pre-treatment.** - **Height to red needles** for all live trees. - **Max Scorch Height**. Highest point on crown where foliar death is evident. - **Percent Crown Volume Scorch.** - **Max Stem Char Height.** - **Evidence of Bark Beetles.**	**Match plot size/BAF used pre-treatment.** - **Height to red needles** for all live trees. - **Max Scorch Height**. Highest point on crown where foliar death is evident. - **Percent Crown Volume Scorch.** - **Max Stem Char Height.** - **Evidence of Bark Beetles.**
Forest Floor Substrate	**Point intercept along species cover transects.** - **Substrate presence** (litter/duff, soil/gravel, rock, 1000 hr fuel, moss/lichen, woody basal, herbaceous vegetation basal). - **Burn evidence**. Visible evidence of fire at each point along transect.	**Ocular estimate in 1m² sampling frames located on left side of 50 foot transect. 0-3 ft, 25-28 ft, 47-50 ft.** - **% Cover** litter/duff, soil/gravel, rock, 1000 hr fuel, moss/lichen, woody basal, herbaceous vegetation basal.
Fine Fuels (1hr (<0.24 in), 10hr (0.25 – 0.99 in), 100hr (1 – 2.99 in))[1]	**Point intercept along species cover transects.** - **Fuel presence** (record substrate underneath fuel. Note that 1000 hr fuels are considered substrate). - **Height (0.25 inch)** of fuel. **Fuel loading in 1 m² sampling frames located on left side of transect. 15 - 18 ft, 40 - 43 ft, 62 - 65 ft.** - **Photoload Estimate[2] (tons/ac)** for 1, 10 and 100 hr fuels.	**1m² sampling frames located on left side of 50 foot transect. 0 - 3 ft, 25 - 28 ft, 47 - 50 ft.** - **Height (0.25 inch)** of 1/10/100 hr fuels lumped together at each corner of sampling frame. - **Fuel loading** using the Photoload technique[2].
Fine Fuels (litter and duff)[1]	**Regularly spaced intervals at 10, 20, and 30 ft along the N, E, S, and W transects.** - **Depth (0.25 in)** of litter and duff.	**1m² sampling frames located on left side of 50 foot transect. 0 - 3 ft, 25 - 28 ft, 47 - 50 ft.** **Depth (0.25 in)** in each corner of sampling frame.
Soil and Vegetation Burn Severity	**Regularly spaced intervals at 10, 20, and 30 ft along the N, E, S, and W transects in 6 inch x 6 inch frame.** - **Substrate and Vegetation Severity** (See Table 6, FMH-21, USDI, 2013). - **Ash Depth (0.25 in).** - **Ash Color**. Black, grey, red, white.	**Regularly spaced intervals, 5-foot increments, from 0 - 45 feet along 50 foot transect (10 total measurements) in 6-inch x 6-inch frame.** - **Substrate and Vegetation Severity** (See Table 6, FMH-21, USDI, 2013). - **Ash Depth (0.25 in).** - **Ash Color**. Black, grey, red, white.
Litter/Duff Consumption	**Regularly spaced intervals at 10, 20, and 30 ft along the E and W transect** - **Consumption (inches)** measured as depth from top of pin to surface of the substrate and mineral soil.	- **Not Monitored**

1. Brown's transects may be used if used to characterize pre-treatment fuel conditions.
2. Protocols for the photoload technique can be found in USFS GTR-190 (Keane and Dickinson 2007). Pages 15-17 are exceptionally helpful.

Table 6. Substrate and Vegetation Burn Severity Codes, FMH-21, USDI 2003.

FMH-21

	Unburned (5)	Scorched (4)	Lightly Burned (3)	Moderately Burned (2)	Heavily Burned (1)	Not Applicable (0)
Substrate (S)	not burned	litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	litter charred to partially consumed; upper duff layer may be charred but the duff layer is not altered over the entire depth; surface appears black; woody debris is partially burned; logs are scorched or blackened but not charred; rotten wood is scorched to partially burned	litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	litter and duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs are deeply charred, and rotten logs are completely consumed. This code generally applies to less than 10% of natural or slash burned areas	inorganic preburn
Vegetation (V)	not burned	foliage scorched and attached to supporting twigs	foliage and smaller twigs partially to completely consumed; branches mostly intact	foliage, twigs, and small stems consumed; some branches still present	all plant parts consumed, leaving some or no major stems/trunks; any left are deeply charred	none present preburn

3.2. Monitoring Guidelines for Front Range CFLR Projects

Monitoring guidelines for the Front Range CFLRP are presented in Tables 7 and 8, which outline the FRRT desired conditions and their associated restoration parameters, expected trends, and appropriate methods for measurement. Table 7 describes *implementation monitoring* activities, which are analyzed on the treatment scale, and conducted before and after the treatment takes place. In some cases, additional measurements may be taken 5 to 10 years after treatment to follow trends in tree density, species, sizes, and ages to evaluate treatment longevity. Table 8 describes *effectiveness monitoring* activities, which are analyzed on the landscape scale (unless otherwise specified), and are usually conducted before treatment, 1-2 years after treatment, and 5-10 years after treatment. These analyses typically require more expertise than implementation monitoring, such as fire behavior modelling and satellite imagery analysis. Additionally, some of these analyses may only be able to be conducted opportunistically as satellite imagery becomes available. Note that guidelines do not include specific values for assessing the success of each variable relative to historical range of variability, as one might expect in the U.S. Southwest or Black Hills. The Front Range Forest Reconstruction Network began in 2012, with initial funding from the Front Range Roundtable, with the goals to describe historic stand scale spatial structure on Front Range montane forests and provide more information on the historic range of variability and reference conditions for conducting restoration activities. Results from that project will likely guide future iterations of this monitoring plan. We acknowledge that this is an uncertainty in the Front Range, and it is our intent that under the AM model described above, we will be able to refine our monitoring plan to reflect the most recent, and best available science as it becomes accessible.

Table 7. Implementation Monitoring Guidelines for Front Range CFLR Projects

Desired Condition	Restoration Parameters	Desired Trends	Variable to Measure	Methods
(1) Establish a more favorable species composition	• Tree species	• Increased ratio of ponderosa pine to other conifers where appropriate • Lower productivity sites favor ponderosa pine • Higher productivity sites promote greater species diversity than lower productivity sites • Enhance aspen where present	• Trees density by species • Basal area by species • When available: Canopy Cover by Species	• CSE/Modified CSE Plot • Understory Plot • When available: Remote sensing data; LIDAR data
(2) Establish a more characteristic fire regime	• Surface fuels	• Decreased litter and duff depths • Decreased or similar coarse woody debris	• Surface fuel conditions	• CSE/Modified CSE Plot • Understory Plot
(6) Establish complex mosaic of forest density, size, and age	• Tree density	• Decreased basal areas • Decreased trees per acre	• Basal area • Tree Density • When available: Canopy cover by species	• CSE/Modified CSE Plots • Understory Plot • When available: Remote sensing data; LIDAR data
(6) Establish complex mosaic of forest density, size, and age	• Tree sizes	• Increased Quadratic Mean Diameters	• Diameters at breast height for larger trees and root collar for seedlings and saplings	• CSE/Modified CSE Plots • Understory Plot
(6) Establish complex mosaic of forest density, size, and age	• Tree ages	• Increased ratios of old trees (>200 yrs) to transitional trees (150-200 yrs) to younger trees (<150 years). • Old, scarred, and character trees are protected • Predominately uneven-aged stands.	• Tree ages, typically assessed using visual clues; in some cases, increment cores will be available	• CSE/Modified CSE Plots
(6) Establish complex mosaic of forest density, size, and age	• Within-stand spatial heterogeneity	• Increased tree clumps and spatial heterogeneity in stands • Increased number of openings (>.25 acre) • Lower productivity sites have more openings and single-isolated trees, and smaller group size • Higher productivity sites have more large tree groups	• Proportion of *stand* represented in canopy, edge openings, large openings • Tree group size	• Spatial heterogeneity analysis (3.1.3)

