Upper South Platte Watershed Monitoring Report:

Learning from forest restoration projects to advance landscape resilience and collaboration

April, 2021

CFRI - 2103

COLORADO FOREST RESTORATION INSTITUTE

FOREST AND RANGELAND STEWARDSHIP
COLORADO STATE UNIVERSITY

Colorado Forest Restoration Institute

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Executive Summary

The Upper South Platte Watershed and the forests it contains provide highly valued ecosystem services to communities along the Colorado Front Range. The Upper South Platte Partnership (USPP) and Forests to Faucets partnership (F2F) lead cross-boundary collaborative efforts across forested areas of the watershed to enhance ecological resilience and reduce wildfire risk. Both collaboratives involve diverse stakeholders who are committed to learning through practice to increase the scale and effectiveness of forest restoration.

The USPP and F2F develop landscape resilience goals using science-based frameworks from RMRS-GTR-373 that balance principles for restoring historic forest structure, reducing the risk of severe wildfires, and enhancing community benefits from forests. Science informed project objectives were co-developed by diverse stakeholders to be measurable targets that manage forests through manipulating tree species composition, forest canopy cover, forest gaps, tree group arrangement, and fuel loading. Monitoring is a critical component of learning through collaborative adaptive management, as it provides stakeholders with objective data to evaluate project outcomes, partnership goals, and desired conditions. Reviewing monitoring results can also bring management partners together to overcome challenges such as climate change adaptation strategies and barriers to the use of prescribed fire.

The purpose of this report is to present a synthesis of monitoring results across multiple forest thinning projects that were collaboratively planned, funded, and implemented under the USPP and F2F partnerships between 2015 and 2018. This report: 1) evaluates outcomes of three phased USPP projects and four F2F projects in the context of partnership goals, and 2) synthesizes lessons learned gathered through structured adaptive management discussions with managers and partnership stakeholders.

Projects generally met objectives to reduce wildfire risk and approximate historic forest densities and composition to enhance ecological resilience in the Upper South Platte, even though some individual metrics such as spatial arrangement of forest structure were consistently more difficult to achieve. Continued momentum towards the application of fire as a management tool will greatly reduce risk of high severity wildfire and enhance forest resiliency to sustain ecosystem services under future disturbances and a changing climate. Co-development of goals and strategies to achieve every step of the adaptive management cycle was a key to successfully implementing complex science-based concepts, learning through mistakes, and achieving desired outcomes in the Upper South Platte Watershed.

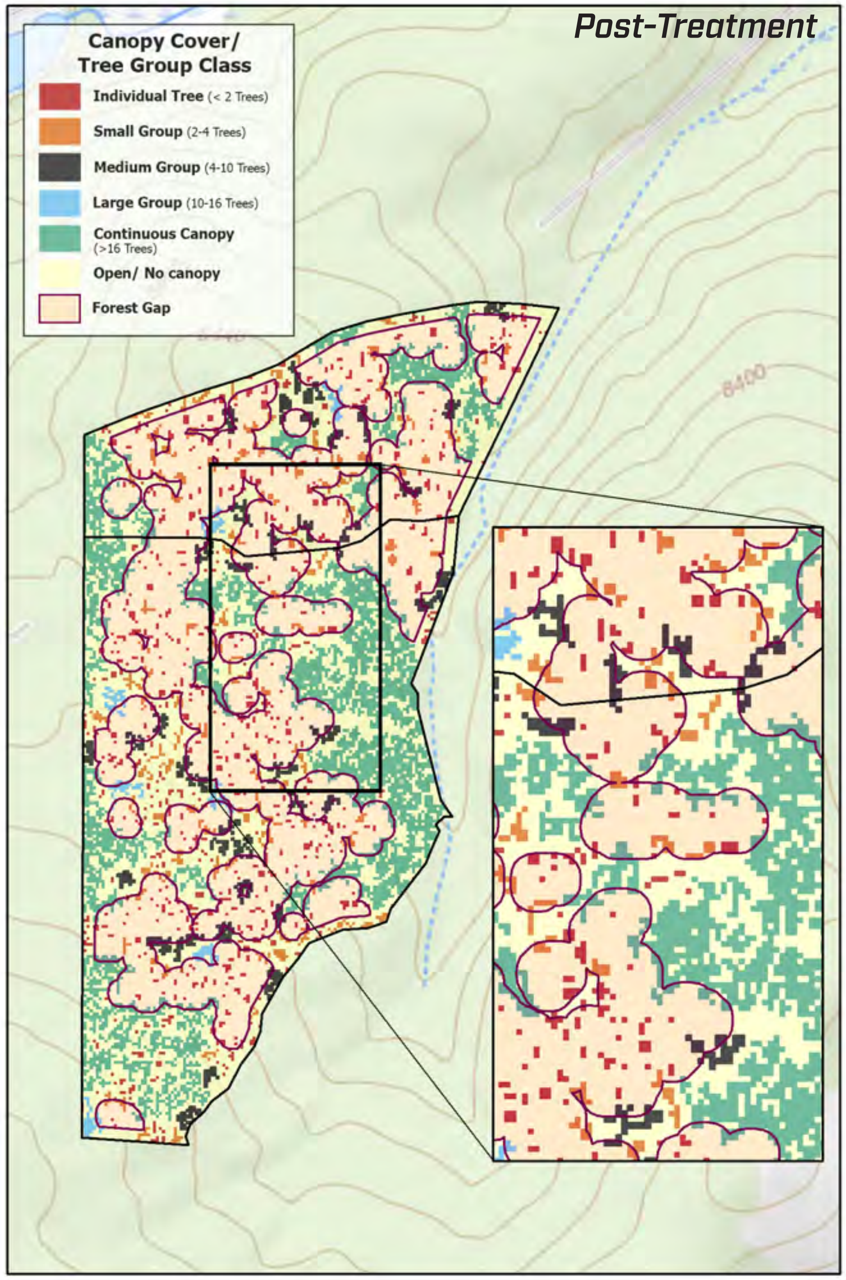
Highlights

A total of 217 long-term monitoring plots were established at ten sites covering 1,978 acres of forest restoration treatments. Monitoring protocols were standardized to facilitate comparisons across projects and programs, with the goal of developing new research and long-term learning opportunities.

Canopy Cover (USPP Goals 1 and 2). Projects aim to maintain a wide range of forest cover while reducing total canopy cover to within a range of 10-40%. Projects build off one another to reduce overall canopy cover to an average of 30% at the sub-watershed scale. Post-treatment canopy cover met restoration goals, and ranged from 13-43% across USPP projects and 16-40% across F2F projects. Collectively, the average canopy cover following thinning was 27% at USPP projects, and 28% at F2F projects. Following treatment, monitoring plots showed more open conditions and maintained canopy cover variability across monitoring plots. Coordination and co-location of projects on local scales increased impact of individual treatments, although these projects had minimal impact to the dense, connected forest cover found across the entire sub-watershed.

Forest Gap and Tree Group Arrangement (USPP Goal 3). Restoration projects strive to increase spatial heterogeneity by creating forest gaps and breaking up continuous canopy into smaller irregularly spaced tree groups. Restoration projects successfully increased gap coverage by 37%, and increased the presence of smaller tree groups. However, all projects except one fell short of meeting the specific target to have individual trees comprise 25% of canopy cover. Through the USPP and F2F collaboratives, managers and stakeholders can discuss strategies to have thinning result in more individual trees, and reevaluate specific goals related to tree group arrangement.

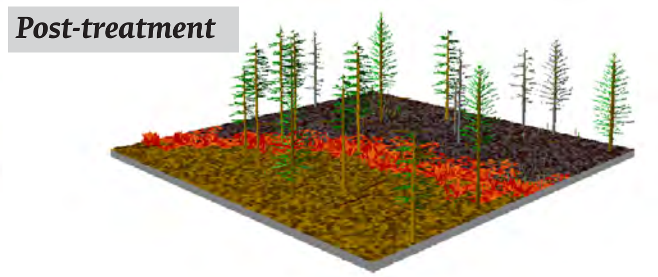
The Ratio of Ponderosa Pine (USPP Goal 4). Desired tree species composition varies and is dependent on specific site conditions. However, ponderosa pine is often underrepresented, thus, thinning is designed to promote the retention of ponderosa pine. Seven out of ten projects successfully increased the ratio of ponderosa pine relative to other conifers. In the three projects where the ratio decreased, the drop was minimal, and these areas had a comparably higher ratio of ponderosa pine to begin with.



Forest gaps and tree groups from remote sensing data.

Before and after photos

Fuel Loading and Potential Fire Behavior (USPP Goals 5 and 6). To evaluate the future use of prescribed fire and wildfire hazard, CFRI analyzed field data to assess changes in fuel loading and modeled changes in fire behavior. USPP and F2F projects included successful slash management to limit increases in surface fuel loading to less than one ton per acre. Additionally, fire modeling showed post-treatment conditions likely produced low to moderate fire behavior—total flame length was predicted to drop by 50% following treatment. Treatments successfully promoted forest conditions that have lower wildfire hazard and the potential to support the future use of prescribed fire.



Photos of fire simulation before and after treatment.

Adaptive Management. During the spring of 2020, CFRI met with implementing organizations to present monitoring results and facilitate structured discussions on a wide range of topics related to adaptive management. Adaptive management is the process of learning by intentionally planning, implementing, monitoring, and evaluating outcomes against measurable goals and objectives. Below are some key lessons learned from evaluating project outcomes and adapting future management practices to be more effective:

- Additional monitoring is desired to better understand responses of understory plant communities, wildlife, and erosion potential following active forest management. This information will help foresters plan projects to address multiple objectives.
- Expand research on biomass utilization opportunities, silviculture operational methods, and project layout to increase implementation efficiencies, reduce project costs, and better achieve forest resilience objectives.
- Enhance forest resilience by more directly addressing climate change by experimenting with different silvicultural strategies and incorporating climate vulnerability into prioritization.
- Have more discussions on science-based management in the field to shorten adaptive management feedback loops, and better integrate science principles into management practices.
- Leverage collective resources and expertise in the partnerships to overcome barriers to implementing prescribed fire. Some of the barriers identified by managers include: air quality impacts, a dense wildland-urban interface, short burn windows, high fuel loading from mastication, and community support.
- Build upon the successful collaboration that already exists to increase communication with and participation from local communities.
- Establish a leadership position in the USPP to increase collaborative capacity and navigate the partnership through conflict and challenges.

Introduction

The Upper South Platte is a highly valued watershed in the central Front Range that supplies over 80% of the water supply to the Denver metro area, contains populous wildland-urban interface communities, is home to unique wildlife and forest habitats, and supports high recreational use. For millennia humans have inhabited the land while fire has sustained functioning forests that provide many of the values we derive from forest ecosystems. However, the risk of severe wildfire in the watershed currently threatens ecological integrity and the ecosystem services people rely on from forests. The area is now a top priority for active forest management within the state and country (Colorado State Forest Service, 2020). The Upper South Platte is also a source of opportunity and innovation, where ecological restoration objectives and fire risk reduction align with the goals of diverse partners and local communities. A coordinated, cross-boundary approach is helping to protect these resources from large catastrophic wildfires and promote healthy and sustainable forest ecosystems. Currently, these forward-looking efforts in the Upper South Platte Watershed are led by both the Upper South Platte Partnership (USPP) and Forest to Faucets partnership (F2F). These partnerships embrace multi-year collaborative approaches across public and private lands and involve many stakeholders to advance forest and fire management in the watershed. Additionally, partners come together to coordinate fire adapted community outreach, and develop new fire management strategies that increase the pace and effectiveness of restoration actions.

Area burned by Lower North Fork Fire with Buffalo Creek Fire scar in middle distance. *Photo Credit: Andrew Slack*

The implementation of forest restoration across a large watershed is complicated. The intent of collaboration through the USPP and F2F is to coordinate partners through a stepwise process to maximize impact on the landscape and protect our shared values. Cooperation is critical as it can be difficult to build consensus around shared values to set goals for focusing limited resources in priority areas. Partners come together to learn from diverse perspectives and co-plan management across agencies and land ownerships, carefully evaluate actions, and adjust plans when necessary. As projects move forward, an adaptive management cycle begins to emerge, where projects become linked in a science-based approach to learning and advancing management practice. There are many frameworks to follow, and the USPP and F2F have built a process (Figure 1) based on concepts presented in Marcot et al. (2012), Aplet et al. (2014), and the GTR-373 (Addington et al. 2018).

The Colorado Forest Restoration Institute (CFRI) works with both the USPP and F2F to advance the adaptive management cycle by applying science across boundaries. CFRI takes big ideas from scientific research and regional planning, and localizes that information so it is useful for managers. Then information and lessons learned on the ground are brought back up to researchers and policy makers to connect local, regional, and national decision making. Additionally, CFRI works to span the boundaries between different organizations to coordinate management across jurisdictions and disciplines to apply a holistic response to management questions. Monitoring outcomes of management actions is critical for this adaptive management process to work, as it supports making adjustments to decision-making based on objective data.

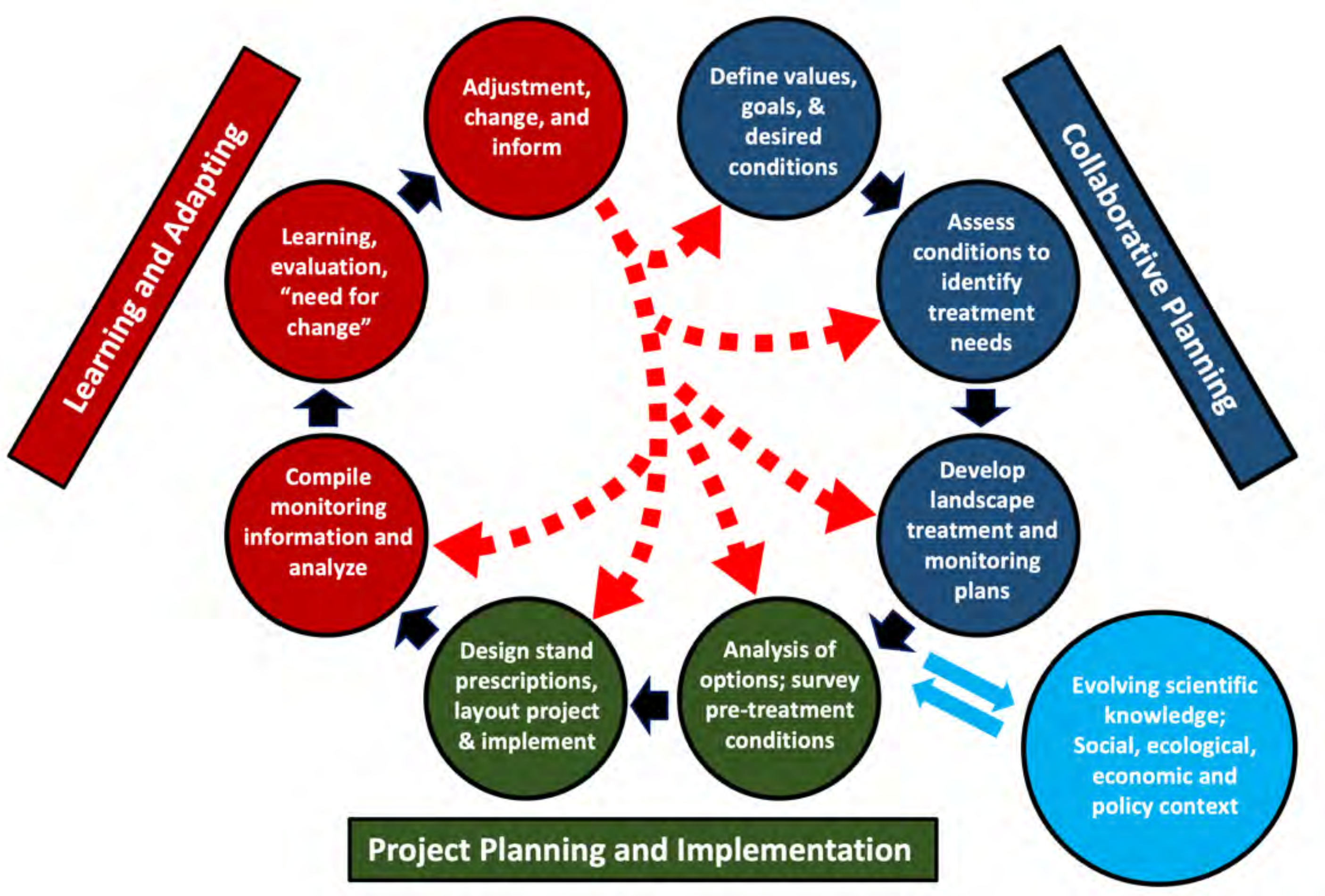


Figure 1. Framework of adaptive management cycle that guides forest management in the Upper South Platte Watershed.

A key concept in GTR-373 for successful adaptive management and implementation of science-based forest restoration principles is the co-development of knowledge amongst stakeholders. This was exemplified in the Upper South Platte Watershed, with the use of advanced science-based tools to collectively prioritize and focus resources within a large landscape, the co-development of landscape resilience objectives by managers and academics, the co-design of monitoring, and the active participation by multiple parties in monitoring data collection. This facilitated efficient feedback throughout the adaptive management cycle, culminating in the co-presentation and evaluation of monitoring results that was jointly led by foresters and CFRI staff at the April 2020 USPP meeting.

The purpose of this report is to provide a synthesis of monitoring outcomes across multiple forestry projects in the Upper South Platte, highlighting results and learning by engaging in structured adaptive management discussion from these projects. We endeavored to answer the questions: 1) Are forest restoration outcomes meeting the stated project objectives across all the monitored treatment sites? 2) How do project outcomes vary amongst projects? 3) How do collective efforts contribute towards landscape-scale restoration? It is in the context of the objectives outlined below that CFRI monitored and evaluated treatment outcomes. Lastly, we provide a summary of structured adaptive management discussions with managers, addressing topics including monitoring, climate change adaptation, joint forest visits with diverse stakeholders, prescribed fire, and collaboration. This report contributes to the learning and adapting phase of the adaptive management process (Figure 1), and is a critical step to advancing forest management that is informed by the body of knowledge accrued since the USPP and F2F formed.