Table 8. Effectiveness Monitoring Guidelines for Front Range CFLR Projects

Desired Condition	Restoration Parameters	Desired Trends	Variable to Measure	Methods	Notes
(2) Establish a more characteristic fire regime	• Fire behavior	• Mixed-severity that trends toward surface fire • Reduced crown fire potential at 90% weather as modeled in fire behavior models	• Tree heights • Canopy base heights (CBH) • Canopy bulk density (CBD) • Surface fuel conditions	• CSE/Modified CSE Plot • Surface fuel and fire behavior modeled with plot data, aggregated across landscape	Example data: decrease in crowning and torching indices in pre- and post-treatment model runs
(3) Increase coverage in native understory plant communities	• Grasses, forbs, and shrubs	• Increased cover of grasses, forbs, and shrubs • Increased diversity of grasses, forbs, and shrubs	• Presence and cover of grasses, forbs, and shrubs	• Understory Plot	Monitored at the treatment scale
(3) Increase coverage in native understory plant communities	• Noxious or invasive plant species	• Similar (or decreased) occurrence and cover of noxious or invasive plant species	• Presence and cover of invasive species	• Understory Plot	Monitored at the treatment scale
(4) Occurrence of wildlife species	• Habitat use by focal species	• Focal species occupying restored sites	• Occupancy • Density	• IMBCR Point Counts • USFS Goshawk Monitoring	Abert's squirrel sampling strategy pending
(5) Watershed Desired Condition(s)	**Under Development**				
(6) Establish complex mosaic of forest density, size, and age	• Tree density	• Relatively higher tree densities on north facing, and/or high elevation sites than lower productivity sites	• Tree Density • Basal Area	• CSE/Modified CSE plots stratified by aspect and/or productivity gradients	See Dickinson and SHSFR (2014)
(6) Establish complex mosaic of forest density, size, and age	• Patch size	• Larger patches (forested and open) on higher productivity sites • Larger patches (forested and open) on steep topography • General negative exponential distribution of patch size, dominated by numerous small patches and isolated large patches	• Proportion of *landscape* represented in edge openings and large openings	• Spatial heterogeneity analysis (Section 3.1.3)	See Dickinson and SHSFR (2014)
(6) Establish complex mosaic of forest density, size, and age	• Landscape-scale spatial heterogeneity and structural stage diversity	• Increase large openings, more open structure • Decrease in closed, dense structure • Wider diversity of opening sizes, including larger non-forested areas within currently forested areas	• Proportion of *landscape* represented in canopy, edge openings, and large openings	• Spatial heterogeneity analysis (Section 3.1.3)	See Dickinson and SHSFR (2014)

Chapter 4: Social and Economic Monitoring

A core intent of law authorizing the Collaborative Forest Landscape Restoration Program is that ecological, economic, and social sustainability be equally and simultaneously supported. The law and the program have provisions relating to: 1) the utilization of forest restoration byproducts for local rural economic benefit and to offset treatment costs; 2) the potential to reduce long-term fire suppression costs; 3) whether an appropriate level of non-Federal investment would be leveraged in carrying out the proposal; and 4) the strength of the collaborative process and the likelihood of successful collaboration throughout implementation. The FRRT concurs with the importance of these goals for the Front Range CFLRP and supported the development of a social and economic monitoring strategy.

Below are the approaches used to address each of these provisions.

4.1. Economic Impacts and Contributions

Three approaches are used to assess the economic impacts of the Front Range CFLRP project. Two of these approaches concern local economic benefit. The first uses the Treatments for Restoration Economic Analysis Tool (TREAT) supplied by the USFS's Ecosystem Management Coordination program. TREAT provides a standardized approach for estimating the number of jobs and the amount of labor income that would be supported by restoration efforts. Based on the recommendations of a USFS economist that contributed to the development of TREAT, the Front Range CFLRP supplemented TREAT with a second, customized model to assess economic impacts and contributions on an annual basis. For both approaches, specific questions related to economic impacts include:

1. How many direct jobs are supported per year and over the 10-year life of the CFLRP?
2. How many induced/indirect jobs are supported per year and over the 10-year life of the CFLRP?
3. What proportion of the direct and indirect jobs supported by task orders is located within project area counties vs. outside of the project area?
4. What are the total estimated economic impacts to counties within the project area?

Data are collected and compiled by the US Forest Service CFLRP Coordinator and CFRI from contracts and task orders for each calendar year. For the TREAT model, the CFLRP Coordinator transmits annual data to the Ecosystem Management Coordination program for further analysis and reporting. For more detailed instructions for how the TREAT model is used, see further: https://www.fs.fed.us/restoration/documents/cflrp/TREAT/TREATUserGuide20151005.pdf. For the Front Range CFLRP customized model, additional data are collected by CFRI from Front Range CFLR contractors and analyzed using the widely-used input-output (I-O) regional economic analysis model, IMPLAN®. IMPLAN economic impact analyses are calculated using counties where contractor expenditures have occurred, the most recent contractor expenditure information, CFLR task orders, and detailed expenditure and operational data from contractors. For a detailed description of the Front Range CFLRP economic impact, please see the 2013 Social and Economic Monitoring Report available from the CFRI website (cfri.colostate.edu). Example data types from contractors can be found in Appendix C. In addition to the Front Range CFLRP IMPLAN modelling results, a narrative of how the three types of federal and non-federal CFLRP-related funds are being used (CFLR funds, leveraged funds, and matching funds) is provided for each year of monitoring. These data are obtained from interviews with project representatives. Results from the economic impact analyses and funding sources are reported annually in writing and via presentations to the FRRT.

The third approach for assessing the economic impact of the CFLRP project pertains to estimating long-term reductions in wildfire suppression costs. Data collection, analysis, and reporting for this analysis are carried about by the US Forest Service's Front Range CFLRP Coordinator working in collaboration with a national US Forest Service technical team using the Risk and Cost Analysis Tool (R-CAT) package. For details on the R-CAT system, see further: https://www.fs.fed.us/restoration/documents/cflrp/R-CAT/RCAT_PeerLearning.pdf.

4.2. Wood Utilization

Complementing the local economic benefits analysis is an assessment of wood utilization from Front Range CFLRP projects. The motivation for this wood utilization assessment came from concerns about the lack of wood utilization infrastructure and markets for forest restoration byproducts as mandated by the law and CFLR program. The goals of the annual wood utilization analysis are to:

1. Identify the types and materials taken off the National Forest according to the Front Range CFLRP vegetation treatment task orders.
2. Determine the number and location of businesses purchasing these forest product materials.
3. Identify the types and values of wood products produced.

To conduct these analyses, the contractor is provided a basic list of questions, and the data are then compiled and analyzed by CFRI using basic descriptive statistical analysis. Results are reported annually in writing and via presentations to the FRRT. An example of questions to contractors can be found in Appendix C.

4.3. Levels of Collaboration

The Front Range CFLRP provides the opportunity for the FRRT to evolve as a collaborative body and process. While the FRRT has been nationally recognized for bringing together a diverse range of government, non-governmental, research, and community-based organizations around a common cause of reducing wildfire risk and sustaining resilient forests, the Front Range CFLRP marks a new challenge centering on collaborative implementation and adaptive management. To this challenge, the FRRT agreed to assess the strength and performance of collaboration throughout the project. CFRI was charged with developing and implementing an assessment approach based on its historical expertise in research and practice in collaborative governance in natural resource management.

Monitoring collaboration over the span of the project is intended to address the following questions:

1. Over the 10-year CFLR period, are a diverse range of interests and organizations committed to the collaborative process?
2. Is the Front Range Roundtable process viewed by participants as sufficiently transparent and fair, and fosters timely communication, group learning, and conflict management?
3. Is the Front Range Roundtable process viewed by external parties as legitimate?

The collaboration assessment occurs primarily through semi-structured interviews with active FRRT participants. This is defined as individuals who have attended three or more meetings or field trips in a year over the past three years involving the Front Range CFLRP.