Partnerships and Program Goals

The Buffalo Creek Fire (1996) and Hayman Fire (2002) were two large wildfires that occurred in the Upper South Platte, and at the time were among the most destructive in Colorado history. The fires invigorated forest management work in the watershed, but early efforts were reactionary and disjointed. There was a growing need to coordinate efforts so forest restoration and management actions could be implemented strategically and have the greatest impact for reducing wildfire hazard.

The F2F partnership began in 2010, as Denver Water and the U.S. Forest Service worked together to concentrate resources and reduce wildfire risk on U.S. Forest Service lands within Denver's watersheds of concern. Three national forests are included in this effort (Pike San Isabel, Arapaho Roosevelt, and White River), and the partnership has mostly functioned as a funding source for restoration, meeting annually to review accomplishments. This collaborative effort initiated a proactive response of using forest management to protect water resources. Over the last five years, the F2F partnership has grown to include the Colorado State Forest Service and Natural Resources Conservation Service and has complemented USPP efforts to have far-reaching impact across the watershed.

The USPP was formed in 2015, and brought together a diverse set of stakeholders with a shared vision to actively manage forest across boundaries. The partnership's goals aligned with the National Cohesive Wildland Fire Management Strategy (Wildland Fire Leadership Council 2014) to focus collaborative efforts in three main areas: 1) Resilient landscapes, 2) Fire-adapted communities, and 3) Safe and effective fire response. The group's membership included a diverse set of management agencies, fire protection districts, non-profits, academic institutions, and water providers that can leverage the knowledge and resources of each partner to

USPP Meeting (pre-pandemic) Photo Credit: Brett Wolk achieve shared goals. Because F2F was focused on federal lands and preceded the USPP, early USPP efforts focused on private and non-federal public lands to complement F2F efforts. However, the U.S. Forest Service and Denver Water are active members of the USPP, and rely on the partnership for sharing knowledge and helping to coordinate cross-boundary efforts. The USPP is currently the main forestry and fire collaborative in the watershed, meeting monthly to address a wide range of topics, and prioritizing work where they will have a greatest benefit across the watershed.

Identifying science-based and measurable objectives is critical for successful forest management, and both the USPP and F2F have looked to the GTR-373 (Addington et al. 2018) for guidance. Concepts from the GTR-373 provide a framework for how to restore many of the forest ecosystems found in the Upper South Platte, and provide a template to craft non-traditional metrics to better evaluate project outcomes. The USPP leveraged local science on fire regimes and historic forest structure (Addington et al. 2018; Battaglia et al. 2018), and balanced that information with social considerations unique to working on non-federal lands to establish science-based, measurable, and achievable objectives. These objectives were intended to set targets that would create forest landscapes resilient to fire and future climates within ponderosa pine and frequent fire forest ecosystems in the Upper South Platte. The landscape resilience goals and objectives co-developed by USPP stakeholders are:

1) *Mean conifer canopy cover over the sub watershed scale.* This is a long-term goal to achieve an average canopy cover of 30% at sub watershed scale, and for this report is evaluated across projects.
2) *Reduction of conifer tree cover, while maintaining a complex mosaic of forest canopy cover at stand scales.* Canopy cover is evaluated at the project scale with the goal of reducing cover to an average of 30%, or within an acceptable range of 10-40%, while maximizing variability by maintaining a range of canopy cover from 0-100% across the project area.
3) *Arrangement of conifer canopy cover within treated stands.* Tree groups are evaluated at the project scale to quantify changes in spatial heterogeneity. The objective is to break up continuous forest canopy into a clumpy arrangement of smaller tree groups interspaced with large forest gaps, and individual or isolated trees making up approximately 25% of canopy cover.
4) *Conifer species composition.* Projects are designed to increase or maintain the ratio of ponderosa pine to other conifers. Local site conditions including historical forest structures, tree species diversity, and climate change adaptation strategies can help guide specific targets. If ponderosa pine is not present at a site, additional management goals should be considered.
5) *Forest conditions that support future application of prescribed fire.* To increase opportunities for prescribed fire, projects should limit the accumulation of fine woody surface fuels and reduce large areas of connected tree crowns. This objective is evaluated by monitoring changes in surface fuel loading and potential fire behavior.
6) *Maximum area of high potential for active crown fire within treated area.* Contiguous areas greater than 25 acres of forest with a high potential for active crown fire likely allow crown fire activity to expand over the topography and natural barriers. Projects should limit the area of high potential for active crown fire to an average of 10 acres and a maximum of 25 acres. This can be evaluated across projects by spatially modeling fire behavior. When fire behavior is not modeled spatially, individual projects are evaluated by how well they reduce the potential for crown fire using field data averaged across a stand.

The USPP Landscape Resilience Objectives document can be found in Appendix 2.

Monitoring Methods

Project Descriptions

The USPP and F2F partnerships conducted numerous large-scale restoration projects. USPP completed a GIS prioritization in analysis in 2015 that identified two priority sub watersheds (USPP, 2015). Projects included in this report were coordinated and implemented in the Lower North Fork priority sub watershed. Meanwhile, the F2F partnership led numerous large-scale forest restoration projects on Forest Service land (Figure 2). Combined, these projects have built off previous fire scars to create contiguous areas of forest conditions with a lower fire hazard. Many of these projects have also been placed around important infrastructure and mountain communities, and future efforts can build off these projects to safely manage fire and improve resilient forest conditions at a landscape-scale. The entire project area is a mixture of private and public land that includes a high density of small parcels surrounding the community of Conifer in the north, Pike National Forest to the south, and large ranches and mountain parks mixed throughout the sub watershed.

CFRI engaged in adaptive management and conducted field-based monitoring at three Upper South Platte Partnership projects: Beaver Ranch, Resort Valley Ranch, and Ridge Road. Each of these projects included numerous phases and monitoring results were separated and presented by phase for each project. The USPP completed treatments between 2015 and 2018 that ranged from 22 to 150 acres in size (Table 1). CFRI also installed monitoring plots at three additional USPP projects where data collection and analyses are ongoing, and these projects were not included in this report. CFRI installed monitoring plots on four of the Forest to Faucets projects: Payne Gulch, Nighthawk - Osprey - Long Scraggy (NOS), Little Morrison, and Spring Creek. Here, treatments were implemented in 2017 and 2018 and ranged in size from 548 to 834 acres (Table 1). Forest thinning was completed on over 3,000 acres across all projects, with 446 acres treated in USPP projects and 2,572 acres treated in F2F projects. For a full description of individual projects please see Appendix 1.

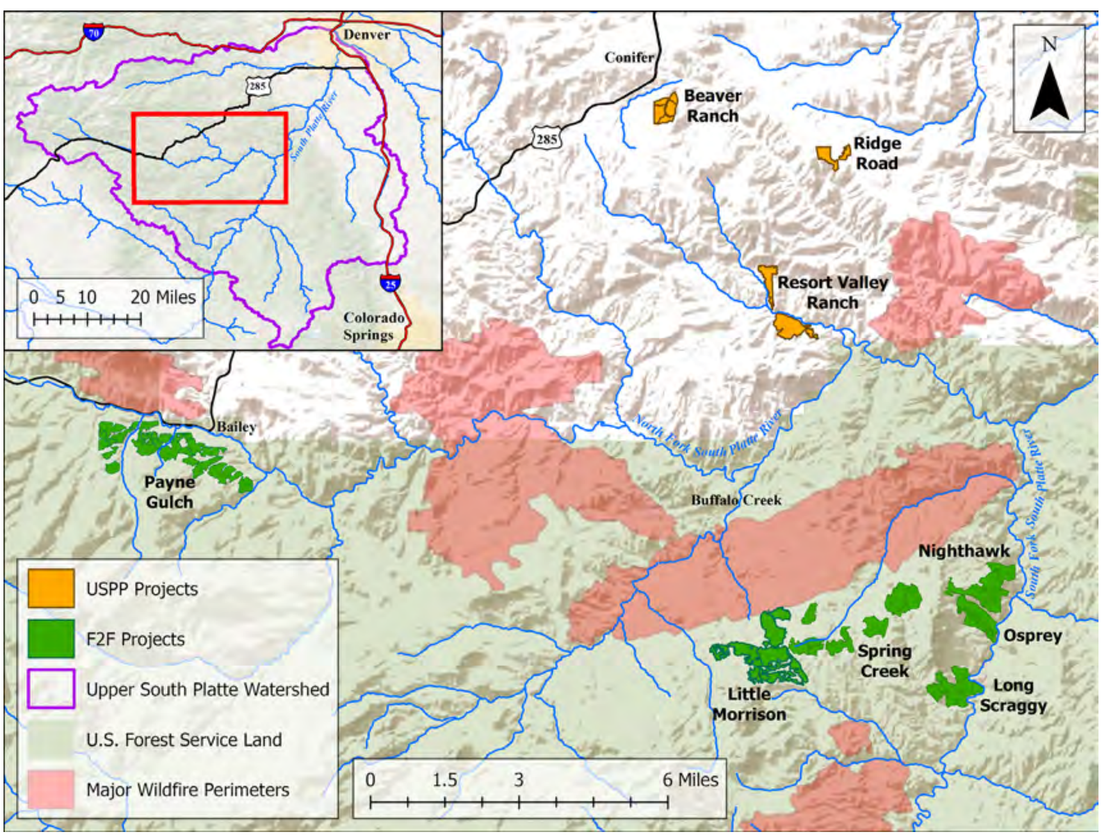


Figure 2. Map of monitored projects in the Upper South Platte Watershed.

Table 1. Implementation information for each project.

Partnership	Project	Ownership	Implementing Agency	Treatment Season and Year	Slash Treatment	Acres Treated
USPP	Beaver Ranch Phase 1	JCOS	CUSP	2015 –2016	Pile Burning and Mastication	60
	Beaver Ranch Phase 2	JCOS	CUSP	Summer – Fall 2017	Pile Burning and Mastication	73
	Resort Valley Ranch 2	Private	JCD	Fall 2016 – Spring 2017	Lop and Scatter and Mastication	78
	Resort Valley Ranch 3	Private	JCD	2017 – 2018	Lop and Scatter and Mastication	150
	Ridge Road Phase 1	Private	JCD	Fall 2015 – Summer 2016	Pile Burning and Lop and Scatter	60
	Ridge Road Phase 2	Private	JCD	Fall 2016 – Summer 2017	Pile Burning and Mastication	25
F2F	NOS	USFS	SPRD	Summer 2017	Pile Burning and Lop and Scatter	834
	Payne Gulch	USFS	SPRD	Fall 2017	Mastication and Pile Burning	545
	Little Morrison	USFS	SPRD	Winter – Spring 2018	Pile Burning and Lop and Scatter	615
	Spring Creek	USFS	SPRD	Summer 2018	Pile Burning and Lop and Scatter	578

Data Collection

To measure the effectiveness of forest restoration treatments in the Upper South Platte Watershed, CFRI used data collected from the field and aerial imagery (remotely sensed).

Field Measurement Protocols

Field crews collected data between 2015 and 2019 and visited all projects twice, within 1 year prior to treatment (pre-treatment) and 1 year following treatment (post-treatment). CFRI designed the protocol for field-based data to collect comprehensive data for assessing changes in forest structure and composition, surface fuel conditions, and understory plant communities.

CFRI applied two complementary plot layouts across all monitored projects in the Upper South Platte Watershed: The Simple Plot and the Mothership Plot (CFRI 2018a, CFRI 2018b). Simple plots were designed to quickly quantify common metrics for forest structure and composition, surface fuels, and describe the dominant shrub and herbaceous species at each plot. The Mothership plots included comparable measurements of forest structure, composition, and fuel loading, while including a more intensive measurement of the understory plant community at each plot (Table 2). Detailed descriptions for both the Simple and Mothership protocols are available on the CFRI website: https://cfri.colostate.edu/publications/

CFRI worked with each implementing agency to determine at which treatment units to place monitoring plots. Not every treatment unit included monitoring plots, and field-based monitoring data does not reflect outcomes in treatment units without plots. Plot locations were randomly determined within treatment boundaries using ArcGIS. Field crews used GPS to locate plots in the field, permanently marked plots with stakes, and recorded GPS coordinates during each visit. When a plot could not be located during the post treatment visit, or if it fell outside of the final treatment boundary, it was dropped from the analysis for this report. In general, one monitoring plot was established for every 3-20 acres of treatment, and smaller projects had a higher density of monitoring plots. For example, on average there was one monitoring plot for every 4.5 acres of treatment on the smaller USPP projects, and one monitoring plot for every 9 acres of treatment on the larger F2F projects. In total, there were 217 plots established across 1,978 acres of forest restoration treatments (Table 2).

Table 2. Monitoring information for each project.

Project	Acres Monitored	Total Plots	Acres per plot	Mothership	Simple	North Facing/ Wetter Conditions	South Facing/ Drier Conditions
Beaver Ranch 1	42	12	3.5	6	6	-	-
Beaver Ranch 2	73	17	4.3	17	0	-	-
Resort Valley Ranch 2	78	13	6.0	0	13	-	-
Resort Valley Ranch 3	134	26	5.2	0	26	14	12
Ridge Road 1	60	13	4.6	0	13	-	-
Ridge Road 2	25	13	2.8	9	4	-	-
USPP Total	412	90	4.6	32	62	14	12
NOS	787	40	19.7	0	40	21	19
Payne Gulch	75	21	3.6	12	9	11	10
Little Morrison	290	22	13.2	22	0	-	-
Spring Creek	414	40	10.4	0	40	20	20
F2F Total	1566	123	12.7	34	89	52	49
Total	1978	217	9.3	66	151	80	73

Overstory trees were inventoried using a variable radius plot determined by a wedge prism (10 or 20 Basal Area Factor) from plot center. For each tree, the following were measured: species, status (live or dead – and if dead, the decay class), diameter at breast height (DBH), total height, and crown base height (CBH). Tree seedlings and saplings were measured in a 1/100th acre plot (11.78 feet radius), where seedlings were defined as any tree shorter than 4.5 feet and saplings were any tree taller than 4.5 feet with a DBH less than 5 inches. Seedlings were recorded by species and height class. For each sapling the species, status, DBH by size class, total height, and CBH were recorded.

Tree canopy cover and tree group size were recorded along a transect that was 50 feet for Simple plots and 75 feet for Mothership plots. The transect direction was randomly chosen from plot center for Simple plots and north-south for Mothership plots. To measure tree canopy cover, a densitometer was used at every foot along the transect to count the number of points covered by any live tree taller than 4.5 ft (point intercept method). The species was recorded for every point covered by canopy. Tree group size was measured along the same transect where the start and end point of openings and canopy clumps were recorded (line intercept method). For each canopy clump, the number of live trees in each clump

Measuring DBH *Photo Credit: Kait Evensen* was counted and recorded in tree group size classes (Table 3) Trees were considered as part of the same group if canopies were interlocking or less than 5 ft apart. Shrubs were measured along this transect only at Simple plots using the line intercept method. Species and average shrub height were also recorded. For Mothership plots, shrubs were measured with the line point intercept method along eight transects radiating out from plot center.

Table 3. Tree group size classification.

Tree Group Size Class	Tree Group Name	Number of Trees	Canopy Cover Area (ft^2)
0	Open	0	0
1	Isolated	1	< 610
2	Small	2 - 4	610 - 1,220
3	Medium	4 - 10	1,220 - 3,050
4	Large	10 - 16	3,050 - 4,880
5	Continuous	> 16	> 4,880

Fine woody fuels were measured in three $1m^2$ quadrats located along a transect. Using the photoload estimating technique (Keane and Dickerson 2007) fine fuel loading was recorded for 1-hour, 10-hour, and 100-hour fuel size classes. In addition to fine woody fuels, Simple plots included an ocular estimate of groundcover, depth of litter and duff, and plant cover and height in the $1m^2$ quadrats. Mothership plots incorporated these measurements along the eight-line point intercept transects. When masticated fuels were found within any quadrat, an additional quadrat was established outside of the plot where all biomass was collected, returned to the lab, oven dried, and weighed. The oven dried weight of fine fuels was used to develop calibration equations for masticated fuel estimates (Morici and Cannon 2018).

Coarse woody fuels (≥ 1000-hour size class), greater than 3 inches in diameter, were inventoried within the 1/10th acre plot. Starting in 2019, stumps were measured and recorded as coarse woody fuels, and the plot size was changed to 1/100th acre for newly established plots only. The diameter at both ends, length, species and rotten/sound was recorded for each piece of coarse wood. Burn piles and "jackpots" of woody debris were measured as a single volumetric unit, where length, width and height of the pile was measured in the field.

For the Mothership plot understory protocol, 8 transects were established along cardinal and ordinal directions and through plot center (included the north-south transect used for tree cover and groups). Using the point intercept method at 25 evenly placed points on each transect (200 total) any plant present, woody fuels, and forest floor substrate were recorded. Each plant was identified to the species level and the height was recorded. Additionally, any plant species found in the 1/10th acre plot that was not encountered along the transects was recorded. Litter and duff depth was measured at three points on each cardinal transect.

Measuring plants *Photo Credit: Karina Puikkonen*

Remotely Sensed Data Preparation

To evaluate management goals related to improving spatial heterogeneity and increasing forest complexity, remotely sensed satellite imagery was classified pre- and post-treatment. Images were classified to identify tree canopy and openings using protocols in Cannon et al. (2018), and then classified imagery was delineated into forest gaps and tree groups. First, leaf-on, cloud-free, and when possible snow-free imagery was acquired pre- and post-treatment that covered the entire treatment area for each project (Table 4). Imagery was orthorectified using a 10-meter (32.6 feet) elevation model, georeferenced using a base map, and resampled to a 3-meter (9.8 feet) resolution for consistency across monitoring projects. We derived the normalized difference vegetation index (NDVI) to aid in classification (Lillesand et al., 2015). Approximately 100 training areas were stratified in each image and random forest classification was used to classify each image into canopy, openings, and shadows. To test the accuracy of the classification, a confusion matrix was calculated by withholding a random subset of 20% of the training areas (Congalton and Green 2009). NDVI values of regions classified as shadows were then re-classified into canopy and openings using a grey-level threshold estimated as the local minimum frequency NDVI-value among shadow areas. The final product was a classified canopy raster, where each cell was categorized as canopy or opening.