Prior to the Front Range CFLRP, an assessment of collaborative progress and performance was conducted for two projects in 2009, the Woodland Park Healthy Forest Initiative and the Uncompahgre Mesas Forest Restoration Project (reports are accessible on the CFRI website http://cfri.colostate.edu). Replicating the methods from these case studies, but with an expanded sample population of the FRRT, a second assessment was conducted in 2011 at the outset of the Front Range CFLRP by CFRI Research Assistant Katherine Mattor. The final report can be accessed on the CFRI website.

A third collaboration assessment is in process, beginning in Fall 2016 and expected to be completed in early Spring 2017 by CFRI Research Assistant Hannah Bergemann.

Chapter 5. Operationalizing Adaptive Management

Because this monitoring plan is built off the FRRT Adaptive Management Model (Chapter 2, Aplet et al. 2014), a robust framework must be in place to evaluate not only project performance, but also the utility of our monitoring efforts. All of the efforts of the AM model culminate with the data compilation, analysis, and evaluation step (Figure 1), in which effectiveness and implementation monitoring informs us of our successes and failures, and encourages us to adapt our management and monitoring framework. The FRRT has built this step into an annual cycle, such that monitoring data are analyzed, presented in an annual "Jam Session," integrated and reported, reviewed in the field, and developed into final recommendations, which may lead to additional questions to address during the next round of data analysis (Figure 4).

At the conclusion of each field season, monitoring data are compiled and analyzed by the appropriate parties, and organized around the desired conditions outlined in this monitoring plan. For example, CSE, understory, and spatial heterogeneity data are analyzed by CFRI, while wildlife data are analyzed by the BCR and members of the Wildlife Working Team, as they are responsible for collecting the data. Upon completion of data analysis, the FRRT convenes for a monitoring Jam Session. This is typically a full day session in early spring, in which interested parties of the LRT discuss the results of various monitoring programs, their implications on project goals and desired conditions, and the utility of the data that are analyzed and presented (e.g. are we collecting the right data to evaluate desired conditions and make management recommendations?). Data outcomes, initial recommendations, and monitoring progress stemming from each presentation are integrated in a summary report compiled by CFRI, and circulated

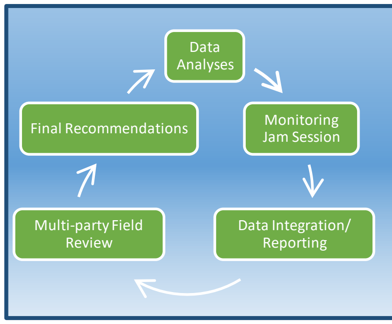


Figure 4. Annual cycle within the data compilation, analysis, and evaluation step of the AM model.

throughout the LRT in late spring/early summer for review. Additionally, discussion and results from the Jam Session are used to develop an informative field trip held in late summer, that allows multiple parties within the FRRT to review past treatments and/or disturbances, and evaluate Jam Session results to put our collaborative efforts and analyses into perspective. Finally, upon receiving feedback from the multi-party field review and Jam Session summary, a final report/proceedings document is authored by CFRI that synthesizes all the steps in the annual cycle and offers final recommendations for project implementation and monitoring strategies on behalf on the collaborative. This annual report is open for feedback until it is disseminated to forest managers and stakeholders in late fall/early winter. These reports are archived on CFRI's website (http://www.cfri.colostate.edu). Summaries are appended to the end of this document.

Appendix A. Monitoring and Study Effort for Front Range CFLRP Projects

Monitoring effort/study	Type of monitoring done	Plot type	# plots/year	Pre/post treatment?	Locations
Common Stand Exam (CSE)	Mixed (overstory, regeneration, fuels, coarse understory)	Variable radius (BAF 10 or 20), Brown's transects, fixed-area 1/250th acre regeneration subplots, understory quadrats	2013* – 419 pre, 473 post 2014* – 156 pre, 156 post 2015 – None 2016* – 104 pre, 205 post * Refers to year data was analyzed	Both	2012 - Phantom Creek, Ryan Quinlan, Estes Valley, Thompson River, Walker Red, Walker Black, Taylor Mountain 2013 - Catamount, Long John, Phantom Creek, Messenger Gulch 2015 – Phantom Creek, Ryan Quinlan
Understory	Understory plant cover and diversity	Variable radius (BAF 10), fixed area 1/100th acre regeneration subplot, Understory species cover point-count transects, tree cover transect, 1/10th acre species presence plot	2015 – 207 pre	Both (pre established 2015, post collected 2017, 2020, 2023)	Red Feather, Gold Hill, Ridge Road*, Trout West, Phantom Creek, West Creek, Raspberry
Spatial Heterogeneity Analysis	Forest spatial pattern	Satellite imagery classified as forest and openings. Raster data is available for entire treatment boundaries. Here, rasters were subset to 0.54 ac circular plots over CSE plot locations (see above)	2016 – 383 pre, 435 post	Both	Catamount, Estes Valley, Long John, Phantom Creek, Taylor Mountain, Walker Black, Walker Red.

Wildlife Tier 1 monitoring– (BCR under contract w USFS)	Birds/tree squirrels; IMBCR protocols	1-km sq grids w 16 points each; point counts	120 grids/yr 2014, 2016. Half in untreated areas, half in areas slated for past/future treatment	Both (need to check GIS and treatment records to confirm treated status)	Throughout FR CFLR "landscape footprint" on diverse lands plus USFS treatment units
Wildlife – camera trapping pilot effort (CPW and USFS)	Camera trapping – all wildlife; Abert's squirrel feeding sign/vegetation estimates	1-4 points within each of 40 of the BCR 1-km grids	20-80 points/yr in 2014, 2015. Half untreated, half "treatment" areas	Both (need to check GIS and treatment records to confirm treated status)	10 untreated and 10 treatment sites on each of 2 NFs
SRLCC study (Briggs, Fornwalt, Feinstein)	Mixed (overstory, fuels, regeneration, understory, wildlife sign, stand transects)	Variable radius (BAF 10) and fixed-area 1/10 acre	66 pre-treatment (2011) and post-treatment (2012/2013); half treated half untreated	Both	Phantom Creek & Estes Valley (USFS); Heil* (BCPOS); some others at Hall and Heil* post-trt only
"Historical stand transects" (Dickinson 2014)	Historical forest opening sizes	1 km transect made up of 100 10m x 10m quadrats	20 transects (5 transects at each of 4 sites)	N/A	Red Feather, Lady Moon, Manitou, Farish
Stand reconstruction study (Battaglia, Brown, Fornwalt et al.)	Historical (1860) forest structure, composition, and spatial patterns	0.5 ha square plots for spatial patterns, 4 circular subplots (total 0.2 ha) for structure and composition	170 plots in 2012 and 2013	N/A	Distributed in 28 small landscapes from south of Colorado Springs to Pole Mountain in SE Wyoming

* Indicates sites that were not CFLR funded but used monitoring methods developed with the CFLR Landscape Restoration Team

Appendix B. Supplemental Information and Tables for Initial Spatial Heterogeneity Analyses

Additional monitoring guidelines for Desired Condition Number 7 – "establish a complex mosaic of forest density, size and age (at stand and landscape scales)" are provided in Tables 7 (stand scale) and 8 (landscape scale). These tables discuss general trends of various spatial metrics calculated using FRAGSTATS; however, these tables do not discuss how variation of some of these trends should be represented on the landscape. For example, Table 9 mentions a general decrease in the percentage of the landscape (PLAND) occupied by dense and moderate canopy cover, and an increase in low and sparse canopy cover and openings. We would expect that treatments will decrease dense canopy cover, but non-uniformly, such that relatively higher tree densities will be maintained where appropriate, such as on north aspects, higher elevations, and in draws. See Dickinson and SHSFR (2014) for greater detail regarding desirable forest structures at stand and landscape scales, and how they should be represented on the landscape.

Table 9. Spatial metrics and expected trends recommended by Dickinson and SHSFR (2014) used to monitor within-stand spatial heterogeneity and forest structural diversity.