Table 4.

Project	Phase	Image Date	Satellite
Beaver Ranch	Pre	2013-Jun-21	WV02
	Post	2018-Mar-16	GE01
Resort Valley Ranch	Pre	2016-Jun-11	GE01
	Post	2018-Aug-09	WV02
Ridge Road	Pre	2015-Nov-09	WV02
	Post	2018-Aug-09	WV02
NOS	Pre	2016-Oct-16	WV02
	Post	2018-Aug-30	GE01
Payne Gulch	Pre	2016-Aug-21	GE01
	Post	2019-July-13	GE01
Little Morrison	Pre	2014-Nov-28	GE01
	Post	2019-Sep-13	WV02
Spring Creek	Pre	2017-June-19	WV02
	Post	2019-July-13	GE01

Large forest gaps were identified from the classified canopy raster and defined as all continuous regions with <5% canopy cover over an area of 0.11 ac (40 ft radius). Although gaps can be defined variously depending on the ecological process of interest, this scale was chosen because resource abundance and growth of regenerating seedlings are predictable in neighborhoods of an approximately 40 feet radius in size (Boyden et al 2012). Tree groups were then delineated from the classified canopy layer by combining neighboring cells categorized as canopy using the 8-cell rule. The 8-cell rule amalgamated canopy cells into a tree group polygon that share either an edge or a corner.

Analysis

To determine if treatment outcomes met the goals and objectives, a suite of metrics was compared before and after treatment to assess changes for each project individually, across projects within each partnership, and across all projects combined. Analyses were designed to assess projects in relation to the Landscape Resilience goals set by the USPP, and highlighted metrics of canopy cover, species composition, tree arrangement, fuel loading and potential fire behavior. However, traditional (e.g. basal area, average tree size) and forest gap metrics were also included to provide further evaluation of each project. USPP goals and objectives are based on concepts from GTR-373 (Addington et al. 2018) and Battaglia et al. (2018). Because the USFS has been a member of the USPP from the start and contributed to defining restoration goals, all F2F projects were evaluated using the same format as USPP projects.

Individual Projects (Monitoring summary reports Appendix 3)

Individual project monitoring summaries (Appendix 3) are divided into three main sections: stand structure and composition, spatial heterogeneity, and fire behavior. Stand structure and composition results highlight changes in canopy cover, the ratio of ponderosa pine, and traditional forest structure metrics. Spatial heterogeneity results use field data and aerial imagery to identify changes in forest gaps and tree groups. Fire behavior modeling uses field data to estimate fuel loading and model the potential fire behavior pre- and post-treatment.

Stand Structure and composition

We used R (R Development Core Team 2021) to calculate forest structure and composition metrics related to the USPP goals, including the ratio of ponderosa pine, canopy cover, and tree group arrangement.

Canopy cover was calculated using counts from the point intercept method for tree cover, as the proportion of the transect occupied by tree canopy. Tree group arrangement was calculated from the line intercept method for tree group size, where each tree group size class was presented as the average percent cover. The sum of the percent cover for each size class represented a second estimate for canopy cover. Overstory species composition, and specifically the ratio of ponderosa pine, was calculated by basal area (BA, ft^2/acre) and trees per acre (TPA). The ratio of ponderosa pine to other conifers was presented in the project monitoring summaries (Appendix 3) as the percent by basal area.

Many traditional forestry metrics (e.g. changes in BA and TPA) for stand structure and composition were also included in this report because project prescriptions included these metrics. Changes in BA and TPA were reported to provide information about thinning targets, thinning intensity, and species favored for removal. Other metrics highlighted in this report included seedlings per acre by species, quadratic mean diameter (QMD), and average CBH.

Spatial Heterogeneity

To assess changes in spatial heterogeneity, metrics were calculated pre- and post-treatment from the large forest gap and tree group data produced from the classified canopy raster. Using individually identified gaps and tree groups, average size, size range, and size variability using the coefficient of variation (standard deviation/mean) were calculated. The median shape index was included as a way to assess shape complexity where a higher value indicated forest gap or tree group shapes that had more edge (McGarigal et al. 2012). The classified canopy raster provided an additional estimate of canopy cover, where the percent canopy cover equaled the number of cells classified as canopy divided by the total number of cells within each project treatment boundary. Lastly, the tree group data was separated into size class bins comparable to the size classes from the tree group arrangement analysis using field data (Table 3). To place each individual tree group polygon into a size class bin, one tree was assumed to cover approximately 305 ft^2 of canopy. Other studies have used this value to represent the canopy of a single tree (Cannon et al. 2018, Churchill et al. 2013) and is based on the 33rd percentile of ponderosa pine canopy diameter.

Fire Modeling

To understand how changes in forest structure and surface fuels altered fire hazard, we input field data from pre-treatment and post-treatment monitoring visits into the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) (Anderson et al. 2020; Reinhardt and Crookston, 2003). All modeling runs used the Central Rockies variant in FVS. Field-collected monitoring data for overstory trees, saplings, seedlings, woody fuels, and ground fuels were prepared in R to a format that could be processed in FFE-FVS. The program then selected up to two of 53 standard fire behavior fuel models for each unit (Anderson, 1982; Scott & Burgan, 2005).

Potential fire behavior and effects were modeled under both severe and moderate fire weather and fuel moisture conditions (Table 5). Severe fire conditions corresponded to days with extreme fire danger or 97th percentile weather conditions. Moderate fire conditions represent typical conditions under which prescribed fires may be implemented. We determined that FFE-FVS program values for the Central Rockies variant were congruent with 97th percentile conditions reported from geographically-proximate Remote Automated Weather Stations (RAWS) and thus adequate to characterize severe conditions, with the exceptions of temperature and herbaceous fuel moisture. To better approximate 97th percentile fire weather conditions observed from RAWS data, we revised the FVS default temperature of 70° F to 90° F, and revised default herbaceous fuel moisture of 120% to 30%. This was done because herbaceous fuel moisture varies throughout the fire season—97th percentile weather conditions can occur when the herbaceous fuel is actively growing and has higher moisture content, or when herbaceous fuel is dormant and cured. We simulated a fire under severe conditions with a cured herbaceous layer, and under moderate conditions with a live herbaceous layer.

Fire simulations for pre-treatment and post-treatment stands were compared to evaluate the changes in fire hazard produced by mitigation activities. FFE-FVS modeled fire behavior and fire effects outputs include torching index, crowning index, fire type, total flame length, and surviving BA. Torching index and crowning index represent the expected windspeed needed to initiate individual tree and group torching and active crown fire behavior, respectively.

Table 5. Weather conditions used to model fire behavior in FVS-FFE.

Fire Weather Conditions	Temperature (°F)	Wind (MPH)	Live Herb Fuel Moisture (%)
Severe	90	20	30
Moderate	70	5	120

Analysis Across Partnership and All Projects combined

Following analyses at individual sites, projects were then combined and assessed within partnerships and across all projects. Analysis across projects was divided into categories that loosely align the USPP Landscape Resilience goals and objectives: canopy cover (goals 1&2), forest gaps and tree groups (goal 3), ratio of ponderosa pine (goal 4), and fuel loading and fire behavior (goals 5&6). Canopy cover analyses used data from the line intercept method averaged across plots to assess changes in canopy cover for each partnership and across all projects. The canopy raster produced from aerial imagery was used to compare forest gaps and tree groups before and after treatment. Every identified gap was used to analyze average gap size and median gap shape for each partnership and across all projects. Gap cover, gap variability, percent canopy cover by isolated trees, and percent canopy cover by continuous canopy were calculated across each project to determine averages for each partnership and all projects. The ratio of ponderosa pine was examined for both overstory trees and seedlings. Both BA and TPA were compared and averaged across projects. Lastly, surface woody fuel loading, total flame length, torching index, and crowning index were reported for each partnership and across all projects by averaging values for each individual project.

Results

Canopy Cover

Prior to forest restoration treatments the average canopy cover across all projects was 48.9%, and thinning successfully reduced canopy cover to an average of 27.1% (Table 6). Thinning intensity was highly variable across projects, and resulted a wide range of canopy cover between individual projects. Post-treatment canopy cover ranged from 13-43% across USPP projects and 16-40% across F2F projects. When only looking at canopy cover within individual projects it could appear that some projects did not meet canopy cover goals (see Appendix 3 for individual project results). However, these projects collectively came very close to the 30% canopy cover goal, while maintaining variability in canopy cover across the landscape.

Another way to look at the variability in canopy cover is at the plot scale, where ideally the full range of canopy cover from 0-100% would be recorded before and after treatment. More than 200 plots were included in the final analysis, and they represented

Table 6. Average percent canopy cover across all monitored plots before and after treatment. Canopy cover fell below 30% when projects were combined by partnership and across all projects.

Partnership	Mean		Median	
	Pre	Post	Pre	Post
USPP	52.5 ± 3.5	26.7 ± 3.0	53.5	21.5
F2F	47.2 ± 2.4	27.5 ± 2.4	48.5	24
All	48.9 ± 2.0	27.1 ± 1.9	49.5	23

the full range of canopy cover before and after treatment. Additionally, monitoring plots were more likely to record open forest conditions post-treatment, and the resulting distribution of canopy cover aligned more closely with USPP goals and desired conditions (Figure 3).

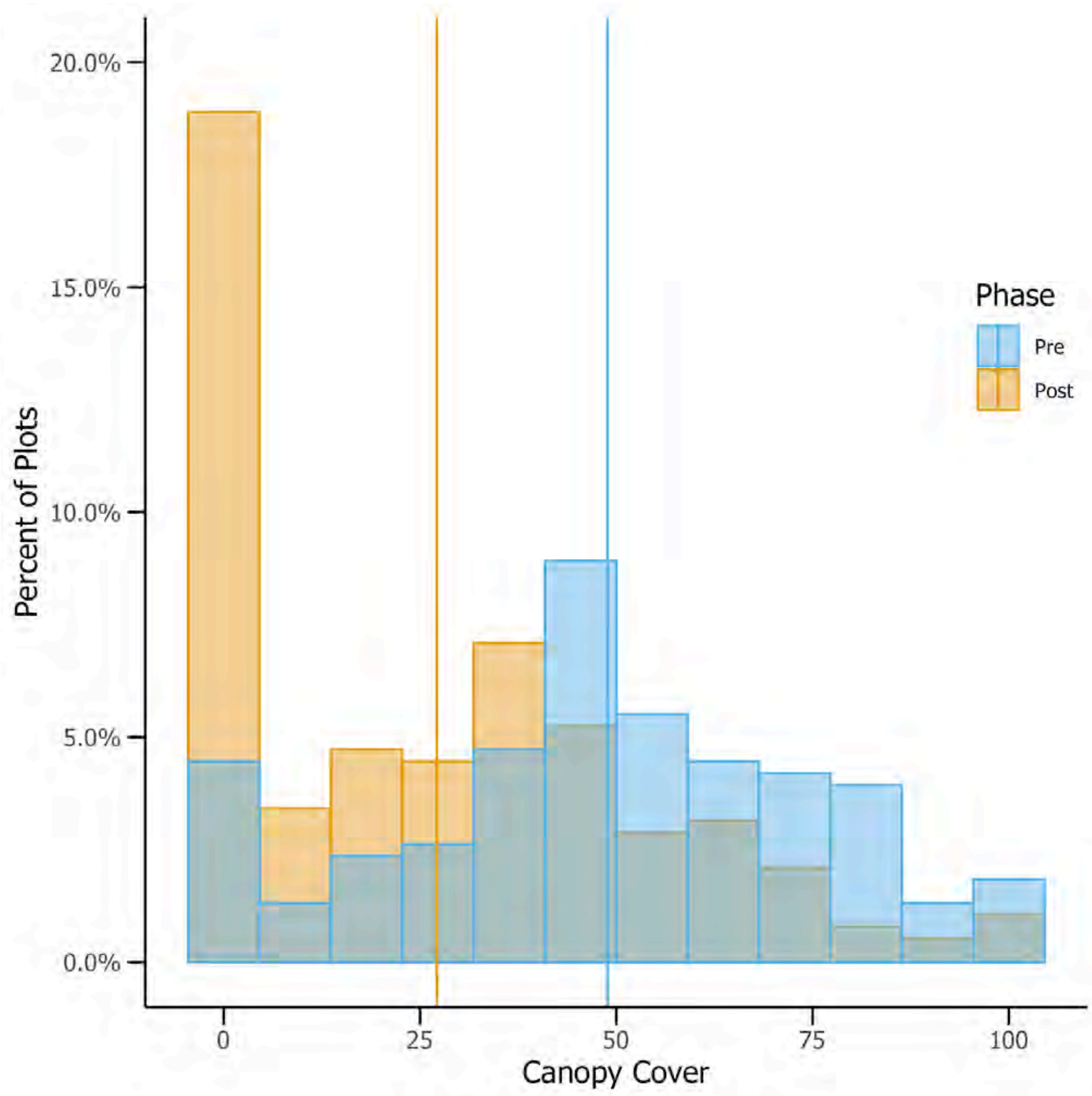


Figure 3. Distribution of canopy cover pre- and post-treatment across all monitoring plots. The Y-axis is the % of all plots and the x-axis is canopy cover. The darker areas show where the distributions for pre- and post-treatment canopy cover overlap. The orange areas show an increase in the percent of plots from pre- to post-treatment, and the blue areas show a decrease. The vertical lines mark the mean canopy cover pre- and post-treatment.

Forest Gaps and Tree Groups

Thinning was successful at creating more forest gaps across all projects and collectively increased gap coverage by nearly 37% (Table 7). Furthermore, forest gaps larger than a couple acres were rare prior to treatment, but thinning increased the average gap size to 3.5 acres. Gap size also became more variable following treatment (i.e. higher coefficient of variation, CV). This led to a wide range in gap size where small gaps continued to persist while more large gaps were created. Lastly, thinning created gaps that were more irregular in shape (i.e. shape index), and indicated more forest edge post-treatment. The combination of higher gap size variability and more gap shape irregularity suggests that forest thinning increased spatial heterogeneity and forest habitat diversity.

Large tree groups greater than 16 trees and continuous canopy made up over 90% of canopy cover before restoration treatments (Table 8). Thinning successfully broke up much of the continuous canopy and increased the presence of smaller tree groups. Individual or isolated trees only occupied about 2% of total canopy cover pre-treatment, and increased to about 10% following treatment. However, when comparing post-treatment conditions to USPP goals and historical reference conditions (25% relative canopy cover in isolated trees, Brown et al. 2015), treated areas were still dominated by large tree groups and individual trees were underrepresented. Spring Creek had the largest increase in individual trees following treatment, but all other USPP and F2F projects did not meet the target of 25% canopy cover represented by individual trees. One potential explanation could be operational limitations; managers often reported leaving untreated reserves because slopes within the treatment unit were too steep for mechanical thinning or landowners preferred to leave certain stands within the treatment unit. Identifying these limitations during project planning and understanding the impacts of intentionally leaving large tree groups can help foresters adjust goals and treatment prescriptions to reflect desired outcomes. However, additional strategies to overcome treatment constraints should be collaboratively discussed at future projects if foresters want to continue working towards the current goals for tree group arrangement.

Table 7. Changes in forest gap characteristics before and after treatment.

Partnership	Cover (%)		Average Size (acres)		Size Variability (CV)		Shape Index	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
USPP	11.3	52.6	0.57	3.96	0.97	2.02	0.97	1.02
F2F	7.4	37.2	0.48	2.77	1.46	2.37	0.94	0.98
All	9.7	46.4	0.53	3.48	1.17	2.16	0.95	0.98

Table 8. Individual and continuous canopy tree group percent cover of total canopy cover.

Partnership	Individual tree group (<2 trees, %)		Continuous canopy (>16 trees, %)	
	Pre	Post	Pre	Post
USPP	2.8	11	91.2	68.6
F2F	1.2	8.3	96.4	62.9
All	2.1	9.9	93.3	66.3

Ratio of Ponderosa Pine

Forest restoration treatments successfully met the goals for tree species composition by increasing or maintaining the ratio of ponderosa pine. Prior to treatment, ponderosa pine was present at every project, and thinning increased the percent of ponderosa pine by BA at seven of the ten projects (Table 9). When the percent of ponderosa pine BA was lower following treatment, the drop was minimal or thinning maintained a relatively high ratio of ponderosa pine that was present pre-treatment. Half of the projects showed a decrease in percent ponderosa pine by TPA, but 3 of these projects increased percent ponderosa pine in terms of BA. When percent ponderosa pine decreased by TPA but increased by BA, thinning removed more ponderosa pine compared to other conifers in smaller diameter classes (DBH < 10 in), but left larger diameter ponderosa pine in place.

Projects in the USPP increased the percent of ponderosa pine by an average of 13.3% by BA and 6.0% by TPA. Resort Valley Ranch had the largest increases by BA, where percent ponderosa pine within treated areas increased by 20% following phase two and nearly 30% following phase 3. Goal 3 of the USPP Landscape Resilience objectives called for increasing the ratio of ponderosa pine or maintaining existing high ratios, encouraging managers to emphasize the removal of other less fire- and drought-resistant tree species in treatment prescriptions. F2F projects only slightly increased the percent of ponderosa pine. However, ponderosa pine was relatively more abundant to begin with and treatments successfully maintained ponderosa pine dominance in stands where it already existed. Payne Gulch is a good example of this, where treatments did not aim to restore a desired species composition, but rather maintained a preexisting nearly pure ponderosa pine forest. See Appendix 3 for monitoring results for each individual project.

Thinning treatments can have an immediate impact on tree species composition, but it is also important to consider conditions for future tree regeneration—including residual stand density and existing seedling composition—when evaluating goals to promote ponderosa pine in the long run. This report only shares data collected 1-year post treatment, and

Table 9. Ratio of ponderosa pine before and after treatment at each project. The percentage of ponderosa pine increased at most projects.