Metric	Definition, interpretation and units	Expected trends with successful restoration
Percentage of landscape [treatment unit] (**PLAND**) occupied by coniferous canopy cover.	Total area covered by canopy as a percent of total treatment unit area (%).	Decrease
Largest patch index (**LPI**) for coniferous canopy.	The percentage of total landscape area comprised by the largest patch (%). It is a measure of the dominance of the largest patch of each patch type.	Decrease
Edge density (**ED**) of coniferous canopy cover.	The length of patch edge per unit area (m/ha) for each patch type. Edge effects where adjacent patches influence each other are an important driver of ecological processes in complex landscapes. Edge density is therefore the likely influence of edge effects in the landscape.	Increase
Patch area (**PA**) of coniferous canopy cover. Mean, range, standard deviation reported. Frequency distribution graphs of patch area may also be plotted.	The size of a patch by type (ha).	Decrease in mean with increase in range and standard deviation
Perimeter area ratio (**PARA**) for canopy. Mean, range, and standard deviation reported. Frequency distribution graphs may also be plotted.	A ratio of the perimeter of a patch to its area is a measure of the shape of a patch (unitless). Edge effects where adjacent patches influence each other are an important driver of ecological processes in complex landscapes. Large perimeter-to-area ratios indicate convoluted or complex edges with greater proportions of the area influenced by neighboring patches.	As the stand becomes more fragmented and/or patches become more irregular with complex and convoluted edges the perimeter-to-area ratio will increase.
Patch density (**PD**) of coniferous canopy.	Simple measure of the density of patches per 100 hectares. Patch density is an indication of the prevalence of patch types (i.e. canopy or opening) and is strongly influenced by the size of patches.	Increase
Euclidean distance (**ED**) to nearest similar patch of coniferous canopy. Mean, range and standard deviation reported. Frequency distribution graphs may also be plotted.	The shortest straight-line distance between the focal patch (m) and its nearest neighbor of the same type is a simple measure of patch context used to quantify patch isolation.	Increase in mean, with increase in range and standard deviation.

Table 10. Spatial metrics and expected trends recommended by Dickinson and SHSFR (2014) used to monitor landscape-scale spatial heterogeneity and forest structural diversity.

Metric	Definition, interpretation and units	Expected trends with successful restoration
Percentage of landscape [HUC-12 watershed] (**PLAND**) occupied by dense, moderate and sparse coniferous canopy cover, and openings.	Total area covered by canopy as a percent of total treatment unit area (%).	Decrease in canopy cover; and increase in sparse canopy cover and openings.
Largest patch index (**LPI**) dense, moderate and sparse coniferous canopy cover, and openings.	The percentage of total landscape area comprised by the largest patch (%). It is a measure of the dominance of the largest patch of each patch type.	Decrease in dense canopy cover; and increase in sparse canopy cover and openings.
Edge density (**ED**) for entire landscape.	The length of patch edge per unit area (m/ha). Edge effects where adjacent patches influence each other are an important driver of ecological processes in complex landscapes. Edge density is therefore the likely influence of edge effects in the landscape.	Increase
Patch area (**PA**) of dense, moderate and sparse coniferous canopy cover, and openings. Mean, range, standard deviation reported. Frequency distribution graphs of patch area may also be plotted.	The size of a patch by type (ha).	Decrease in mean for dense canopy cover, and increase in sparse canopy cover and openings; with increase in range and standard deviation for all patch types.
Perimeter area ratio (**PARA**) for entire landscape. Mean, range, and standard deviation reported. Frequency distribution graphs may also be plotted.	A ratio of the perimeter of a patch to its area is a measure of the shape of a patch (unitless). Edge effects where adjacent patches influence each other are an important driver of ecological processes in complex landscapes. Large perimeter-to-area ratios indicate convoluted or complex edges with greater proportions of the area influenced by neighboring patches.	As the stand becomes more fragmented and/or patches become more irregular with complex and convoluted edges the perimeter-to-area ratio will increase.
Patch density (**PD**) of entire landscape.	Simple measure of the density of patches per 100 hectares. Patch density is an indication of the prevalence of patch types (i.e. dense, moderate and sparse coniferous canopy cover, and openings) and is strongly influenced by the size of patches.	Increase
Euclidean distance (**ED**) to nearest similar patch of dense, moderate and sparse coniferous canopy cover, and openings. Mean, range and standard deviation reported. Frequency distribution graphs may also be plotted.	The shortest straight-line distance between the focal patch (m) and its nearest neighbor of the same type is a simple measure of patch context used to quantify patch isolation.	Increase in mean for dense canopy and decrease for sparse canopy and openings, with increase in range and standard deviation for all patch types.

Appendix C. Example CFLRP Economic Impacts and Wood Utilization Survey

CFLRP Economic Impacts & Wood Utilization: Questions for Contractors

Prepared by: ____
Date Updated: ________

1. **Information about the project(s) you worked on during calendar year 20__:**
   (if more than one forest, please indicate; add more lines as needed)

Forest 1:_____________	Ranger District	County	Mechanical Acres Completed	Manual Acres Completed	Date signed	Date started
Project or task order name	_____*Ranger District*		###	###		
____ **NF Total**			_____	_____		

2. **What type of restoration work did this site/project(s) include *(check all that apply)*:**
   Please provide additional detail as necessary in questions 3 and 4)

   _____Ag/grazing
   _____Air quality
   _____Fresh surface water
   _____Groundwater
   _____Sediments
   _____Shoreline
   _____Wetland/marsh
   _____Woodland/forest
   _____Bird habitat/populations
   _____Fish habitat/populations
   _____Mammal habitat/populations
   _____Reptile/amphibian habitat/populations
   _____Forestry
   _____Other_____________________________
   _____Other_____________________________
   _____Other_____________________________

3. **Which of the following roles did your firm play in this restoration project *(check all that apply)*:**

   _____Project management
   _____Management consulting
   _____Restoration planning/design
   _____Site Surveying
   _____Other project implementation
   _____Monitoring
   _____Product vendor
   _____Other_____________________________

_____On-site construction _____Other______________________________

4. **Please describe your role in the project:**

5. **Site/project(s) and firm location:**

   Use the following table to list the location of any off-site locations for your firm (e.g. your office or a storage area) associated with ***this project(s)***. If there are more than two off-site locations, please choose the top two locations.

Site/Project(s) Location	State	County
Off-site Location 1		
Off-site Location 2		

6. **Please provide the total amount you billed the US Forest Service/ (name of national forest) in calendar year 20__ for these projects?**

7. **Overall breakdown of costs:**

   Use the following table to identify the percent split between labor and non-labor costs for **this restoration site/project(s)**. Labor costs include benefits, wages, and proprietor's income. Non-labor costs include all other expenses including overhead, administration and subcontracting.

Expenditure Category	% of total site/project(s) cost
Labor Costs	
Non-Labor Costs	
	100%

8. **Direct employment for this project:**

Please indicate the total number of labor hours (including employees and managers) that worked on ***this restoration site/project(s)*** in each location (please refer to the locations identified in Question #1).

Project Name (Task Order or Contract)	Number of **Acres completed** for this task order:	Number of labor hours for employees working primarily at the **Site/Project(s) Location:**	Number of labor hours for employees working primarily at **Off-Site Location 1:**	**Total** number of labor hours for this restoration project:
				(Sum)
Total:				

a. Do the above labor hours include work done by subcontractors?

_____Yes
_____No

b. If yes, what is the total number of labor hours billed by the subcontractor(s)? ____________

9. Subcontracting:

a. If you hired subcontractors, in the space below please provide:

i. the name(s) of the subcontractor(s)
ii. a description of the work performed by each sub-contractor
iii. where each sub-contractor is based

b. If necessary, can we have your permission to contact the subcontractor(s)? If yes, please provide the appropriate contact information.

10. Breakdown of non-labor costs:

Use the columns in the table below to answer the following two questions about non-labor expenses for ***this restoration site/project(s).*** If you are unable to provide exact percentage breakdowns, please use your professional judgment to provide best-known estimates.

Column 1:	What percentages of total non-labor expenses were spent on the following types of expenses for this project? This column should add to 100%.
Column 2:	What percentages of these non-labor expenses were purchased within the local area surrounding the project location? ***(Note: the local area is defined as a reasonable commuting distance).***
***Note:**	Equipment refers to durable goods such as vehicles and machinery. Materials refer to goods purchased as inputs specifically for this project (e.g. gravel, fencing, office supplies, etc.)

Non-Labor Costs	Percentage of total non-labor expenses:	Percentage expended within the local area surrounding the site/project(s) location:
Equipment rental / leasing / daily use rates		
Equipment maintenance and repair		
Materials		
Travel		
Overhead /Administration		
Other (please describe)		
	100%	

11. Breakdown of materials costs:

Please use the table on the following page to indicate the types of materials used for ***this restoration site/project***. Place a check mark next to all materials that were used in the project. **Please complete columns 1 and 2 *only* for the materials used in the project.**

Column 1: Please indicate the percent of total material costs spent on each material. This column should add to 100%. If you are unable to provide exact percentage breakdowns, please use your professional judgment to provide best-known estimates.

Column 2: Please use the check boxes to indicate if the material was purchased from a retailer.

Materials	**Column 1** Percentage of total materials cost:	**Column 2** Purchased from a retailer? **Yes**	**No**
___General retail merchandise (e.g. food, clothes, work gloves)		☐	☐
___Office Supplies		☐	☐
___Gasoline/ Diesel		☐	☐
___Tools and Parts (for equipment and vehicles)		☐	☐
___Seeds		☐	☐
___Communications equipment		☐	☐
___Other____		☐	☐
___Other____		☐	☐
___Other____		☐	☐
___Other____		☐	☐
	100%		

12. Breakdown of travel costs:

If you had travel costs for this project, use the columns in the table below to answer the following two questions about travel expenses for ***this restoration site/project(s)***. If you are unable to provide exact percentage breakdowns, please use your professional judgment to provide best-known estimates.

Column 1: What percentages of total travel costs where spent on the following types of expenses for this project? This column should add to 100%.

Column 2: What percentages of these non-labor expenses were purchased within the local area surrounding the project location? ***(Note: the local area is defined as a reasonable commuting distance).***

Travel Costs	**Column 1** Percentage of total travel costs:	**Column 2** Percentage expended within the local area surrounding the site/project(s) location:
Per diem		
Car/truck rental (for travel)		
Gas (for travel)		
Other (including airfare)		
	100%	

13. **Breakdown of labor costs:**

What percentage of total labor costs (direct wages and non-payroll) typically go to the following types of workers? The column should add to 100%.

Type of Worker	Percentage of total labor costs that go to labor for the following worker types:
Project Managers	
Forester/ Biologists/ecologists/other	
Engineers and other planners/designers	
Mechanics	
Administrative Staff	
Machine and equipment operators	
Truck drivers	
Manual laborers	
Technicians	
Others (please describe)	
Others (please describe)	
	100%

14. Was there any wood utilization associated with these projects?

Yes ______ (Please continue to question 15)

No ________ (Thank you for your assistance, you do not have to continue!)

15. What percentage of the total amount of material harvested is:

***Manual* (out of 100%)**

a. Available for value-added use? _______%

b. Piled and burned (not for prescribed burn) _______%

c. Left for wildlife habitat? _______% or _______ tons/acre

***Mechanical* (out of 100%)**

a. Available for value-added use? _______%

b. Piled and burned (not for prescribed burn) _______%

c. Left for wildlife habitat? _______% or _______ tons/acre

16. How many businesses purchase material from you (specifically related to this project)?

Forest 1: ______________________ (Copy for additional forests)

a. Total businesses: _________

b. Colorado businesses: _________

c. Other states: (please specify state and number of businesses): ________________________

Overlap?

If there are two or more forests associated with this project, are there any businesses that purchase from multiple forests? If yes, how many businesses? _______

17. What types of materials did you sell from the restoration site and project(s)? Where did these materials go?

Forest 1: ______________________ (Copy table for additional forests)

Materials Sold			Locations material was sold to: (please identify locations)		
	Amount (preferably board feet/ CCF)	The county the project was located in	County in CO	State outside of CO	County outside of CO (if available)
Sawtimber ***(Specs? ____________)***					
Small diameter timber ***(Specs? ____________)***					
Blue stain					
Products other than logs (POL)					
Limbs/ brush					
Bark Fines					
Other ***(please specify):***					
Total:					

18. **What kinds of products were created from the wood? What percentage of the materials removed from the site went to each category of products? Where are the purchasers located? What is the value of the product?**

Forest 1: ______________________ (Copy table for additional forests)

Products created	Percent of total material sold:	Product Value (low, medium, high)	Locations material was sold to: (please specify location and percentage across row)			
			The county where the project was located:	Other county in CO:	State outside of CO:	TOTAL
example: firewood	*10%*	*Low*	*Larimer, 5%*	*Moffat, 2%; Montrose 3%*	*n/a*	*100%*
Wood Fuel Pellets						100%
Biomass Electricity						100%
Firewood						100%
Pallets & Crates						100%
Dimensional lumber						100%
Logs - log homes						100%
Logs - other						100%
Beams & Timbers						100%
Trusses						100%
Posts/ poles						100%

Products created (continued)	Percent of total material sold:	Product Value (low, medium, high)	Locations material was sold to: (please specify location and percentage across row)			
			The county where the project was located:	Other county in CO:	State outside of CO:	County/ town outside of CO:
Flooring & Paneling						100%
Doors						100%

Windows							100%
Veneer							100%
Custom Cabinets							100%
Mass produced cabinets							100%
Mass produced furniture							100%
Custom furniture							100%
Siding & Decking							100%
Molding							100%
Holiday trees & transplants							100%
Paper products							100%
Products created (continued)	Percent of total material sold:	Product Value (low, medium, high)	Locations material was sold to: (please specify **location** and **percentage** across row)				
			The county where the project was located:	**Other county in CO:**	**State outside of CO:**	**County outside of CO:**	
Shavings							100%
Soil Fertilizer/ Biochar							100%
Animal Bedding							100%
Landscape ties							100%
Chips							100%

Mulch	100%
Compost	100%
Fencing	100%
Other - specify	100%
100%	

Appendix D. Front Range CFLRP Ecological Monitoring Summaries

*D.1. 2011-2012 (*Young et al. 2013)[1]

Monitoring in 2011 and 2012 was via CSE plots throughout the PSI and AR National Forests. On the PSI, treatments took place on the Phantom Creek 1, 2, and 3 project areas, and the Ryan Quinlan project, but only Phantom Creek yielded pre- and post-treatment data. On the AR, projects took place at Red Feather, Estes Valley, Thompson River, Walker Red, Walker Black, and Taylor Mountain. Analysis focused on tree density, tree size, tree composition, and spatial heterogeneity. Results for both sites revealed that treatments resulted in decreased tree densities (basal area and trees per acre), increased quadratic mean diameter, and a general shift towards favoring ponderosa pine over other conifers on the PSI. However, Douglas-fir percent composition increased on the AR, along with ponderosa pine (Table 11). Increases in ponderosa pine and Douglas-fir on the AR were balanced by a reduction of lodgepole pine.

Spatial heterogeneity was evaluated by measuring variability of BA and TPA between stands at Phantom Creek, assuming errors would be greater between plots for heterogeneous stands compared to homogenous stands. Results showed that variability was higher before treatment, indicating treatments homogenized the project area (Figure 5). Results from the 2011 and 2012 monitoring data led to several recommendations and next steps.

Table 11. Summary monitoring results from 2012 for TPA, BA, QMD, percent ponderosa pine, and percent Douglas-fir across the PSI and AR National Forest project areas. Note the increase Douglas-fir percentage.