Project	By Basal Area (%)			By Trees per Acre (%)		
	Pre	Post	Difference	Pre	Post	Difference
Beaver Ranch 1	2.1	9.1	7	0.6	6.9	6.3
Beaver Ranch 2	19.5	15.8	-3.7	5.5	5.3	-0.2
Resort Valley Ranch 2	57	77.4	20.4	25.5	29.3	3.8
Resort Valley Ranch 3	36.3	65.6	29.3	7.6	18.1	10.5
Ridge Road 1	43.4	60.4	17	32.4	27.2	-5.2
Ridge Road 2	13.4	23.6	10.2	14.2	34.7	20.5
USPP projects combined	28.6	42.0	13.4	14.3	20.3	6.0
NOS	49.3	47.5	-1.8	29.6	40.5	10.9
Payne Gulch	92.2	90	-2.2	84.8	83.6	-1.2
Little Morrison	29.7	32.6	2.9	13.1	10.6	-2.5
Spring Creek	50.1	64.4	14.3	26.8	26.6	-0.2
F2F Projects Combined	55.3	58.6	3.3	38.6	40.3	1.8
All Projects Combined	39.3	48.6	9.3	24.0	28.3	4.3

it was too soon to capture any tree regeneration response to the treatments. Therefore, it will be important to track trends over time, as thinning will have impacts on future tree regeneration for many years following treatment.

Ponderosa pine seedlings were somewhat scarce at USPP projects prior to treatment, and comprised less than 5% of all tree seedlings across all projects (Figure 4). Treatments only slightly increased the ratio of ponderosa pine seedlings to other species; however, the percent of Douglas-fir seedlings did fall by 13% following treatment and the percent of other species such as aspen increased. F2F projects did not increase the ratio of ponderosa pine seedlings, but had a comparatively higher proportion of ponderosa pine seedlings pre-treatment that was maintained following thinning. For example, Payne Gulch had the largest drop in the ratio of ponderosa pine seedlings of any project, but continued to have the highest percent of ponderosa pine seedlings following treatment at 73%. Furthermore, thinning created more favorable conditions for ponderosa pine regeneration by reducing overall stand density, opening up the canopy, and allowing more light to reach the forest floor. Changes in seedling composition may begin to shift in favor of ponderosa pine, and future post-treatment monitoring visits may be able to detect this shift.

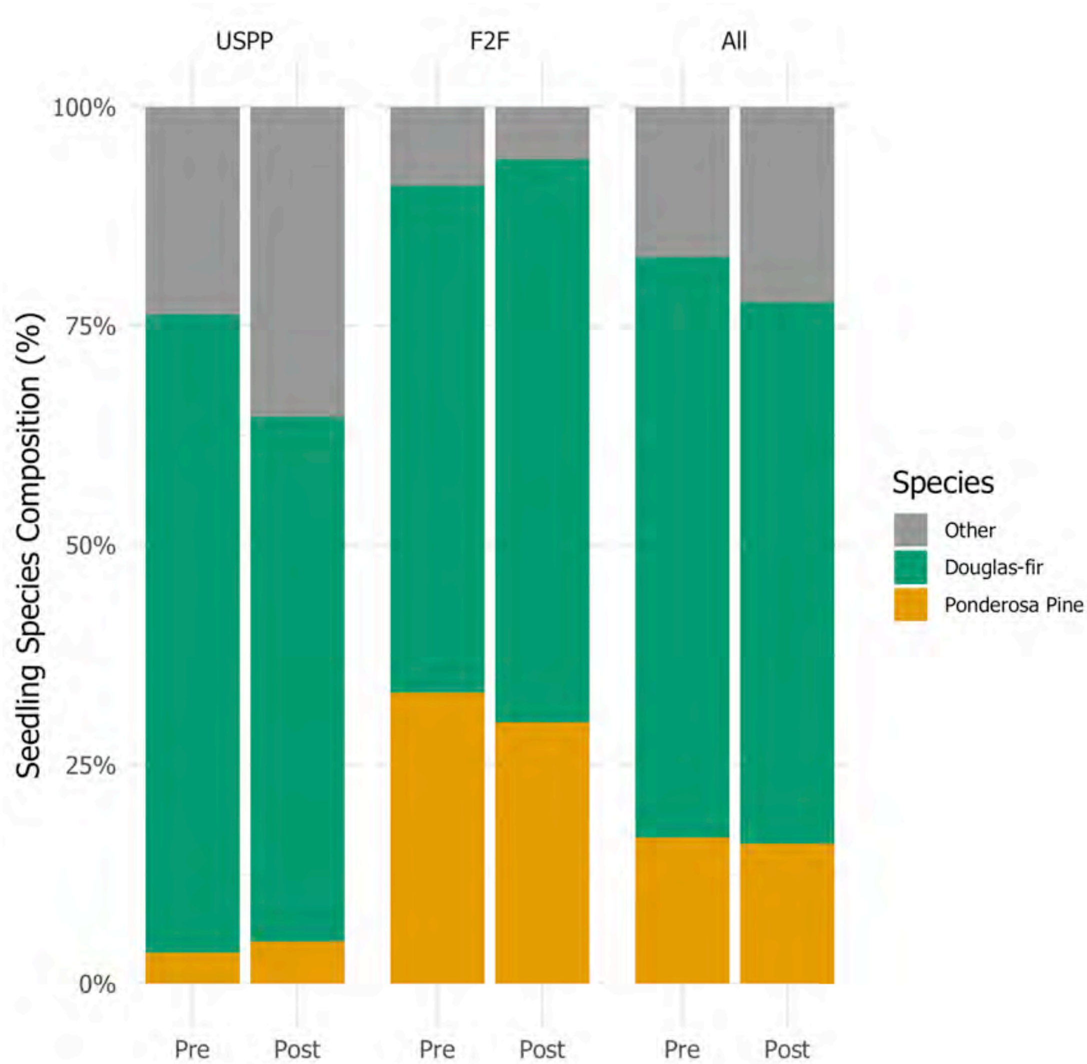


Figure 4. Seedling composition before and after treatment. Percent ponderosa pine seedlings at USPP projects slightly increased following treatment, but remained low. F2F projects maintained a ratio of ponderosa pine seedlings around 1/3 of all seedlings.

Fuel Loading and Potential Fire Behavior

USPP and F2F projects were successful in limiting the amount of woody fuels added to the forest floor following treatment. On average, fine woody fuel loading increased by 14% and coarse woody fuel loading increased by 28% (Table 10). However, when considering the amount of cut material created from thinning the increase in fuel loading was minimal. The projects with the highest post-treatment woody fuel loading were Ridge Road phase 1 and Spring Creek (see Appendix 3 for individual project results), but total woody fuel loading remained below 6 tons/acre at both projects. Surface fuel loading within other thinning and mulching treatments has been shown to increase 2-3 fold in Colorado forests to values well above 12 tons/acre (Battaglia et al. 2010).

Managers were able to avoid large increases in fuel loading in the Upper South Platte Watershed by using a variety of slash treatments. Nearly every project included a product removal component, where cut material was removed off site and sold when the wood had value. Furthermore, managers used pile burning, grind and haul, and mastication to further reduce and break down the remaining woody fuel. The ability to remove slash off site and burn slash piles likely had a strong influence on limited higher fuel loading post-treatment. For example, the Resort Valley Ranch and NOS projects had the largest increases in fuel loading following thinning, but these projects had limited or no product removal because of non-merchantable material and lack of access, respectively. The results from projects in the Upper South Platte Watershed highlight the importance of fuels and slash treatment following restoration thinning to achieve desired conditions. Surface fuel loading following many of these projects creates more favorable conditions to use prescribed fire for future management.

Modeled fire behavior suggested that wildfire risk was largely reduced across all projects following treatment. The average total flame length under severe fire weather conditions was cut in half from 22.8 feet to 11.7 feet (Table 11), and active crown fire was not predicted at any project. Total flame length was predicted to be higher post-treatment at three projects. Payne Gulch had the largest increase, but FFE-FVS predicted surface fire before and after treatment, and total flame length only increased by 3 feet to just over 6 feet. On average the torching index

Table 10. Average surface woody fuel loading (tons/acre)

Partnership	Fine Woody Fuel Loading		Coarse Woody Fuel Loading		Change in Total Woody Fuel Loading
	Pre	Post	Pre	Post	
USPP	1.54	2.08	2.21	2.33	0.67
F2F	1.32	1.04	1.97	3.25	1.00
All	1.45	1.66	2.11	2.70	0.80

Table 11. Total flame length (feet) before and after treatment. Total flame length was modeled under moderate and severe weather conditions.

Project	Pre		Post	
	Moderate	Severe	Moderate	Severe
USPP	1.8	27.7	1.9	12.8
F2F	2.3	15.6	2.0	10.1
All	2.0	22.8	2.0	11.7

increased by 75% to 15.8 mph, and crowning index nearly doubled to over 50 mph (Figure 5). Finally, nine of the ten projects predicted surface fire under moderate weather conditions following fire. Forest thinning greatly increased the opportunity for the use of prescribed fire in the future at both USPP and F2F projects.

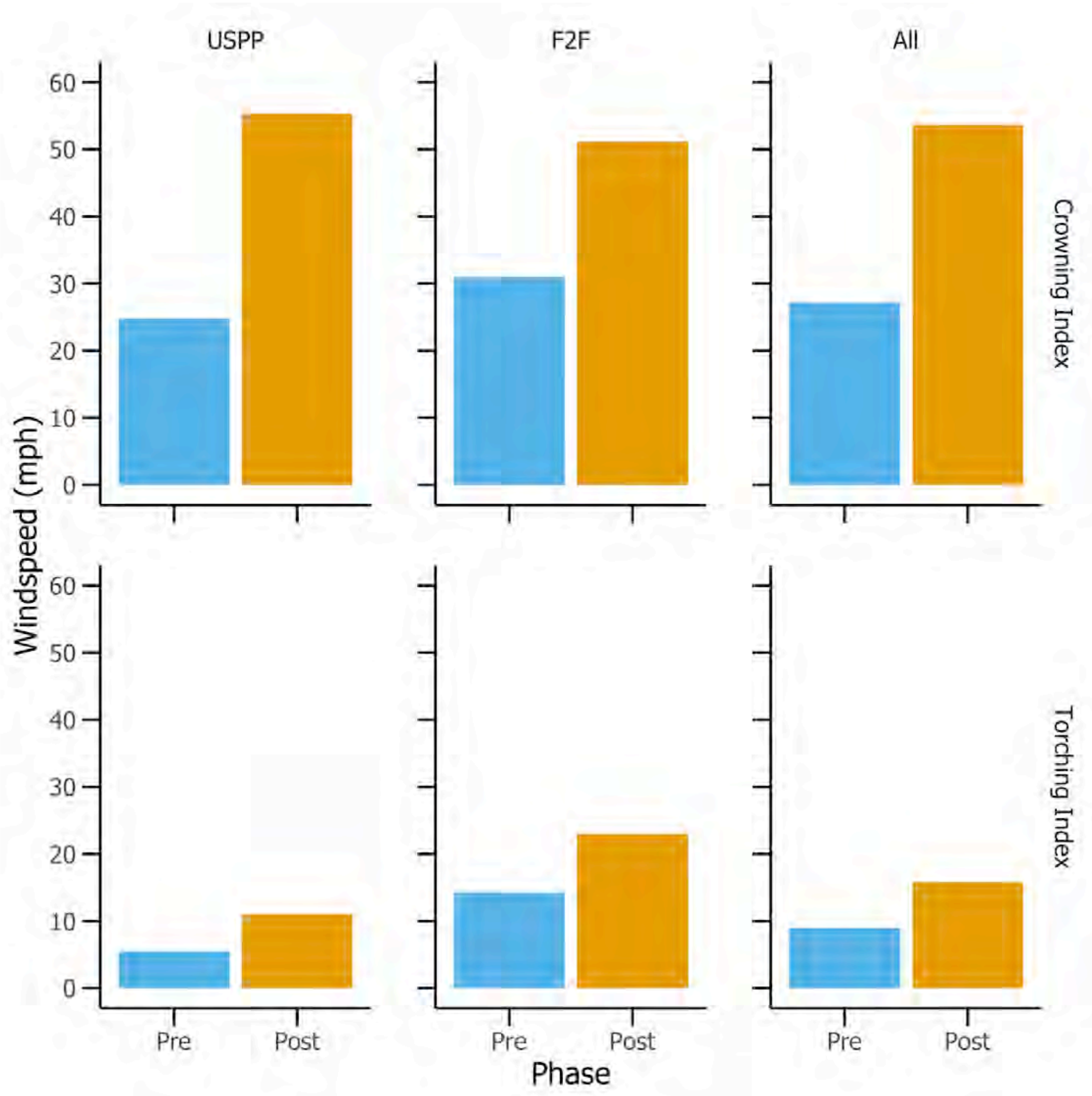


Figure 5. Torching index and crowning index before and after treatment. Indices estimate the wind speed needed initiate torching and crown fire activity. A higher value indicates a lower risk of individual or group torching and active crown fire.

Adaptive Management

During the spring of 2020, CFRI compiled ecological monitoring results from individual projects into draft summary reports and shared them with the lead implementing organization and partner organizations in the Upper South Platte. These draft reports were used as a tool to cultivate adaptive management discussions about each organization's projects, and the USPP and F2F as a whole. The goals of these targeted discussions were to learn from completed projects, identify actions to progress forest management in the future, and reflect on specific project outcomes and collaboration over the last 5-10 years.

CFRI met with each organization virtually through video conference calls during March and April of 2020. First, the monitoring results for individual projects were reviewed and assessed based on how well they had met the partnership's goals and objectives. Then, big-picture discussion topics evaluated and identified what's working, barriers that make management difficult, and potential actions to improve collaborative forest management. Topics included monitoring, planning and implementation, climate change adaptation, prescribed fire, applied science, using the GTR-373 (Addington et al. 2018), and collaboration. The adaptive management discussions were part of a related but separate effort to evaluate how managers use the GTR-373 (Brown et al., *In prep*). Lastly, the monitoring results from all projects were presented to a collective group of partners from the USPP and F2F. Following that presentation, discussion included polling questions that gauged management priorities. All discussion questions and polling results can be found in Appendix 4.

Prioritization

Most managers emphasized that coordinating with partners and identifying opportunities for cross boundary work is a driving force for prioritization within their respective organizations. For example, initial prioritization in the Lower North Fork sub watershed was effective in getting partners to coordinate projects and create larger areas of contiguous treated landscape. During the adaptive management discussions, some managers mentioned that some projects in the Lower North Fork were not a priority for their organization until resources and collaboration through the USPP brought partners together to focus on the priority watershed. Previous prioritization was based on wildfire risk, and polling questions asked during the group discussion (Appendix 3) continued to identify wildfire risk as the most important factor when prioritizing forest restoration treatments. However, managers highlighted other factors that they would like to see considered in future prioritization efforts:

1. Climate change vulnerability
2. Ingress/egress for safe emergency response
3. Prioritization at smaller scales to identify specific areas within sub watersheds that will have the greatest impact
4. Treatment accessibility and feasibility
5. Recreation
6. Wildlife

Recent and ongoing planning efforts to develop Community Wildfire Protection Plans and forest management plans for individual organizations have started to include some of the prioritization needs mentioned above.

Implementation

Mangers identified the following difficulties with implementation:

1. Park users concerned with closures and aesthetics
2. Equipment issues when work is completed in house
3. Disagreement between mangers and private landowners
4. Neighboring landowners
5. Contractor availability
6. Terrain and lack of access
7. Cost and increasing scale
8. NEPA restrictions (USFS projects)

Climate Change

Restoration projects in the Upper South Platte currently address climate change from a high level, landscape-scale perspective and most managers have not directly considered climate change when developing projects or marking stands for treatment. Managers described an indirect approach to incorporating climate change into management decisions by: leaning on the USPP goals and objectives to generally improve forest health; applying broad concepts such as promoting forest diversity across scales; and aligning treatment goals intended to reduce wildfire risk with increasing forest resiliency to drought, insects and fire. Managers would like to take a more direct approach to incorporating climate change, and identified the following topics as learning opportunities:

1. Climate modeling to have a better understanding of how conditions will change
2. Climate vulnerability assessments.
3. Continued long term monitoring to see how past treatments are holding up under climate change
4. Species migration and how management actions can facilitate acceptable change
5. Direct mitigation strategies: reducing carbon emission during operations, promoting carbon sequestration
6. Strategic reforestation in burn scars
7. How to use changes in topography as a guide

Mangers recognized that climate change presents a lot of uncertainty, and it's difficult to determine specific management actions without having clear targets for future conditions. However, continuing to expand and improve the toolbox of management strategies will increase the ability to manage for an uncertain future under climate change. Concepts from Millar et al. (2007) and Swanston and Janowiak (2012) that have been used in the Adaptive Silviculture for Climate Change project (https://www.adaptivesilviculture.org/) can be resources for managers to expand restoration planning that includes specific goals focused on climate change adaptation. Throughout the adaptive management discussions managers mentioned being pro-research, and were open to experimenting on future projects. This could involve planting seedlings from lower elevations or further south in the species range following thinning projects. Future adaptive management discussions through the USPP can address the learning opportunities listed above, provide avenues to collaboratively plan research to learn more about local climate change impacts, and push future management to directly consider climate change adaptation.

Prescribed fire

Following thinning, fire is an important management tool to lower fire hazard by reducing or eliminating the non-merchantable slash. From the perspective of fire hazard, forest thinning could potentially be counterproductive when slash is left on site. Ever since the 2012 Lower North Fork Fire (an escaped prescribed fire), managers have been ambivalent about the use of fire in the Upper South Platte Watershed. Pile burning has been limited, especially on private land, and broadcast prescribed fire has not been used in the Upper South Platte since 2012.

There are numerous barriers that prevent managers from implementing broadcast burning and pile burning. Those presented in discussion within the collaborative include:

1. Air quality impacts on local communities and the larger Denver metro area has made permitting difficult.
2. Dense WUI creates few opportunities for managed wildfire or larger prescribed burns, complicating operational efficiency and effectiveness.
3. Burn windows using traditional burn strategies are brief and capacity is limited, so resources and weather rarely align.
4. Burning in past treatments with masticated fuel beds complicates burn plans and faces resistance.
5. Community support for fire is lacking, and maintaining strong communication and outreach with the neighboring community and fire managers is difficult.

Prescribed fire in northern Colorado *Photo Credit: Katarina Diaz-Warnick*

At times, expanding the use of fire as a forest management tool in the Upper South Platte seems unattainable. However, these barriers are actually quite common throughout Colorado and the western U.S. (Schultz et al. 2018), and learning from local and regional collaboratives that have shown success can help resolve barriers (e.g. Northern Colorado Fireshed Collaborative, Front Range Roundtable, statewide organizations like the Prescribed Fire Council, and The Nature Conservancy national TREX fire training program). Furthermore, effective collaboration through the USPP is beginning to address many of these obstacles and the idea of prescribed fire use is gaining momentum in the watershed. Local fire protection districts are increasing staff and capacity and getting more interested in participating in prescribed fire implementation. Lastly, the USPP has established a united front to advocate for the use of prescribed fire. The collective voice of USPP partners improves support from the community to pursue more pile and broadcast burning, and strengthens efforts to involve regulators and policy makers at the state level in overcoming barriers.

Joint forest visits

The USPP and F2F partnerships strive to achieve science-based management; however, translating science-based forest management goals into on-the-ground decisions is difficult. To bridge the gap between high level concepts and implementation, managers expressed a desire to have more field trips involving managers and scientists so the forest can be used to demonstrate concepts. Managers mentioned joint forest visits as an effective and collaborative approach to address the following topics:

1. Tree marking and project layout techniques
2. Collaboratively developing and planning projects
3. Identifying the desired or rare structures in the forest that should be retained and promoted
4. Using topography and microsite conditions as a guide
5. Climate change adaptation
6. Reviewing monitoring results
7. Public outreach and education

Field Workshop at Spring Creek
Photo Credit: Katherine Oldberg

Monitoring

Managers in the Upper South Platte recognized the importance of coupling restoration actions with structured ecological monitoring to evaluate outcomes. However, managers also acknowledged that in the past monitoring was often a lower priority when resources and personnel were limited, and when there was a high backlog of forest stands needing treatment. Therefore, leaning on collaborative groups such as the USPP and F2F to assist with monitoring has been crucial for managers to measure project success. During the adaptive management discussions, feedback about the metrics being presented in the summary monitoring reports was generally positive. Managers appreciated the inclusion of traditional metrics, such as basal area and trees per acre, that often form the foundation for prescriptions. However, adding assessment of non-traditional metrics such as canopy cover, tree group arrangement, and forest gaps helped foresters link prescriptions to partnership goals and better capture spatial heterogeneity in desired outcomes. Managers were comfortable including goals that addressed non-traditional metrics, but there was still uncertainty about how and if these metrics could be directly incorporated into project prescriptions.

In addition to the information presented in this report and the monitoring summary reports (Appendix 3), managers identified other metrics and analyses to include in monitoring at future projects. In particular, managers expressed interest in including:

1. Understory plant communities, regeneration, and noxious weeds
2. Wildlife use and habitat features such as snags and associated plant species
3. Erosion potential and water quality monitoring in the absence of wildfire
4. Soil monitoring
5. Social monitoring and public perception of treatments
6. Spatial and advanced fire modeling

Data currently collected as part of CFRI's Mothership protocol can provide information about changes in understory plant communities, tree regeneration, noxious weeds, and protected or uncommon plant species. However, plant community responses to forest restoration treatments often take 3-5 years to develop, and future data collection and analysis will address these topics. CFRI monitoring data can also track forest structure and plant species important for specific wildlife habitat. Lastly, CFRI will continue to expand upon the current presentation of potential fire behavior, and provide information to answer questions related to forest management impacts of wildfire behavior. Monitoring wildlife use of treated landscapes, erosion potential, soils, and socio-economic impacts will require collaboration with scientists across disciplines.

Future Research Needs

During the adaptive management discussions, managers said that there is currently plenty of scientific information on ponderosa pine ecosystems. Additionally, the GTR-373 was identified as a great resource that synthesizes all of the pertinent ecological information managers need to inform restoration actions in ponderosa pine forests. However, managers frequently brought up needing more scientific understanding for forest restoration and desired conditions in higher elevation forests, and forests without a ponderosa pine component. Managers described using approaches similar to those they take in lower montane when working in higher elevation forests, and recognized that might not be right. In addition, managers recognized that building long term resilience to climate change likely requires different strategies moving up the slope. At higher elevations, ecological objectives are potentially less aligned with the immediate fire risk reduction goals to protect homes, water supplies, and other values at risk that define restoration goals at lower elevations. Foresters will benefit from more flexibility to explore different treatment options for managing higher elevation forests in the Upper South Platte, with a greater emphasis on research and monitoring to increase learning from these projects. This could include a simple experimental treatment design adjusting factors such as thinning intensity and target species composition across projects.

Managers also identified many future research interests not related to forest ecology. Specifically, the following was mentioned:

1. Biomass utilization: supply analyses, alternative or novel wood products development.
2. Operational methods: accessing steep slopes, increasing efficiency, reducing treatment cost, and building the relationship between contractors and foresters.
3. Socio-economic impacts: working with private landowners, recreation impacts, and restoration impacts on the local economy.
4. Tree marking and project layout efficiency.
5. The USPP and F2F partnership provide a path forward to bring in additional partners and researchers to help answer these questions. Sometimes new research will be needed, but other times managers can connect with experts through presentations, workshops, and conferences to gain knowledge from existing research.

Collaboration

A strong collaborative culture exists in the watershed, and many managers highlighted the USPP as an effective partnership with engagement from a wide range of stakeholders. There is strong support from leadership within each partner organization, and the partnership was well funded during phase one. Managers were able to coordinate projects and combine areas of cross-boundary treatments. Furthermore, over the past 5 years partners started to collaborate on individual projects, overcoming access and capacity barriers. For example, crews from the fire protection districts have carried out pile burning and thinning on smaller scale projects and on steeper slopes. The partnership also provided a forum that supported good communication between management and science. Numerous meetings and field trips provided learning opportunities that strengthen management based on the best available science. Lastly, the USPP goals and objectives are frequently used as a framework to develop projects, and have helped link managers to the guiding principles described in the GTR-373.

During the adaptive management discussion, managers identified a few factors that could help improve the partnership effectiveness:

1. Leadership within the partnership is lacking: creating a position that is focused on the partnership and is responsible for taking the lead on overcoming challenges.
2. Better communication with the public and local communities
3. Committing more time to maintaining relationships with all partners
4. Revisit and update the partnership's founding documents, roles, and responsibilities.
5. Ensuring that the right people attend the right meetings, and keeping the Management and Science Team focused on collaboratively planning projects.
6. Building stronger consensus around the guiding principles for forest restoration and how to implement those principles on the ground.

Over the past 5 years there was turnover within partner organizations and with USPP members, and more stakeholders came to the table. The change in personnel brought new interests and needs that have obscured the role of the partnership. Evaluating the role of partnership and adjusting the organizational structure is a relevant step in the adaptive management cycle that could provide clarity for the USPP and maintain effective collaboration in the Upper South Platte Watershed.

Post-treatment ponderosa pine stand in the Upper South Platte Watershed *Photo Credit: Andrew Slack*

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Appendix 1: Detailed Project Descriptions

USPP

Beaver Ranch

Beaver Ranch is a 450-acre community park located in the wildland urban interface surrounding Conifer, Colorado. The park is owned by Jefferson County Open Space and managed by non-profit, Beaver Ranch Community, Inc. Under the park's mission the partnership between JCOS and BRCI is responsible for managing numerous values, including recreation and natural resources for benefit of park visitors. More information about Beaver Ranch Park can be found the Master Plan:
https://www.jeffco.us/DocumentCenter/View/9884/Beaver-Ranch-Park-Master-Plan?bidId=

In 2015, the Coalition for the Upper South Platte (CUSP) was brought in to lead forest restoration on 132 acres of the park. The project was one of the first to be funded and collaboratively planned under the USPP. Phase one treatments began on the western half of the project area, and completed 60 acres of mechanical thinning in 2016. The treated area was on primarily on east to southeast facing aspects with elevations ranging from 8,250 – 8,400 feet. The pre-treatment forest type was dry mixed conifer dominated by lodgepole pine and Douglas-fir. In addition to following the USPP goals and objectives, prescriptions were specifically designed to favor ponderosa pine and aspen, and create irregular openings. A total of 12 monitoring plots were installed on 42 acres of phase one, and field data does not cover the north treatment unit.

Phase two treatments completed the eastern half of the project area in 2017, and thinned a total 72.5 acres. The treated area for phase two was on a northwest to north aspect, and elevation ranged from 8,200 - 8,500 feet. Similar to phase one, the pre-treatment forest type was dry mixed conifer and mostly dominated by lodgepole pine and Douglas-fir. The treatment area in phase two had wetter site conditions and likely influenced a denser stand when compared to phase one. Treatment prescriptions were planned to favor ponderosa pine and aspen, and to create openings with small patch cuts of lodgepole pine. The thinning intensity was intended to be relatively lighter due to the wetter site conditions. A total of 17 monitoring plots were placed across the entire 72.5 acres of the phase two treatment area.

Resort Valley Ranch

Resort Valley Ranch East Inc is a private entity that owns 2,550 acres in southern Jefferson County. RVRE began working with the Jefferson Conservation District (JCD) in 2016 as part of the Pine Country Lane project that included 9 landowners and approximately 232 acres of forest restoration. The landowners at RVRE continued to work with JCD to implement forest restoration and protect their land from the negative impacts of high-severity wildfire. RVRE experienced approximately a dozen lightning-caused ignitions a year and the landowners gained firsthand knowledge of the risks that potential wildfire behavior posed to the Ranch. The RVRE was identified as a priority area for forest restoration because the high potential for post-fire erosion and its proximity to the Richmond Hill neighborhood.

Phase two of the project completed close to 100 acres of forest thinning in 2017. The treatment unit was on a south to southwest aspect with elevations ranging from 7,000-7,300 feet. The historical forest type was likely dominated by ponderosa pine, but has shifted to have an abundance of Douglas-fr and Rock Mountain Juniper. The prescription was designed to target mostly small diameter Douglas fir and Juniper to increase the representation of larger diameter ponderosa pine. Additionally, thinning was aimed to create forest gaps to expand the presence of open meadows that promote native grass-forb-shrub communities. 13 monitoring plots were established across 78 acres of the treatment unit.

Phase three shifted to the north facing slopes of the property and across the drainage from phase two. Thinning operations were completed on 150 acres in 2018. A mixed confer forest type was likely present historically on the gentle slopes with an elevation ranging from 6,800-7,200 feet. However, in the absence of fire, large patches of dense, small diameter Douglas-fir have established. Thinning treatments were planned to remove mostly small diameter Douglas-fir, and increase the presence of forest gaps. A total of 26 plots were installed across 134 acres of the project, and were separated by dry or wet site conditions.

JCD continues to work with the landowners at RVRE, and have added and additional 239 acres of forest restoration as part of phase 4 that was mostly completed in 2019. However, no CFRI monitoring plots were installed in the phase 4 treatment area and this report only included results from phase two and three.

Ridge Road

The Ridge Road project includes a series of smaller scale treatment units on private property owned by several homeowners along the ridgeline that makes up the eastern boundary of the Lower North Fork sub watershed. JCD began working with homeowners in the neighborhood in 2015, and more properties have joined the project since.

Phases one and two of the Ridge Road project completed mechanical and hand thinning operations on 60 and 22 acres, respectively. The aspect faced south on the gentle slopes of the board ridgeline, and elevations within the treatment units ranged from 8,500-8,700 feet. The higher elevation of the project area is in the transition from the lower to the upper montane where dry mixed conifer forests are more widely present when compared to lower elevations. The prescription called for mostly removing Douglas-fir to increase the ration of ponderosa pine. In the anticipation of drier conditions in future with a greater risk of fire the treatment strategy was to increase overall forest resiliency. To achieve this goal, prescriptions favored ponderosa pine and larger diameter trees in the mixed conifer forest. There a total of 22 plots that were measured pre- and post-treatment, with 13 plots in phase one included and 9 plots and phase two.

Forests to Faucets

Payne Gulch Environmental Assessment

The Payne gulch project was located on the north facing slopes of the North Fork of the South Platte River near the town of Baily. The elevation ranged from 7,700 feet along the North Fork of the South Platte to 8,800 feet on the ridgeline above. Forest restoration in Payne Gulch was covered under the Payne Gulch Fuels Management Project Environmental Assessment. The primary purpose of the project was to implement hazardous fuel reductions and reduce the risk of high-intensity wildfire surrounding the recreation residences across 1,652 acres. Additionally, treatments were designed to improve forest health and enhance ecological diversity. The Decision Notice and Finding of No significant Impact can be found here: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5429824.pdf

Between September and December of 2017, 548 acres were treated in Payne Gulch. The forest type was predominately ponderosa pine; however due to years of fire exclusion tree density and basal area were higher than historical conditions. This likely resulted in a loss of the mosaic pattern of vegetation that historically promoted higher forest resilience to fire, drought, insects and disease. Ponderosa pine was high in abundance prior to treatment relative other project areas in the Upper South Platte Watershed. Therefore, prescriptions aimed to reduce canopy cover and fire risk while maintaining ponderosa pine and larger trees of all species. Thinning also intended to increase spatial heterogeneity and restore a mosaic pattern across the landscape by creating more forest gaps and tree groups.

CFRI installed monitoring plots in two treatment units that covered 75 acres of the project area. The first unit was on a north facing aspect (north unit) and the second was south facing (south unit). These units were selected to compare differences between north and south facing aspects. A total of 21 plots were installed and surveyed pre- and post-treatment, with 11 plots the north unit 10 plots in the south unit.

Upper South Platte Environmental Assessment

CFRI installed monitoring plots on three projects covered under the Upper South Platte Watershed Protection and Restoration Project Environmental Assessment. These projects included Nighthawk, Osprey, and Long Scraggy (NOS), Little Morrison, and Spring Creek, and are described in detail below. The project area covered in the EA included 140,000 acres of private and public lands across three sub watersheds: Horse Creek, Waterton/Deckers, and Buffalo Creek. Most projects were located between the burn scars from the Buffalo Creek and Hayman fires, and were designed to create a connected fuel break across the landscape. The Decision Notice and Finding of No significant Impact can be found here: https://www.fs.usda.gov/detail/psicc/landmanagement/planning/?cid=fsm9_032631

The primary objectives of forest restoration treatments were to protect water quality, reduce the risk of large-scale wildfires, and create sustainable forest conditions. Specifically, the use of thinning and prescribed fire was described in the EA as methods to restore less dense forest conditions with a greater presence of forest gaps and meadows. These conditions historically provided wildlife habitat, and were more resilient to wildfire. As new scientific information became available project prescriptions evolved to meet updated goals and objectives, including the goal of increasing spatial heterogeneity that supports a mosaic pattern of vegetation across the landscape.

Nighthawk, Osprey, and Long Scraggy (NOS)

The NOS project was located along the east facing slopes along the South Fork of the South Platte river. Elevations within the project boundary ranged from 6,200 feet at the river to over 8,700 feet at the summit of Long Scraggy peak. Forest thinning operations occurred during the summer of 2017 and completed a total of 834 acres. The steep terrain and lack of accessibility limited thinning operations to mostly hand thinning and building burn piles to treat slash and cut material.

The project area covered a relatively large area and range of elevation, and therefore forest type changed along topographic gradients. Generally, ponderosa pine was the dominant overstory tree species at lower elevations, southern aspects and along open ridge pines. When forest conditions were wetter at higher elevations and on northern aspects, Douglas-fir was the most common over story tree species. Some juniper was present at lower elevations and aspen stands occurred on south aspects at higher elevations. Prescriptions targeted mostly smaller diameter trees to reduce tree density and retained ponderosa pine and larger diameter trees. Canopy cover was reduced to create varying tree groups sizes ranging from 2 to greater than 50 trees.

A total of 40 plots were installed during the fall of 2016 and summer of 2017 covering 787 acres of the project. Plots were then separated between north and south aspects to examine how treatments varied on different aspects and stand conditions. There were 21 plots located on north aspects and 19 on south aspects.

Little Morrison

Little Morrison was one of the first projects implement concepts from the GTR-310 and GTR-373. The project was located to the west of the Deckers road and south of the Buffalo Creek fire. The project area consisted of gentle slopes facing northeast, and elevations ranged from 7,600 to 8,000 feet. In additional to ecological goals, forest restoration treatments needed to consider additional values. The area is heavily used for recreation, including hiking and mountain biking, and is a popular location for Christmas tree cutting.

During the late winter and spring of 2018, a total 615 acres were thinned. Operations included mechanical thinning with product removal and some pile burning of slash. The SPRD experimented using heavy equipment during the winter months when there was snow on the ground in hopes of mitigating any negative impacts to soils and the understory. The project included mostly a dry mixed conifer forest type dominated by Douglas-fir. Prescriptions aimed to reduce tree density and canopy cover and favor ponderosa pine and larger diameter trees for retention. Thinning also considered maintaining some smaller diameter Douglas-fir that were desirable for Christmas tree cutting, and would typically be mostly removed at other projects. In 2017, CFRI established a total of 22 plots across 290 acres of the project.

Spring Creek

The Spring Creek Project was located to the east of Deckers road, across from the Little Morrison project and connected to the NOS project to the east near Long Scraggy Peak. Slopes within the treatment boundary were gradual, facing mostly northwest with elevations ranging from 7,500 – 7,800 feet. During the summer of 2018, 578 acres of dry mixed conifer forest were thinned. The historical forest was likely dominated by ponderosa pine, and prescriptions were designed to restore the ponderosa forest type. Across the entire project area, basal area per acres was about the same for Douglas-fir and ponderosa pine prior to treatment, with slightly more Douglas-fir on north facing slopes and more ponderosa pine on south aspects. A Total of 40 plots were installed and then separated between north and south aspects for analysis.