	PSI pre-treatment	PSI post-treatment	AR pre-treatment	AR post-treatment
TPA	170	91	148	90
BA (ft² per acre)	84	58	69	62
QMD (in)	9.9	11.0	9.0	10.3
Percent ponderosa pine	52.8	59.1	47.0	52.0
Percent Douglas-fir	35.4	30.0	25.0	28.0

Given the increase of Douglas-fir on the AR National Forest, it was suggested that this be further investigated to determine if more Douglas-fir is being retained than is desirable. It was also revealed that the CSE protocol does not yield data to assess changes in tree age, leading to further discussions about continuing to track that metric in desired conditions. Finally, the spatial heterogeneity analysis led to further interest in exploring additional methodologies for assessing spatial heterogeneity in the future.

[1] Full report can be found at: https://cfri.colostate.edu/wpcontent/uploads/2016/05/2013_FR_CFLRP_EcologicalMonitoringReport2011-2012.pdf

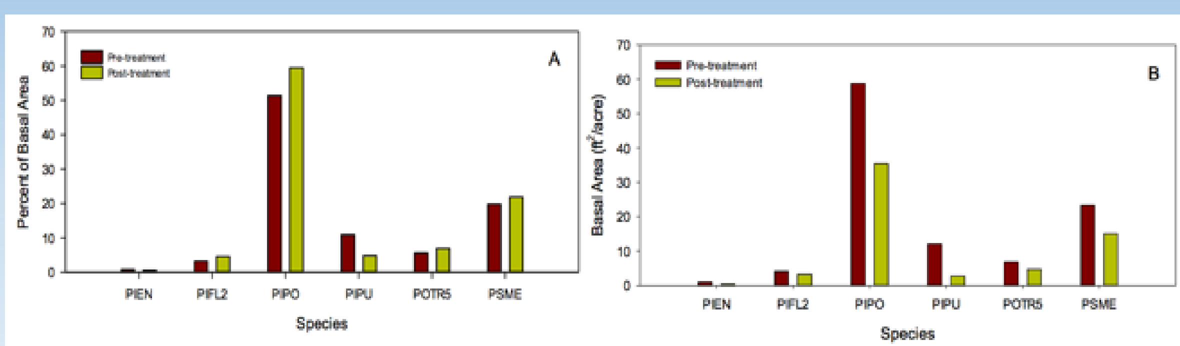
D.2. 2013 (Addington et al. 2014)[1]

Monitoring conducted in 2013 focused on building upon previous monitoring in 2011 and 2012 using CSE data. On the PSI, data were collected for the Catamount 1, Long John, Phantom Creek 4, and Messenger Gulch 2 projects. On the AR, data were primarily collected pre-treatment for the Boulder Heights, Forsythe, and Gold Hill projects, and are not included in this summary. Similar to 2011-2012, monitoring results showed decreases in tree density and increases in QMD on the PSI, where pre- and post-treatment data was available (Table 12).

The proportion of ponderosa pine and Douglas-fir relative to other species also increased (similar to AR results of 2011-2012) across the PSI in 2012-2013. It was noted that the desired condition for this trend is not consistently observed, potentially because ponderosa pine often makes up most of the initial basal area, and achieving a noticeable proportional increase of ponderosa pine over other species would require a significant removal of other species (Figure 5).

2013 was the first year that fuels data were available (on the PSI) both pre- and post-treatment. These treatments resulted in significant increases of surface fuels; and increases in canopy base height and decreases in bulk density (Table 13) that led to increases in average crowning indices from 26 to 46 mph. These results sparked interest in longer term monitoring to track how fuels conditions change through time since treatment, especially under prescribed fire scenarios that are highly desired in the future given surface fuel responses to treatments.

Figure 5. (A) Percent basal area by species on the PSI. (B) Actual basal area by species on the PSI.



[1] Full report can be found at: https://cfri.colostate.edu/wp-content/uploads/2016/05/2014_FR_CFLRP_EcologicalMonitoringReport2013_Final.pdf

Results from 2013 analysis built upon previous analyses, showing how treatments influence desired conditions in terms forest composition, fuels characteristics, and aspects of forest structure. Overall, treatments generally move forest composition and structural characteristics towards desired conditions on the stand level, however surface fuels results validate the need to implement prescribed fire in future treatments. These analyses also highlighted the limitations of CSE data in evaluating certain trends such as landscape-scale spatial heterogeneity, wildlife response, and understory plant communities, which will need to be addressed using different approaches in the future. These limitations have provided direction to the LR team on where to focus new monitoring efforts moving forward.

Table 12. Summary monitoring results from 2013 for TPA, BA, and QMD across the PSI. AR data is not included as there was no post-treatment data available.

	PSI pre-treatment	PSI post-treatment
TPA	109	62
BA (ft^2 per acre)	215	96
QMD (in)	13.1	14.6

Table 13. Surface and canopy fuels pre- and post-treatment for 2013 projects in the Pike-San Isabel NF. Means with different letters from pre- to post-treatment are significantly different at $\alpha = 0.05$.

Surface Fuel Component	Catamount 1		Long John		Phantom Creek 4		Messenger Gulch 2	
(tons/acre)	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*	*Pre*	*Post*
Total surface fuels	11.1[a]	21.2[b]	13.5[a]	16.9[a]	12.5[a]	17.6[a]	--	17.0
Litter	1.0[a]	0.6[b]	1.0[a]	0.4[b]	0.9[a]	0.7[a]	--	0.6
Duff	4.4[a]	6.0[b]	5.9[a]	7.6[a]	4.1[a]	5.2[a]	--	8.1
Fine Wood (0-3" dia.)	1.5[a]	5.9[b]	2.3[a]	4.8[b]	2.3[a]	6.6[b]	--	4.1
Coarse Wood (>3" dia.)	3.5[a]	7.9[b]	3.5[a]	3.8[a]	4.7[a]	4.8[a]	--	3.9
Live Herbaceous	0.2[a]	0.3[b]	0.2[a]	0.3[b]	0.2[a]	0.2[a]	--	0.2
Live Shrub	0.4[a]	0.4[a]	0.4[a]	0.1[b]	0.4[a]	0.2[b]	--	0.1
Canopy Fuel Component								
Canopy base height *(ft)*	5.3[a]	8.9[b]	6.2[a]	20.0[b]	6.3[a]	8.8[a]	--	8.4
Bulk density *(kg/m^3)*	0.15[a]	0.05[b]	0.10[a]	0.03[b]	0.09[a]	0.06[b]	--	0.06

D.3. 2014-2015[1]

Pre-treatment data were collected at the Ridge and Hybrook projects on the PSI and the Red Feather 4 project on the AR during the summer of 2014. Given the lack of any new, post-treatment CSE data to analyze, the LR Team was able to focus on aspects of monitoring that had thus far been overlooked, namely stand- and landscape-scale spatial heterogeneity.

Spatial heterogeneity and landscape-scale monitoring were analyzed using NAIP imagery and spatial statistics using FRAGSTATS. Main outcomes of the spatial heterogeneity analysis include:

> "At the stand scale, the treatments have reduced forest cover, increased canopy patch density, decreased canopy patch size (max and mean), increased distances and range of distances among canopy patches. However, the heterogeneity of canopy patch sizes (range and standard deviation of patch area) has decreased, which is counter to the current desirable trends. However, we recommend that this desirable trend be revised to allow some reduction in the heterogeneity of patch sizes, while specifying an acceptable minimum. Furthermore, the CFRLRI should continue to focus on creating a range of patch sizes at the stand-scale through adaptive management." (Dickinson et al. 2014)

Similar outcomes of landscape-scale monitoring were included in the analysis:

> "Changes at the landscape scale were also encouraging, with small reductions in dense canopy cover and increases in sparse canopy cover across the landscape. Some artifacts in the results due to the methods were identified, however the overall conclusions in terms of the trends are robust. Therefore, we recommend that these results be provisionally accepted, and the methods be further refined to address these concerns for future monitoring cycles. To date, the changes at the landscape-scale have been relatively small as expected because the projects are currently relatively small and widespread across the region. However, as further projects are completed over the coming years, a greater proportion of each landscape will be treated and landscape-scale forest complexity will increase." (Dickinson et al. 2014)

Although significant headway was made analyzing spatial heterogeneity at both the stand and landscape scale using these methods, the relatively abstract metrics produced by FRAGSTATS (see Appendix B) led to some confusion among the LRT, and the group agreed that simpler metrics should be explored in the future.