Appendix 2: USPP Landscape Resilience Objectives

Upper South Platte Partnership Landscape Resilience Management Objectives For Ponderosa Pine and Frequent Fire Montane Forest Restoration Activities			
Measure	**Desired Condition**	**Measure**	**Source**
(1) Mean conifer canopy cover over the sub watershed scale (HUC 12)	Average 30% (range 0-100%) within currently forested areas over the entire 55,000 acre sub-watersheds by the year 2030	Remote Sensing	Front Range Stand Reconstruction Network
(2) Reduction of conifer tree cover, while maintaining a complex mosaic of forest canopy cover at stand scales	Maximizing variability within each project from 0-100%, with 30% average conifer canopy cover (acceptable average 10-40%) within each project.	Remote Sensing and/or Field Based Measure	Front Range Stand Reconstruction Network, Front Range Roundtable Landscape Restoration Team, Desired Forest Structures for a Restored Front Range, Professional Judgment
(3) Arrangement of conifer canopy cover within treated stands	~25% of canopy cover in individual trees ~75% of canopy cover in groups of 2+ trees	Field Based Measure	Front Range Stand Reconstruction Network
(4) Conifer species composition	Increased ratio of ponderosa pine to other conifers where present, but OK if 100% ponderosa to start.	Field Based Measure	Front Range CFLRP Monitoring Plan, Desired Forest Structures for a Restored Front Range, Front Range Stand Reconstruction Network
(5) Forest conditions that support future application of prescribed fire	Limit accumulation of fine woody fuel on the soil surface and minimize or isolate large areas of connected tree crowns.	Field Based Measure, Burn Boss Consultation	Burn Plan Complexity Criteria
(6) Maximum area of high potential for active crown fire within treated area	10 acres average (range: 0 acres to 25 acres)	Remote Sensing	Desired Forest Structures for a Restored Front Range, Professional Judgment

Upper South Platte Partnership Landscape Resilience Team
Landscape Resiliency Objectives Rationale

Strategy

- These objectives were created to be easy to implement and measure without needing any modeling.
- The landscape resilience goals are embedded in an inclusive, holistic goal of seeing fewer trees on the landscape in order to reduce the risk of high severity fire. The basic premise of reducing tree density will accomplish all the project evaluation criteria, and can be measured as implementation monitoring. More intensive and strategically targeted effectiveness monitoring, including forest spatial structure, species diversity, herbaceous plant abundance and diversity, etc., will determine actual treatment effectiveness.
- Desired conditions are cited in ranges or averages, leaving room for project creativity and context-specific success.
- All averages, ranges, and thresholds come from specific scientific sources upon which the USPP Landscape Resilience Work Group members and their organizations have agreed to, in concept; sources are consistent to promote cohesion.
- These goals are based on historic, current, and future climate and weather patterns. We aim to use past climate and associated forest structure to inform resilient landscapes for future climates, and not create landscapes that return to a past static state, while also considering current social context.
- Projects can still be successful without achieving all desired conditions.
- Colorado Front Range Collaborative Forest Landscape Restoration Program monitoring goals are not explicitly included in the landscape resilience goals, but all the concepts are addressed.

Management Objective Metrics

(1) Mean conifer canopy cover over the sub-watershed scale (HUC 12)

- The average canopy cover should be 30 percent across the entire watershed over the long term.
- Treatments should be working towards the larger goal of lowering conifer canopy cover on a sub-watershed scale. This is a big picture goal over the next several decades and not something to consider for each project.

(2) Reduction of conifer tree cover, while maintaining a complex mosaic of forest canopy cover at stand scales

- The range of tree cover at any one spot within a project is 0 percent to 100 percent and this variability should be maximized, allowing for flexibility and natural variances. Naturally more productive and denser areas (e.g. north facing slopes) could – and should – be higher density, but in order to increase landscape resilience at a meaningful scale the project should be large enough to isolate these denser areas and/or reduce tree densities to average desired range of 10 – 40% within the project area.
- A conifer canopy cover range of 10 percent to 40 percent discourages clearcuts in entire project areas, encourages reductions that will have a high chance of success for reducing crown fire and fire severity, while still allowing for flexibility in naturally denser areas, such as north-facing slopes. The average condition as measure in the Front Range Stand Reconstruction study was 30% canopy cover. We chose a higher maximum desired condition of 40% to allow for more flexibility in designing projects.
    - 40% canopy cover is a threshold in some fire models (Fuel Characteristic Classification System) when a crown fire is highly unlikely to occur.
    - The range of 11-40% is the 'low density' cover class in the Desired Forest Structures for a Restored Front Range. This low density cover class is lacking on landscape, most in need of

management intervention to maintain, and the forest structure most likely to be resilient to future disturbances.
  - Rob Addington estimates that ~55% canopy cover is the minimum when FlamMap determines a fire can transition from a surface fire to a crown fire in the South Platte area.
- Conifer tree cover is measured at a stand scale. There are likely, but not always, multiple stands within a project based on similar forest composition and site productivity. The average canopy cover across all stands in a project is desired to be 10-40%, thus some strands could be much denser than others, and some much more open, but the average across the project should be in the 10-40% range while also meeting as many of the other objectives as possible.

(3) Arrangement of conifer canopy cover within treated stands

- Treatments should be focused on increasing spatial heterogeneity and complexity, favoring single trees and groups over evenly spaced single trees. New studies are showing that reducing tree density in a patchy framework significantly reduces fire hazard similar to management techniques of even spacing and raising crown base height, while also increasing ecological services and resilience.

(4) Conifer species composition

- Ponderosa pine and Douglas-fir are both important tree species components on the landscape, and we are not promoting the eradication of Douglas-fir or selection of ponderosa at every site.
- Desired species composition at each site is qualitative due to specific site conditions. We encourage looking for evidence of old trees and forest structures to determine basic stand conditions and forest history.
- At lower elevations, small diameter Douglas-fir are much more abundant than historical conditions indicate and removing these small Douglas-fir trees increases forest resilience. Maintaining Douglas-fir on the landscape is important for landscape resilience in the event insects, pathogens, or other disturbances decimate ponderosa pine, but significant reductions of Douglas-fir generally increase resilience.
- Data show the current species abundance ratio of large trees (ponderosa to other conifers) is very similar to the historic ratio in 1860. Looking to the future, retaining large douglas fir on the landscape is important for species diversity, which increases landscape resilience.
- At higher elevations or more productive wetter stands, if ponderosa pine is not present at the project site it's less clear how management will increase forest resiliency and achieving the USPP Landscape Resilience goals. We suggest using the presence of *any* ponderosa pine as a proxy indicator species for being near the "Goldilocks" zone where forest restoration and community protection intersect, and management to increase landscape resilience is most likely to succeed. If management is proposed in higher elevation lodgepole pine dominated stands that lack any ponderosa, there needs to be a clear explanation of how treatment will increase landscape resilience and the USPP goals.
- Ponderosa pine does not need to be and should not be the dominant species at every project site, e.g. a project that moves from 90-10 to 80-20 other conifer to ponderosa pine ratio would be a success in higher elevation wetter sites. Similar to retaining some douglas fir at lower elevation dryer sites, retaining some ponderosa to increase species diversity as higher sites is desirable.

(5) Forest conditions that support future application of prescribed fire on the landscape

- We want to provide for the potential use of prescribed fire in the project area at some point in the future. Treatments need to be designed to avoid leaving fuel conditions that are non-conducive to prescribed fire activities.

- This can be measured by speaking with fire management officers, prescribed fire managers, or burn bosses to determine appropriate treatment methods to allow future prescribed fire use.
- Generally low intensity prescribed burns are desired and fuel conditions to support this and minimize areas of active crown fire potential should be targeted. While some prescribed fire goals aim to include large areas of active crown fire for ecological purposes, the social context within the Upper South Platte watershed make these types of burns unlikely in the foreseeable future.

(6) Maximum area of active crown fire within treated area

- Weather conditions greatly impact the probability of crown fire, but there are actionable steps based on scientific information that can be taken to reduce the potential.
- At higher elevation and/or more productive sites, patches of crown fire can be ecologically desirable in treatment areas. However, given WUI and other values, those patches should be minimal in size and broken up by adjacent areas where crown fire is highly unlikely even under the most extreme fire weather scenarios.
- Area of active crown fire in treated areas greater than 25 acres will increase the probability of undesirable high-severity post fire outcomes.
- Based on opinion of the group, contiguous areas of active crown fire greater than about 25 acres will create crown fire conditions that likely expand over topography and other natural barriers, indicating that project size was too small or not aggressive enough to have a meaningful impact on the landscape scale fire dynamics.

Appendix 3: Individual Project Monitoring Reports

Beaver Ranch Phase 1

COLORADO FOREST RESTORATION INSTITUTE | FOREST AND RANGELAND STEWARDSHIP COLORADO STATE UNIVERSITY

Upper South Platte Partnership Monitoring Summary
Beaver Ranch Phase 1

Goals and Objectives:

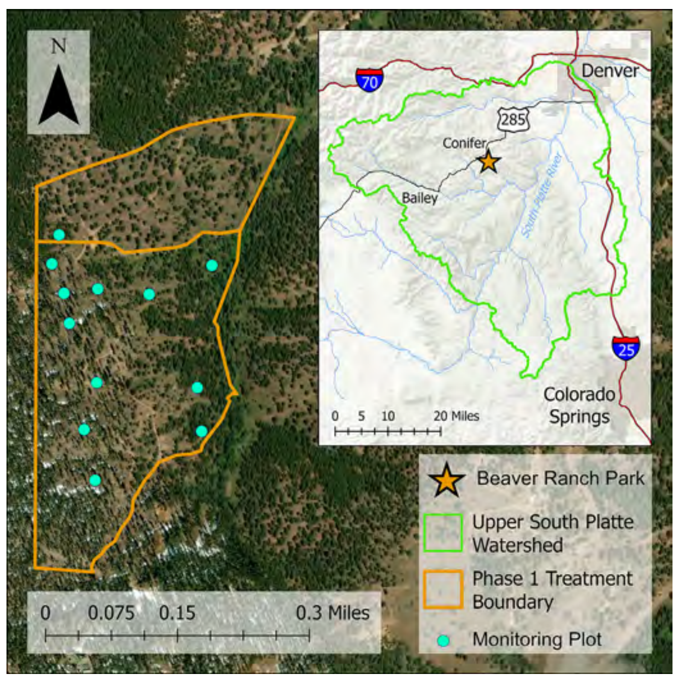
Phase 1 treatments were designed to: retain ponderosa pine and aspen while reducing Douglas-fir and lodgepole pine; create more forest openings; increase age diversity; and reduce the potential for high severity wildfire. The landscape resilience management objectives for the Upper South Platte Partnership include: reducing mean canopy cover; maintaining a complex mosaic of forest canopy; increasing the ratio of ponderosa pine to other conifers; and creating conditions that support the future use of prescribed fire. More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu.

Highlights:

The project was successful in reducing canopy cover to a mean of 31.5%, and mostly removed Douglas-fir and lodgepole pine. This resulted in a higher ratio of ponderosa pine, although the stand remains dominated by other conifers. After thinning treatments, larger trees were more prevalent, and size diversity increased. Furthermore, treatments reduced the potential for undesirable high severity fire, and created conditions that could facilitate future use of prescribed fire. The coverage of forest openings increased to over 50%, with a greater presence of larger and more complex gaps, enhancing diverse habitat availability. The treatment facilitated field tours and adaptive management opportunities as a public demonstration site.

Table 1. Project Information

Implementation agency	Coalition for the Upper South Platte
Ownership	Jefferson County Open Space
Year completed	2016
Acres treated	60
Acres monitored	42
Forest type	Mixed conifer
Implementation method	Mechanical thinning
Slash treatment	Product removal, mastication, pile burning




Pre-treatment

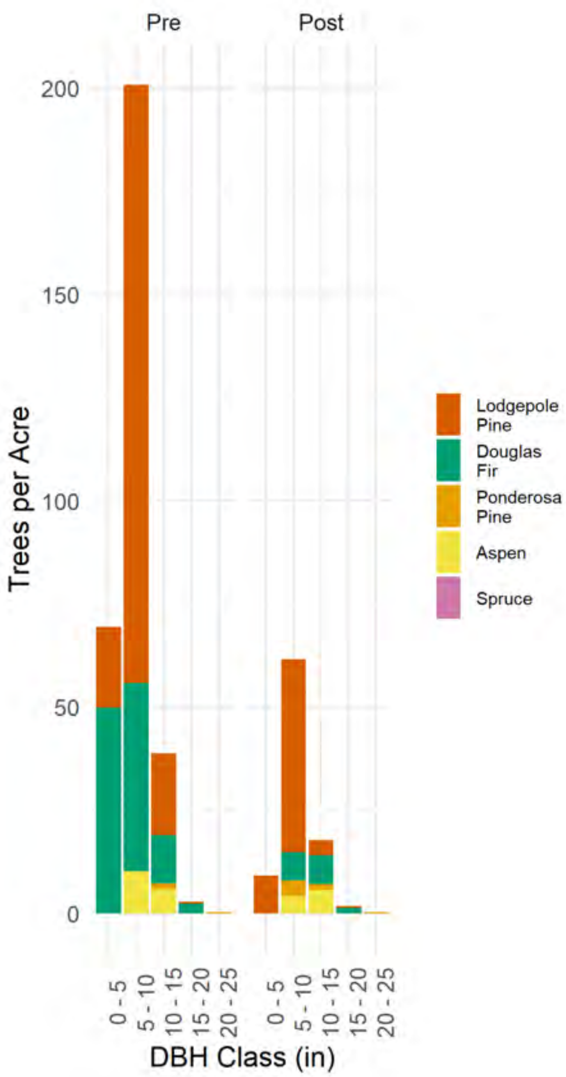
1 year post-treatment

Stand Structure and Composition

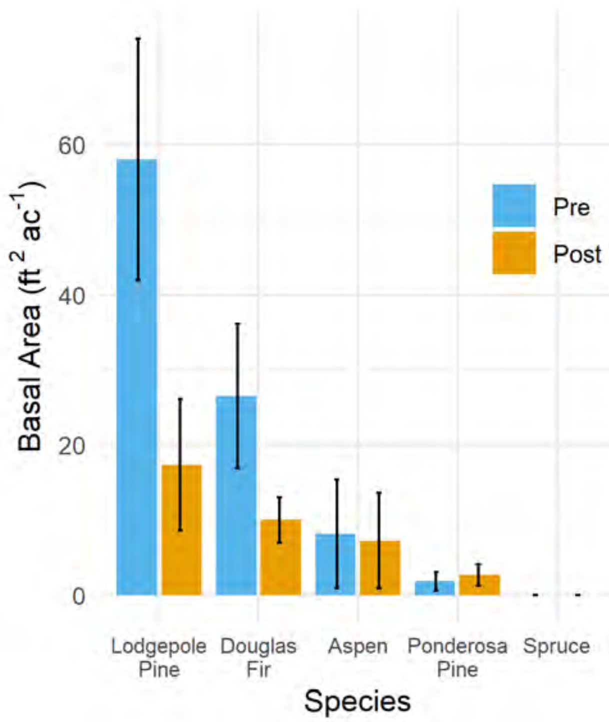
Table 2. Stand characteristics pre- and post-treatment

Phase	Trees per Acre	Basal Area (ft²/ac)	Canopy Cover (%)	Seedlings per Acre	Percent Ponderosa by BA	Quadratic Mean Diameter	Crown Base Height (ft)
Pre	312 ± 72	94 ± 15	51 ± 5.7	385 ± 98	2.1	8.0 ± 0.5	11.4 ± 2.1
Post	90 ± 33	37 ± 9	31.5 ± 6.5	174 ± 89	9.1	10.0 ± 0.9	12.2 ± 2.6

Stand characteristics pre- and 1 year post-treatment



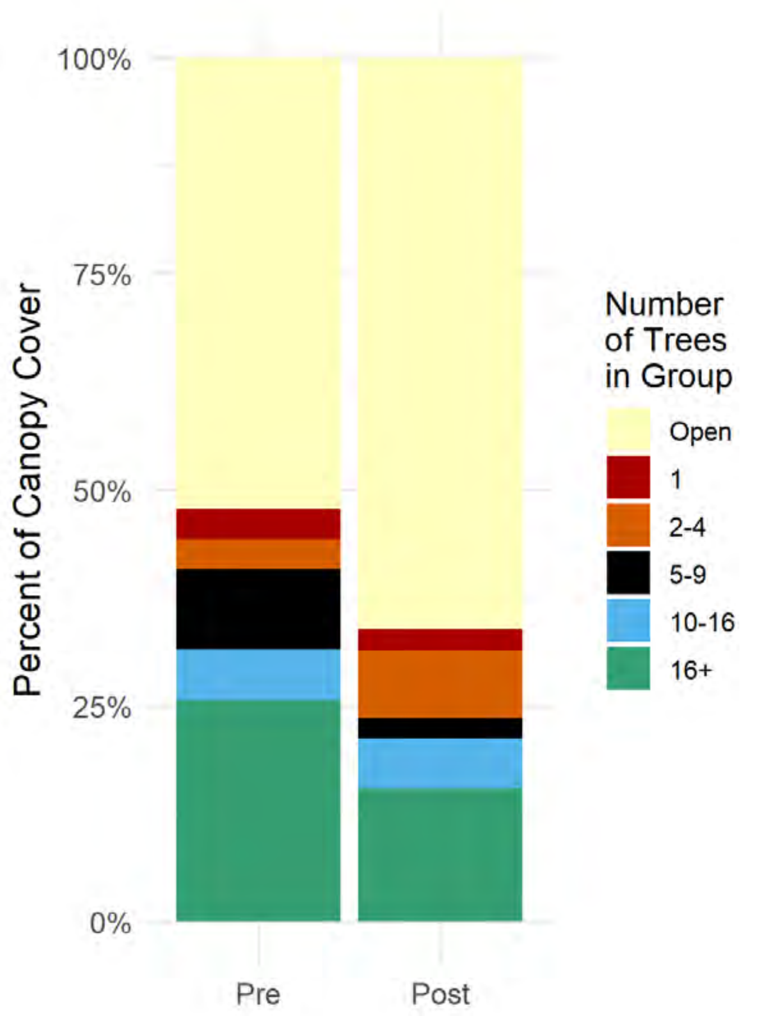
Change in basal area by species



Methods: Data was collected on the ground from 12 plots to assess the changes in stand structure and composition.

Highlights: Thinning treatments were most effective in reducing smaller-diameter lodgepole pine and Douglas-fir, but these species continue to have a greater presence than ponderosa pine.

Spatial Heterogeneity



Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: Thinning was successful in reducing overall canopy cover by breaking up contiguous canopy into smaller tree groups. The proportion of canopy cover represented by isolated tress increased, but remained below 25 percent. Treatments also increased forest openness by creating variously sized gaps and increased gap shape complexity.

Table 3. Changes in tree groups pre- and post-treatment (remote sensed data).

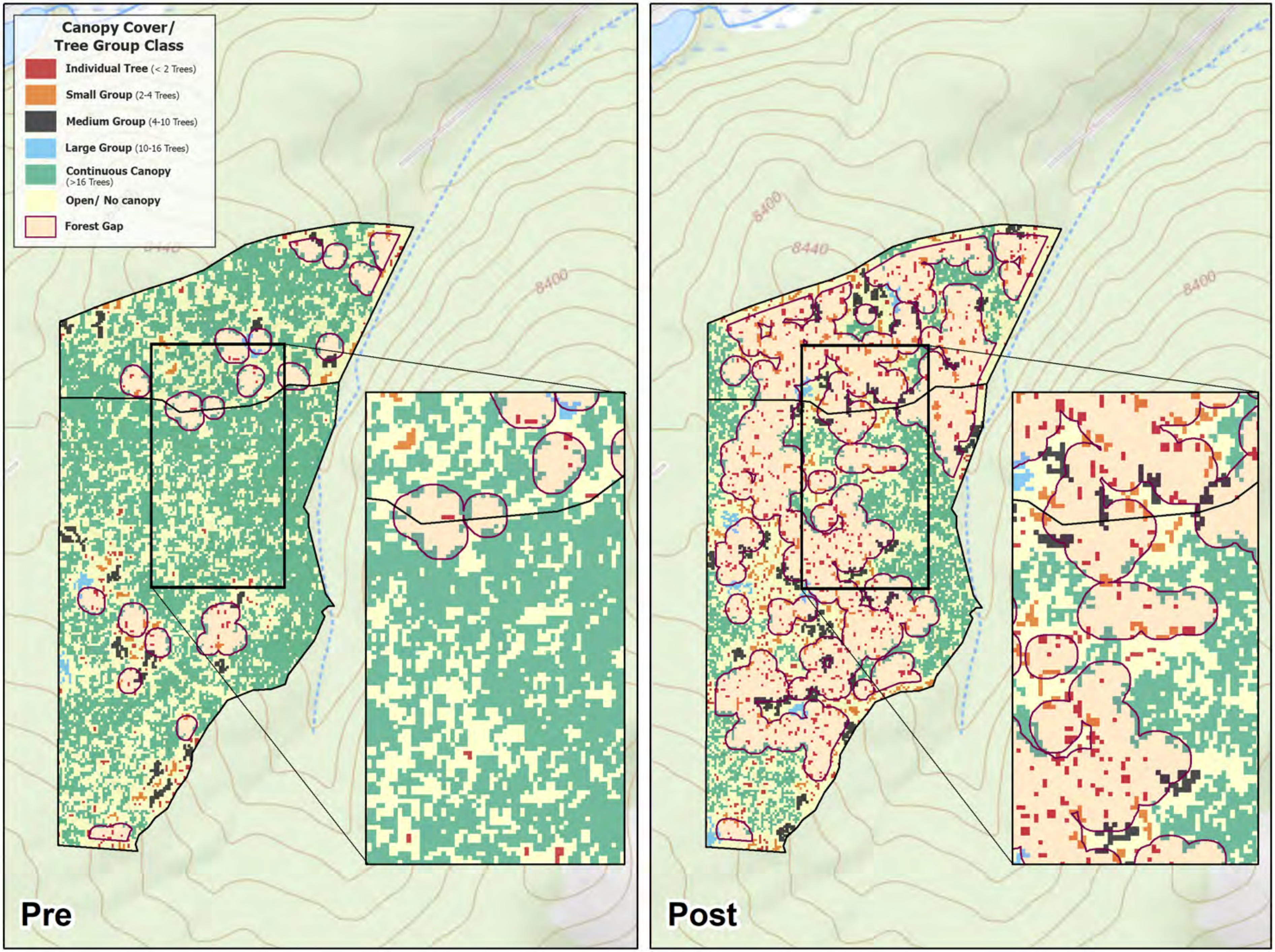
Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	56.3	0.20	1.9	93.5
Post	30.3	0.03	14.5	59.4

**Percent of total canopy cover*

Table 4. Changes in forest gaps pre- and post-treatment (remote sensed data).

Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	9.8	0.32	0.17 - 0.87	0.53	0.91
Post	52.3	3.16	0.17 - 27.31	2.69	1.05

Spatial Heterogeneity



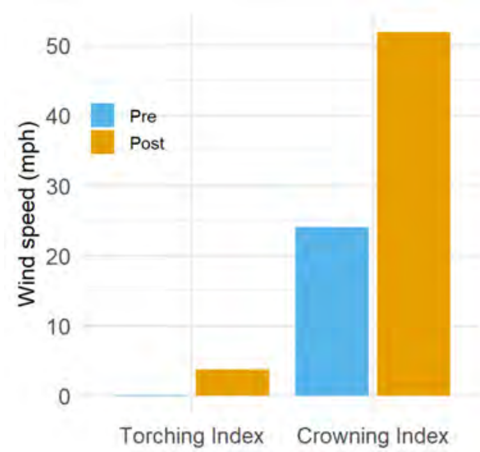
Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
Pre	1.64 ± 0.32	3.06 ± 0.61	0.64 ± 0.08	0.69 ± 0.16	9.0 ± 3.0
Post	2.61 ± 0.25	2.05 ± 0.48	0.85 ± 0.16	0.57 ± 0.10	3.1 ± 0.8

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Passive	Passive	Surface	Passive
Total flame length (feet)	3.6	35	3.9	13.8
Surviving tree basal area (%)	29	1	37	1



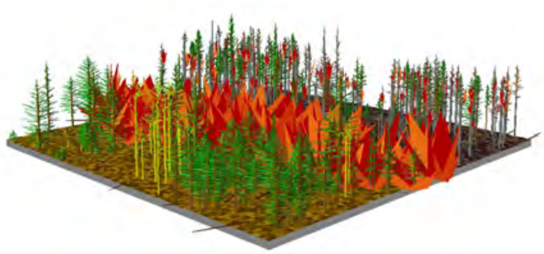
The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

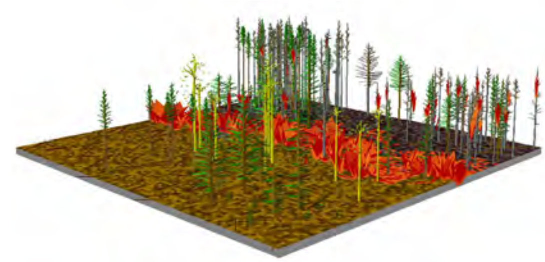
Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS).

Highlights: Following treatment, fine woody fuel loading increased. However, the predicted fire type changed to surface fire under moderate weather conditions, and the crowning index doubled to over 50 mph.

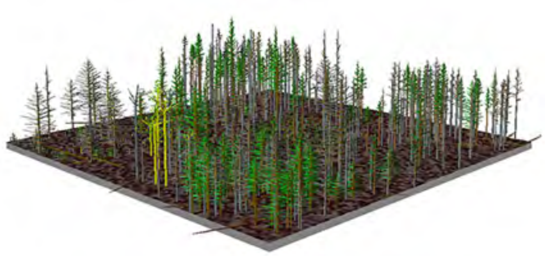
Pre-Treatment | ***1 Year Post-Treatment***

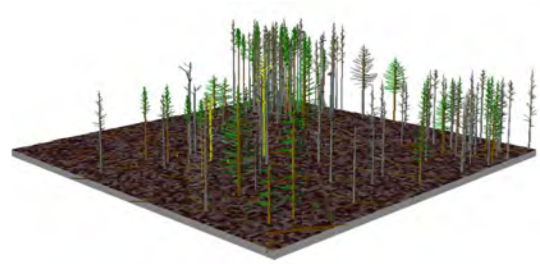
During Fire





After Fire





FOREST AND RANGELAND STEWARDSHIP
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COLORADO FOREST RESTORATION INSTITUTE

UPPER SOUTH PLATTE PARTNERSHIP

March, 2021
Monitoring methods and more information are available at cfri.colostate.edu
Contact: Andrew Slack
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Beaver Ranch Phase 2

COLORADO FOREST RESTORATION INSTITUTE

FOREST AND RANGELAND STEWARDSHIP
COLORADO STATE UNIVERSITY

Upper South Platte Partnership Monitoring Summary
Beaver Ranch Phase 2

Goals and Objectives:

Phase 2 treatments were designed to: retain ponderosa pine and aspen while reducing Douglas-fir and lodgepole pine; create more forest openings; increase age diversity; and reduce the potential for high severity wildfire. The landscape resilience management objectives for the Upper South Platte Partnership include: reducing mean canopy cover; maintaining a complex mosaic of forest canopy; increasing the ratio of ponderosa pine to other conifers; and creating conditions that support the future use of prescribed fire. More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu

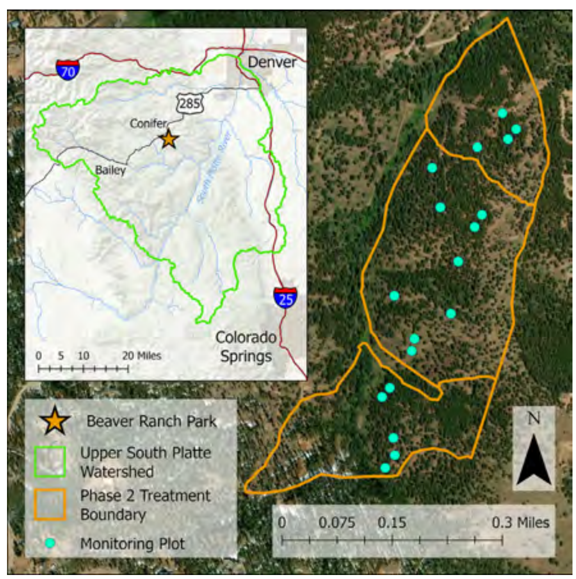
Highlights:

Forest restoration treatments marginally altered forest structure and did little to change potential fire behavior. Basal area, canopy cover, and trees per acre were slightly reduced, and there was no change to species composition or tree size distribution. The project achieved goals specific to the site-level prescription by intentionally leaving a higher basal area in wetter conditions on this north-facing slope. Balancing this goal with USPP and wildfire risk reduction objectives is challenging. This project provided minimal benefits for watershed and community protection, as predicted fire intensity and post-fire tree mortality remained high.

This site provides excellent opportunities to foster discussion about identifying desired conditions at wetter sites, where forest structure is complex and ecologically appropriate conditions may conflict with USPP fire mitigation objectives. This project site could be a great location to demonstrate to the public the diverse and complex set of forest conditions and management goals in the Upper South Platte.

Table 1. Project Information

Implementation agency	Coalition for the Upper South Platte
Ownership	Jefferson County Open Space
Year completed	2017
Acres treated	73
Acres monitored	73
Forest type	Mixed conifer
Implementation method	Mechanical thinning
Slash treatment	Product removal, mastication, pile burning




Pre-treatment

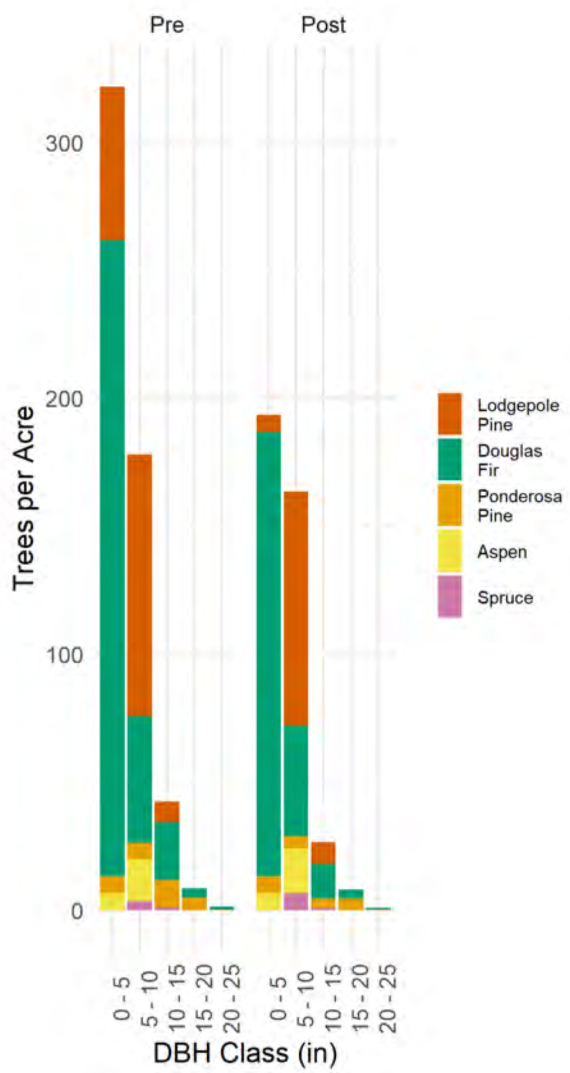

1 year post-treatment

Stand Structure and Composition

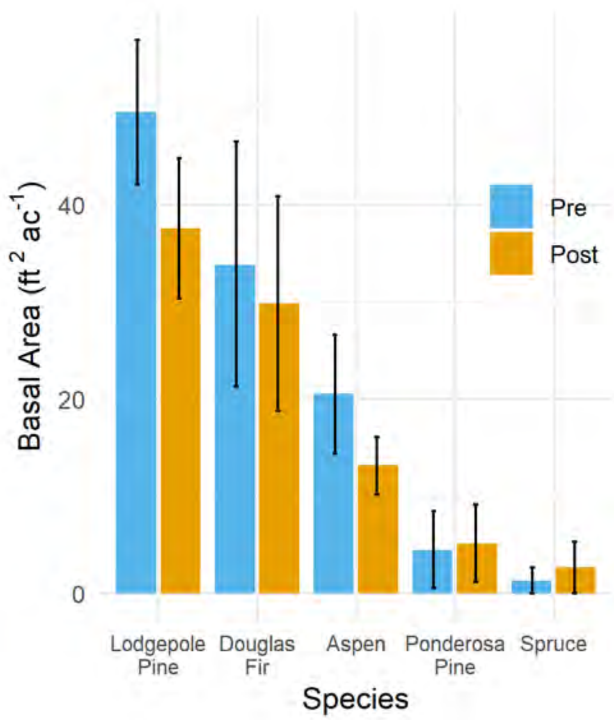
Table 2. Stand characteristics pre- and post-treatment

Phase	Trees per Acre	Basal Area (ft²/ac)	Canopy Cover (%)	Seedlings per Acre	Percent Ponderosa by BA	Quadratic Mean Diameter	Crown Base Height (ft)
Pre	552 ± 124	110 ± 14	51.8 ± 4.7	1476 ± 407	19.5	7.6 ± 0.8	13.9 ± 1.0
Post	392 ± 109	88 ± 13	41.4 ± 6.5	865 ± 247	15.8	9.0 ± 1.0	13.0 ± 1.6

Stand characteristics pre- and 1 year post-treatment



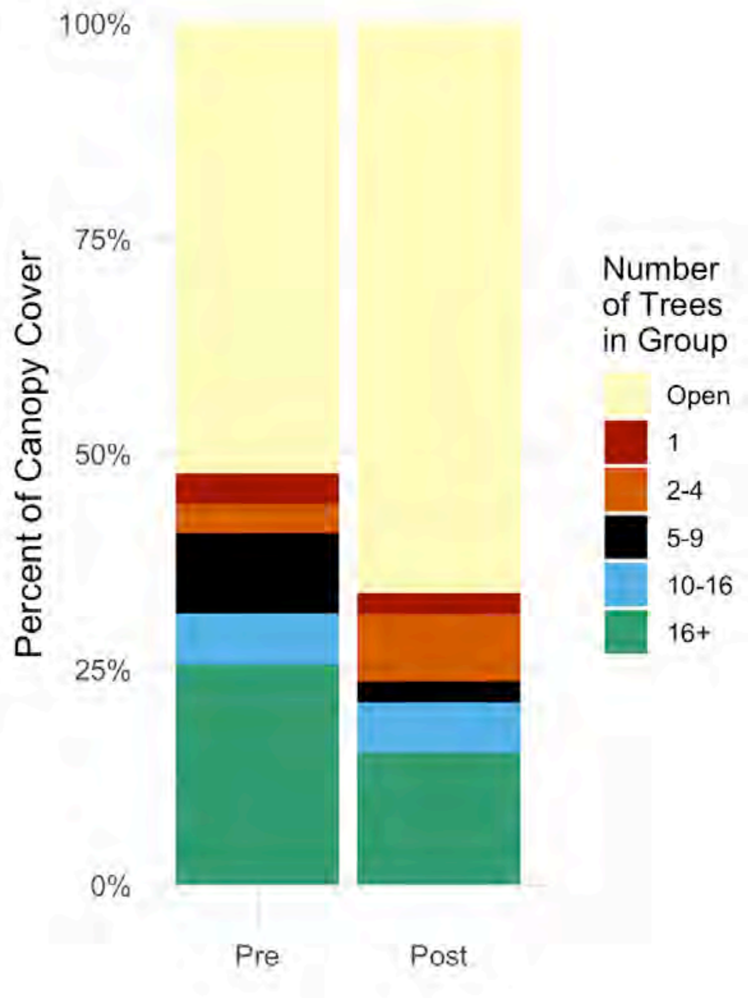
Change in basal area by species



Methods: Data was collected on the ground from 15 plots to assess the changes in stand structure and composition.

Highlights: Canopy cover was slightly reduced to 41.5%, and the ratio of ponderosa pine to other conifers fell. While there was relatively little change in stand structure and composition, the post-treatment conditions may be ecologically appropriate for the cooler and wetter environment of the riparian zone and northwest aspect on this site.

Spatial Heterogeneity



Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: Thinning treatments had little effect of the presence and size of forest gaps; however, the increase in median shape index could suggest that the treatment added complexity to existing gaps.

Table 3. Changes in tree groups pre- and post-treatment (remote sensed data).