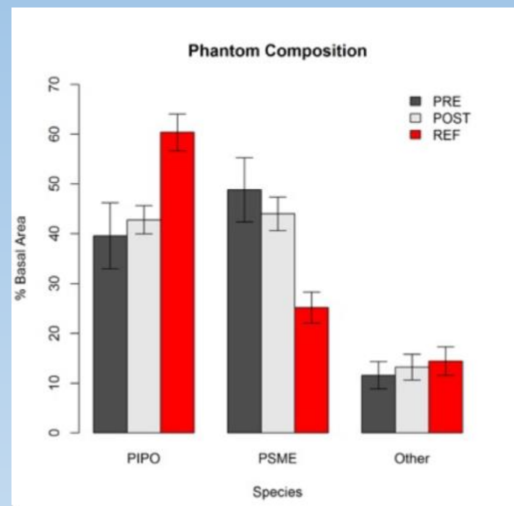
[1] Full summary can be found at: https://cfri.colostate.edu/wp-content/uploads/2016/06/2015_FR-CFLRP-Monitoring-Jam-Session-2015-Summary-Final.pdf

D.4. 2015-2016 **(Cannon and Barrett 2016)**[1]

Post-treatment CSE data were not collected during the summer of 2015. Given the lack of any new CSE data available for analysis, the LRT focused on a more in-depth analysis of two CFLRI project areas to compare pre- and post-treatment stand conditions with reconstructed historical forest structure in areas near the treatments. The goal of these analyses was to determine if current monitoring protocols were sufficient to make recommendations to improve future restoration treatments.

Similar to previous years, structural analysis showed that treatments were moving forest composition and structure towards desired conditions, but several apparent differences existed between post-treatment and historical conditions. For example, while treatments reduced the relative abundance of Douglas-fir, post-treatment abundance was still considerably higher than were historically present at the Phantom Creek project (Figure 6a). Additionally, while post-treatment basal area at Phantom Creek reflects historical conditions (67 ft^2 /acre post-treatment, compared to 63 ft^2 /acre historically), sites appeared to be homogenized due to similar residual basal areas across productivity gradients, which does not reflect the LRT's desired conditions or historical structure (Figure 6b).

Spatial analysis focused on using simpler metrics than were presented in 2014, and aimed to take classified imagery (Figure 7a) to estimate certain aspects of forest structure (e.g., percent cover, percent "interstitial" openings, percent large openings, canopy patch size, etc.) and compare post-treatment



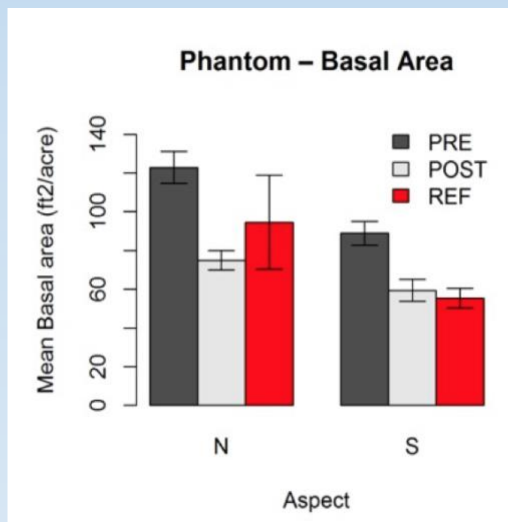


Figure 6. (a) Relative abundances for ponderosa pine (PIPO), Douglas-fir (PSME), and other species, for pre- and post-treatment, and historical conditions at Phantom Creek. (b) Basal area summarized by aspect for pre and post-treatment, and historical conditions at Phantom Creek.

[1] Full report can be found at: https://cfri.colostate.edu/wp-content/uploads/2016/09/2016_FR_CFLRP_Jam_Session.pdf

conditions with estimated historical conditions. Results from analyzed sites indicated that while treatments are creating appropriate levels of canopy openness, more of the resulting openings apparently occurred in close proximity to canopy edge (“interstitial” openings) rather than as part of larger openings (Figure 7b). Treatments also altered tree group size to better reflect historical conditions, but isolated trees and very large groups (>15 trees) were over-represented while moderate sized groups (2-15 trees) were under-represented (Figure 7c) relative to historical stand conditions.

Although this represented a relatively small analysis (only two sites) that proved difficult to draw robust conclusions from to make formal recommendations, the LRT agreed that the monitoring protocols currently in place can help inform forest management recommendations given additional analysis of currently collected monitoring data. A more comprehensive report including a wider range of CFLR projects and more robust analyses is currently in preparation by LR Team members.

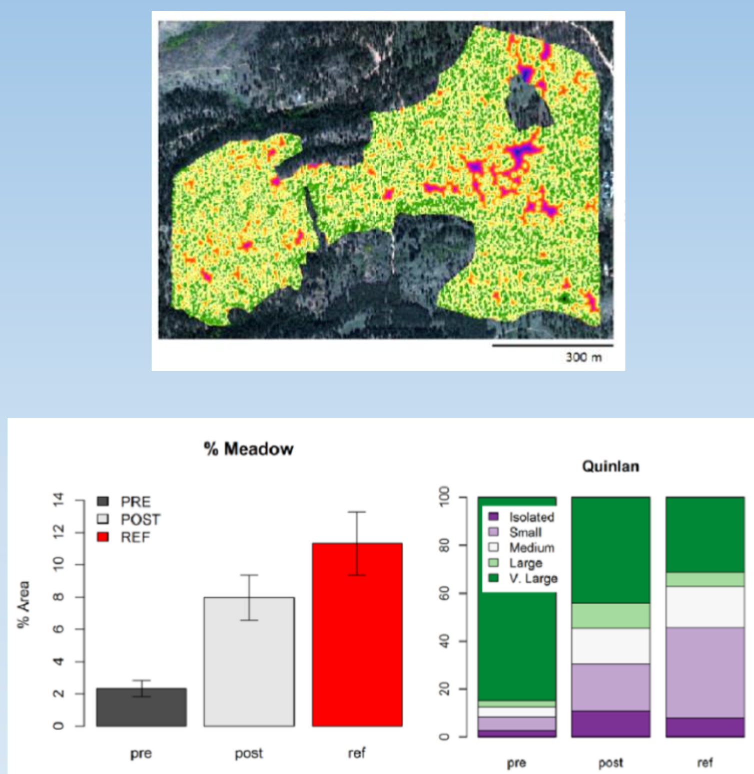


Figure 7. (a) Classification of a post-treatment imagery for a portion of the Ryan Quinlan project area (Teller Co.). Green indicates canopy patches, yellow indicates openings near canopy edge, and pink-purple colors indicate large interior openings. (b) Proportion of treatment area in large openings 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 conditions.

Appendix E. Front Range CFLRP Social and Economic Monitoring Summaries

E.1. 2011 (Mattor et al. 2012)[1]

Social and economic monitoring was first conducted in 2011, which included the over-arching goals identified in Chapter 4 (Economic Contributions, Wood Utilization, and Levels of Collaboration) as well as Social Perceptions.

Economic Contributions

In 2011, the Front Range CFLRP contractor worked on six task orders, fulfilling 3, and partially completing the other 3. This work resulted in 38 full and part time jobs, and contributed approximately $1.8 million in labor income and $1.6 million in value-added (GDP).

Wood Utilization

A total of 3,170 acres were treated under the Front Range CFLRP in 2011 (1,468 acres on the PSI and 1,592 on the AR). There was a stark difference in mechanical vs manual treatments on the two forests which had implications in the amount of wood material available for wood utilization. 93% of the materials removed from the PSI were through mechanical treatments, whereas only 25% of the material removed on the AR was mechanically. Because of this, more material was hauled of the PSI, and a greater diversity of products were developed from these materials (Figure 8). All materials removed were purchased by local businesses in counties on or adjacent to where work was completed.

National Forest	Material	Green Tons
Pike-San Isabel	Sawtimber and Small Diameter timber	7,641
	Products other than Logs (POL)	2,754
	Limbs/ Brush	2,106
	Bark Fines	6,615
	Total:	***19,116***
Arapaho-Roosevelt	Small Diameter timber	170
	Blue Stain	155
	Products other than Logs (POL)	1,268
	Limbs/ Brush	1,134
	Total:	***2,727***

National Forest	Products created	Percent of total material sold:	Product Value
Pike - San Isabel	Pallets & Crates	38%	Medium
	Mulch	23%	Low
	Chips (Landscaping and Playground Material)	21%	Low
	Compost	14%	Low
	Dimensional lumber	2%	High
	Soil Fertilizer/ Biochar	1%	Low
	Firewood	1%	Low
Arapaho - Roosevelt	Playground Material, landscaping	71%	Low
	Pallets & Crates	17%	Medium
	Firewood	7%	Low
	Wood Fuel Pellets	5%	Low

Figure 8. Green tons of material sold from each forest (left) and products created from materials (right).

[1] Full report can be found at: https://cfri.colostate.edu/wp-content/uploads/2016/05/2012_FR-CFLR-SE-monitoring-report_Final.pdf

Levels of Collaboration

15 FRRT members representing diverse representations of interests were interviewed to develop a detailed assessment of Front Range CFLRP collaboration. High levels of trust and strong commitments to work towards agreements on important, project related decisions were reported. This was primarily attributed to open and frequent communication between Front Range CFLRP partners and monitoring team/LRT members. Many members also agreed that the collaborative had influence on the implementation of CFLRP projects by providing feedback, resources, and information for future treatments. Challenges to the collaborative included some missing interests within the group, a lack of a clear sense of roles and responsibilities by some members, and a lack of feeling influential on the implementation of current projects due to previously completed planning processes that pre-dated the CFLRP project grant.

Social Perceptions

A literature review was conducted (please refer to 2011 report, page 11) to research the social perceptions towards prescribed fire to help identify future complications with the proposed increase of prescribed fire described in the Front Range CFLRP. Although a general support for the use of prescribed fire was found, several key concerns were identified, including:

1. Fear of escaped catastrophic fire
2. Poor air quality
3. Harm to wildlife and fish habitat
4. Impacts on aesthetics

Recommendations of this review included furthering the analysis to focus more on the Front Range, including social scientists in future discussions, and increasing mechanisms of public outreach to establish a better public understanding of prescribed fire.

E.2. 2012 (Mattor et al. 2013)[1]

Monitoring in 2012 focused on economic contributions and wood utilization. Public outreach was also monitored in response to analyses done on social perceptions towards prescribed fire the previous year. Also, a quick narrative of funding accomplishments was provided for the first time. Levels of collaboration was not monitored in 2012.

Funding and Accomplishments

A total of $3.8 million were funded for CFLRP projects in 2012. Additionally, about $4.6 million in matching funds were recorded for 2012, coming from USFS matching funds (primarily salary), "funds contributed through agreements" (e.g. from partner organizations to implement and monitor efforts), "partner in kind contributions" (primarily for monitoring efforts), and "service for work accomplishments through goods-for-service funding within a stewardship contract." The CFLRP also leveraged roughly $2.8 million in funds in non-Forest Service System lands projects areas associated with the CFLRP project area from the Colorado State Forest Service, The Coalition for the Upper South Platte, and Denver Water. 2012 resulted in 2,181 acres of forest vegetation improvements; 9,763 acres of water or soil resources protected, maintained, or improved; and 5,506 acres of WUI high priority acres treated.

Economic Contributions

Seven task orders were associated with the Front Range CFLRP in 2012, and five were fulfilled completely. In addition, the Rocky Mountain Research Station, Rocky Mountain Tree Ring Research, and the Colorado Forest Restoration Institute received CFLR funding for monitoring and consulting, and the AR and PSI spent about $50,000 for common stand exams. Combining restoration and monitoring activities, 2012 CFLR projects resulted in 74 full or part time jobs, $3.6 million in labor income, and $2.4 million in GDP to the local economy.

Wood Utilization

A total of 4,117 acres were treated under the Front Range CFLRP in 2012 (2,057 in the PSI and 2,060 on the AR). 81% of the materials removed on the PSI were done mechanically, whereas 89% of the AR was completed manually. Manually harvested material was not available for value-added uses, whereas 99% of the mechanically harvested material were. Twelve businesses purchased harvested material from Front Range CFLRP treatments, 10 of which were from Colorado, and two from New Mexico. A large portion of the biomass from both forests went to wood chips used for post-fire rehabilitation efforts. The value-added materials included sawtimber, small diameter timber, firewood, and bark fines. Materials from the Pike & San Isabel National forests were turned into an

[1] Full report can be found at: https://cfri.colostate.edu/wp-content/uploads/2016/05/2013_FR-CFLR-2012-SE-monitoring-report_Final.pdf

assortment of products with the largest portion (54 percent) going to landscaping materials and four percent going to high-value dimensional lumber. The majority of value-added materials (20 percent) from the Arapaho & Roosevelt National Forest went to dimensional lumber, followed by posts/poles (15 percent) and pallets & crates (6 percent).

Public Outreach

In response to the literature review conducted in 2011, considerable effort was given towards identifying public outreach mechanisms in 2012. Four focus group meetings with public outreach experts yielded four primary mechanisms for the FRRT to support outreach across Front Range communities:

1. Support and organize opportunities for outreach experts and organizations to meet
2. Lobby for, support, and/or organize statewide outreach campaigns
3. Organize and support resource sharing for communities and outreach specialists
4. Promote consistent messages across state and local groups

E.3. 2013 (Mattor and Cheng 2014)[1]

Monitoring in 2013 focused on Funding and Accomplishments, Economic Contributions, and Wood Utilization. Levels of Collaboration were not monitored in 2013.

Funding and Accomplishments

A total of $3.3 million were funded for CFLRP projects in 2013 with a total of 2,978 acres treated. Additionally, about $3.9 million in matching funds were recorded for 2013, coming from USFS matching funds (primarily smoke permits for pile burning, road decommissioning, noxious weed control, and reforestation), "funds contributed through agreements" (e.g. from partner organizations to implement and monitor efforts), "partner in kind contributions" (primarily for monitoring efforts), and "service for work accomplishments through goods-for-service funding within a stewardship contract." The CFLRP also leveraged roughly $35.8 million in funds in non-Forest Service System lands projects areas associated with the CFLRP project area from the Colorado State Forest Service, The Coalition for the Upper South Platte, Denver Water, Colorado Springs Utilities, NRCS, and The Waldo Recovery Group. As of 2013, a total of 11,331 acres had been treated on National Forest System land through the CFLRP, with additional acreage through leveraged funds with partners.

Economic Contributions

Six task orders were associated with the Front Range CFLRP in 2013. One was fulfilled completely, two were partially completed, and three that were initiated in 2012 were completed. In addition, the Colorado Forest Restoration Institute received CFLR funding for monitoring and consulting, and the AR and PSI spent about $80,000 for common stand exams. Combining restoration and monitoring activities, 2012 CFLR projects resulted in nearly 15 full or part time jobs, $276,760 in labor income, and $524,672 in GDP to the local economy.

Wood Utilization

A total of 1,811 acres were treated under the Front Range CFLRP in 2013 (718 in the PSI and 1,093 on the AR). 66% of the materials removed on the PSI were done mechanically, whereas 77% of the AR was completed manually. Manually harvested material was not available for value-added uses, whereas 99% of the mechanically harvested material were. Three businesses purchased harvested material from Front Range CFLRP treatments, all of which were from Colorado. A large portion of the biomass from both forests went to wood chips used for post-fire rehabilitation efforts. All of the biomass material was sold as sawtimber and is assumed to have been processed into dimensional lumber.

[1] *Full report can be found here: https://cfri.colostate.edu/wp-content/uploads/2016/06/2014_FR-CFLR-2013-social-economic-monitoring-report.pdf

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