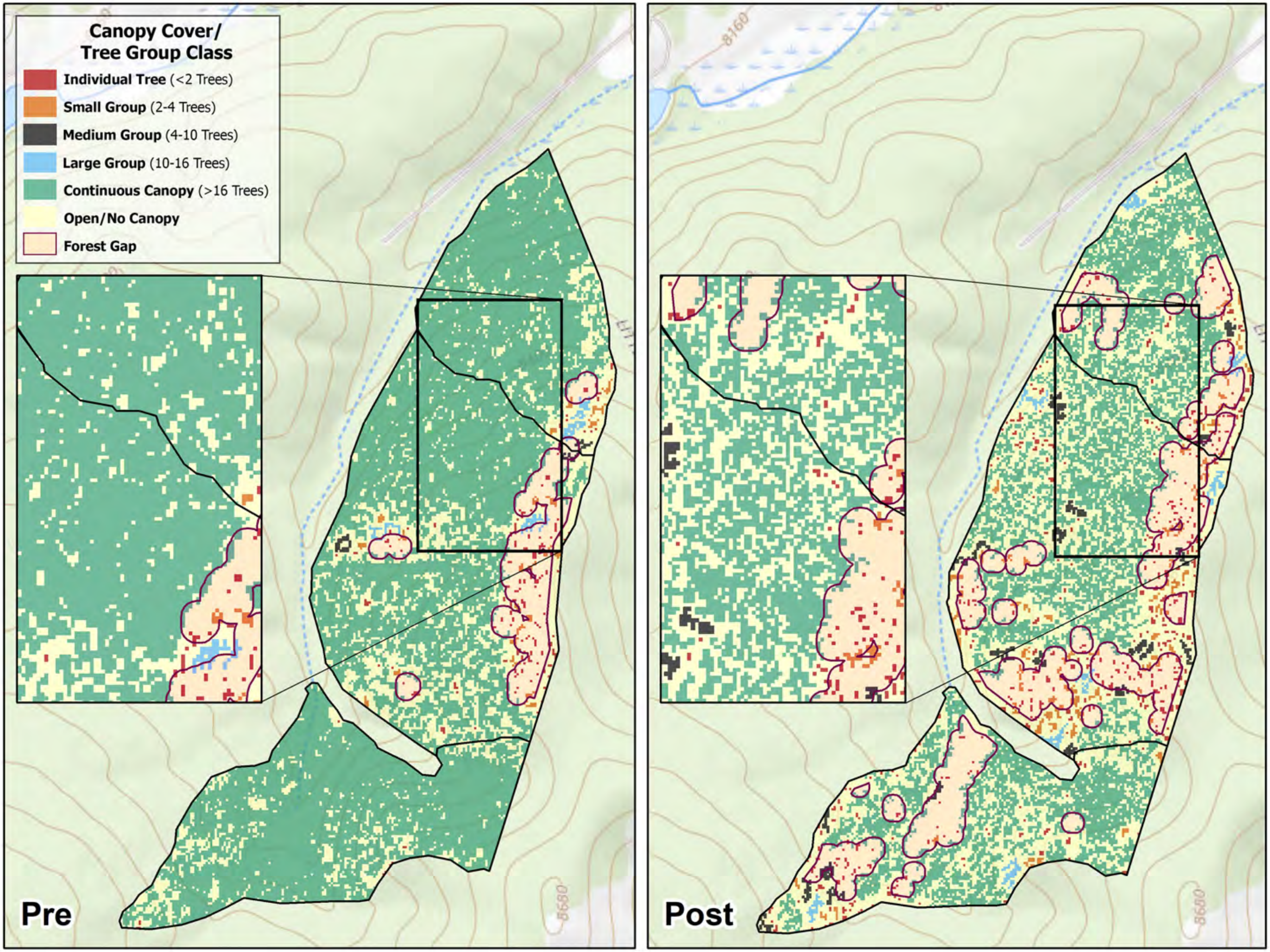
Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	72.6	0.37	1.0	97.2
Post	42.1	0.06	6.4	83.3

**Percent of total canopy cover*

Table 4. Changes in forest gaps pre- and post-treatment (remote sensed data).

Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	7.4	1.33	0.10 – 4.42	1.53	0.97
Post	22.8	0.82	0.07 – 3.11	1.04	1.07

Spatial Heterogeneity



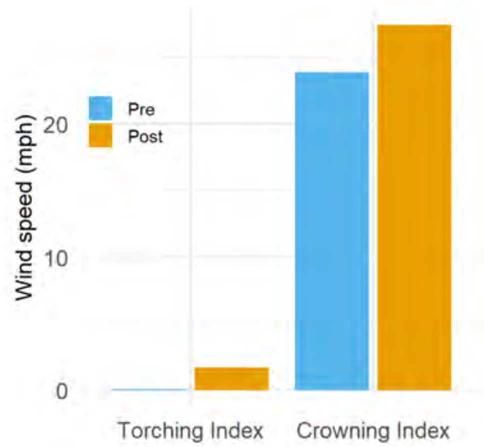
Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
Pre	1.52 ± 0.26	3.06 ± 0.59	0.76 ± 0.06	0.99 ± 0.10	7.5 ± 1.7
Post	1.46 ± 0.14	3.98 ± 0.62	0.97 ± 0.14	0.88 ± 0.13	4.3 ± 1.6

Table 6. Modeled fire behavior pre- and 1 year post-treatment

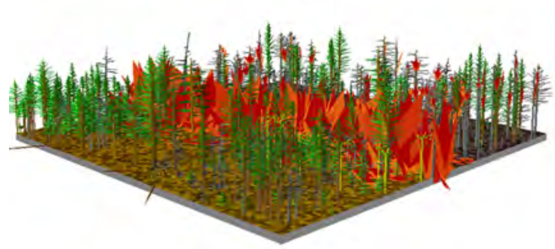
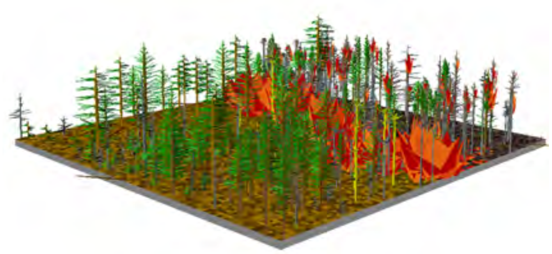
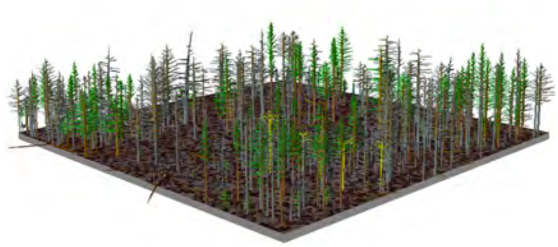
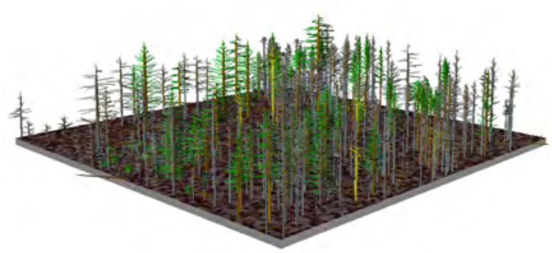
Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Passive	Passive	Passive	Passive
Total flame length (feet)	3.7	35.5	3.3	25.9
Surviving tree basal area (%)	44	1	48	1



The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS).

Highlights: Following treatment, fine woody fuel loading increased. However, the predicted fire type changed to surface fire under moderate weather conditions, and the crowning index doubled to over 25 mph.

	Pre-Treatment	*1 Year Post-Treatment*
During Fire		
After Fire		

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Resort Valley Ranch Phase 2

COLORADO FOREST RESTORATION INSTITUTE | FOREST AND RANGELAND STEWARDSHIP COLORADO STATE UNIVERSITY

Upper South Platte Partnership Monitoring Summary
Resort Valley Ranch Phase 2

Goals and Objectives:

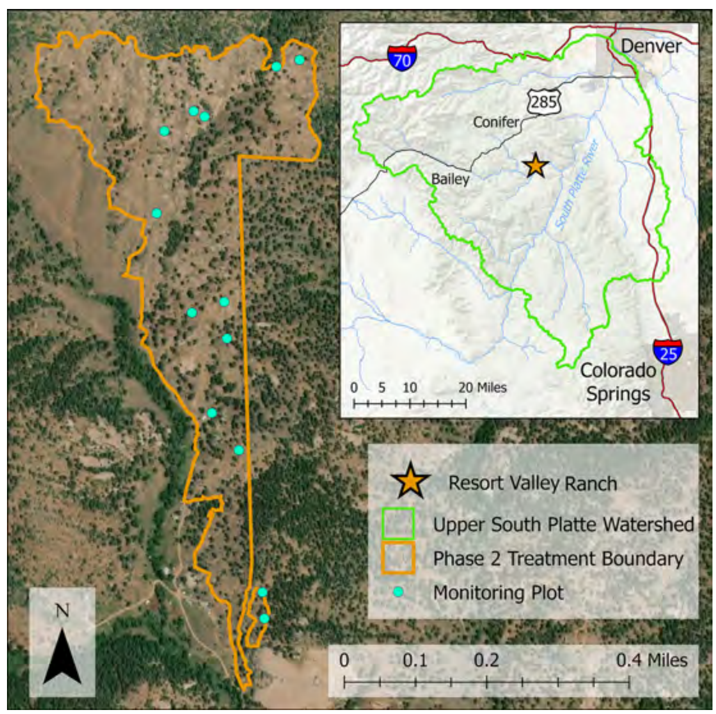
Forest restoration treatments at Resort Valley Ranch aimed to: reduce canopy cover below 50%; reduce basal area to less than 50 ft2; increase the presence of irregularly shaped gaps; and reduce the risk of widespread high severity crown fire. The landscape resilience management objectives for the Upper South Platte Partnership include: reducing mean canopy cover; maintaining a complex mosaic of forest canopy; increasing the ratio of ponderosa pine to other conifers; and creating conditions that support the future use of prescribed fire. More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu

Highlights:

Trees per acre, basal area, and canopy cover were substantially reduced following treatment, and well below the goals for this project. Thinning avoided removing larger ponderosa pine, which doubled the average tree size and increased ponderosa to over 75%. As expected, surface fuel loading increased, but the risk of high severity fire was also reduced. Conditions following treatment potentially support the future use of prescribed fire. The high intensity of thinning increased the presence of forest gaps, but did not increase the complexity of forest canopy or gap size variability. However, as managers continue to strive for a diverse mosaic across the landscape, this project along with other projects of varying intensity may contribute to USPP goals at the watershed scale.

Table 1. Project Information

Implementation agency	Jefferson Conservation District
Ownership	Private
Year completed	2017
Acres treated	78
Acres monitored	78
Forest type	Ponderosa – juniper
Implementation method	Mechanical thinning
Slash treatment	Removal, lop and scatter, mastication




Pre-treatment

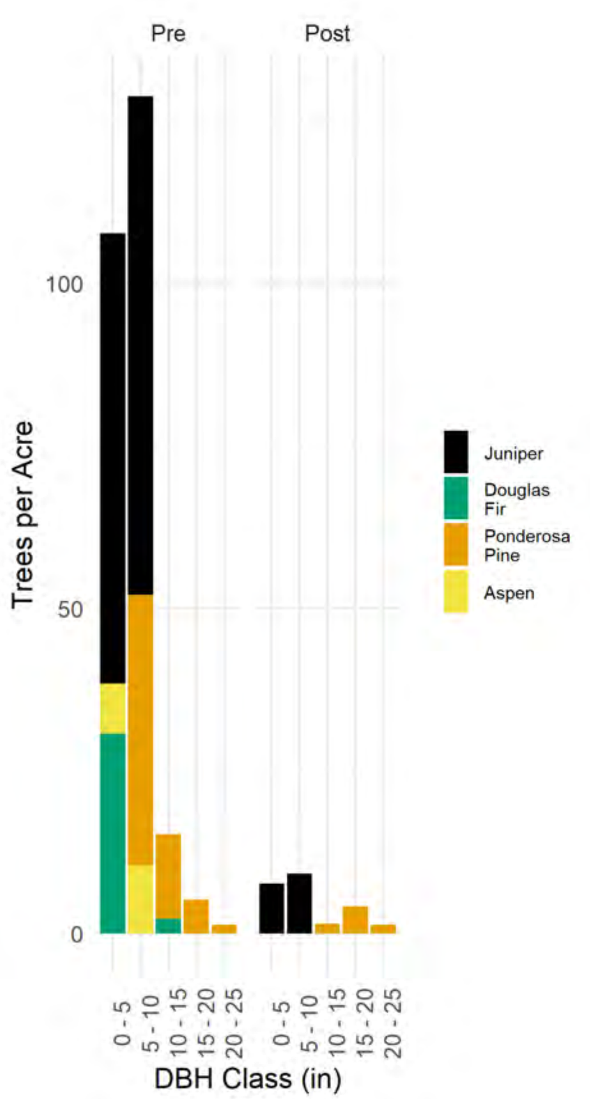

1 year post-treatment

Stand Structure and Composition

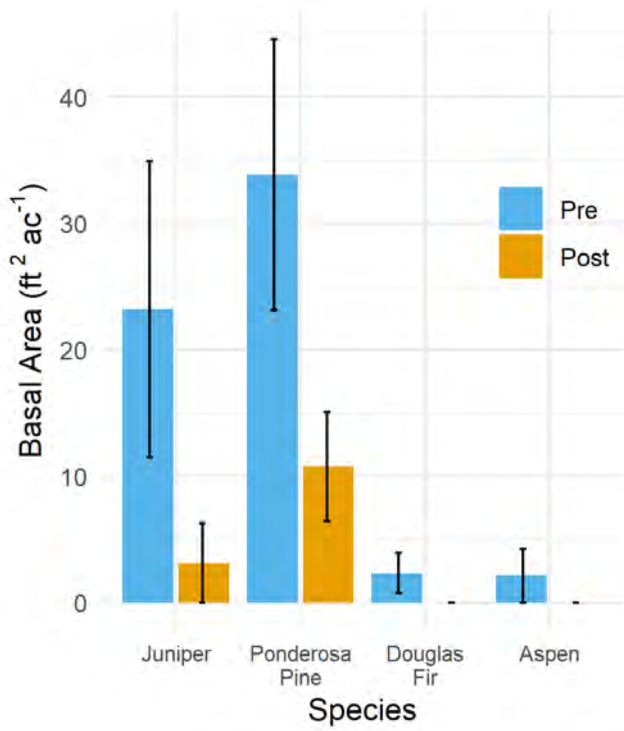
Table 2. Stand characteristics pre- and post-treatment

Phase	Trees per Acre	Basal Area (ft²/ac)	Canopy Cover (%)	Seedlings per Acre	Percent Ponderosa by BA	Quadratic Mean Diameter	Crown Base Height (ft)
Pre	258 ± 72	61 ± 14	29.2 ± 8.0	111 ± 111	57.0	7.7 ± 0.9	5.4 ± 1.0
Post	24 ± 18	14 ± 7	9.8 ± 4.4	205 ± 139	77.4	15.1 ± 1.3	5.7 ± 0.7

Stand characteristics pre- and 1 year post-treatment



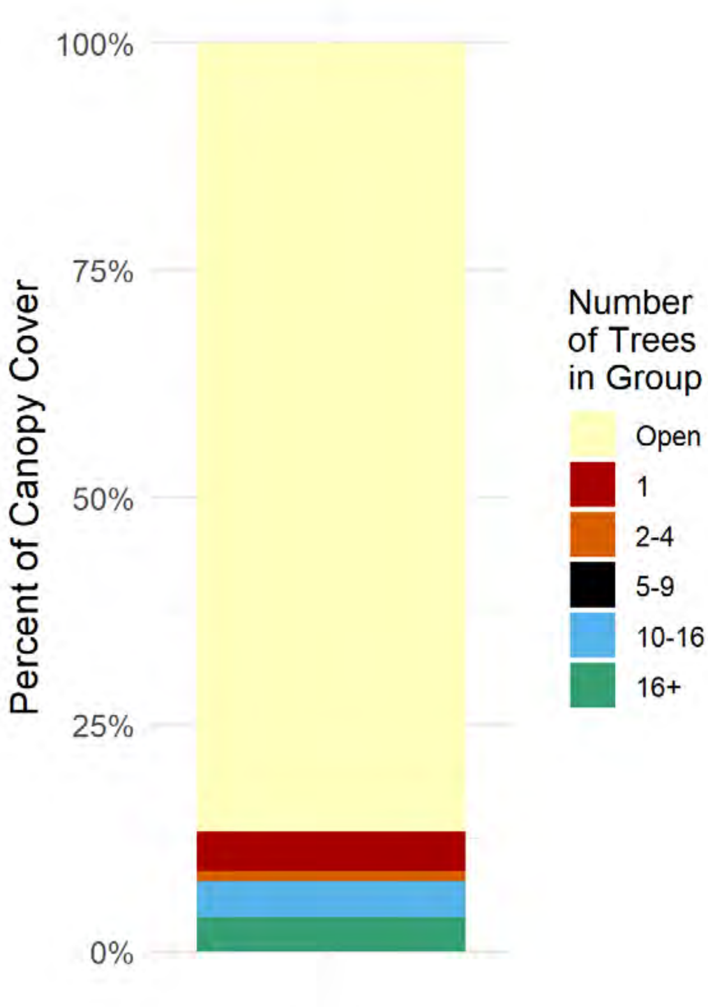
Change in basal area by species



Methods: Data was collected on the ground from 13 plots to assess the changes in stand structure and composition.

Highlights: The small component of Douglas-fir and aspen that existed before treatment was removed, which prevented shifts in future overstory species composition. Canopy cover was reduced to below 10%, and individual trees and larger forest gaps make up most of the remaining tree cover.

Spatial Heterogeneity



Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: Forest gap coverage increased by over 40%, and the overall gap shapes became more irregular. Thinning created a single forest gap that covered most of the area within the treatment boundary. Because of this large gap, there was little diversity in gap size overall.

Table 3. Changes in tree groups pre- and post-treatment (remote sensed data).

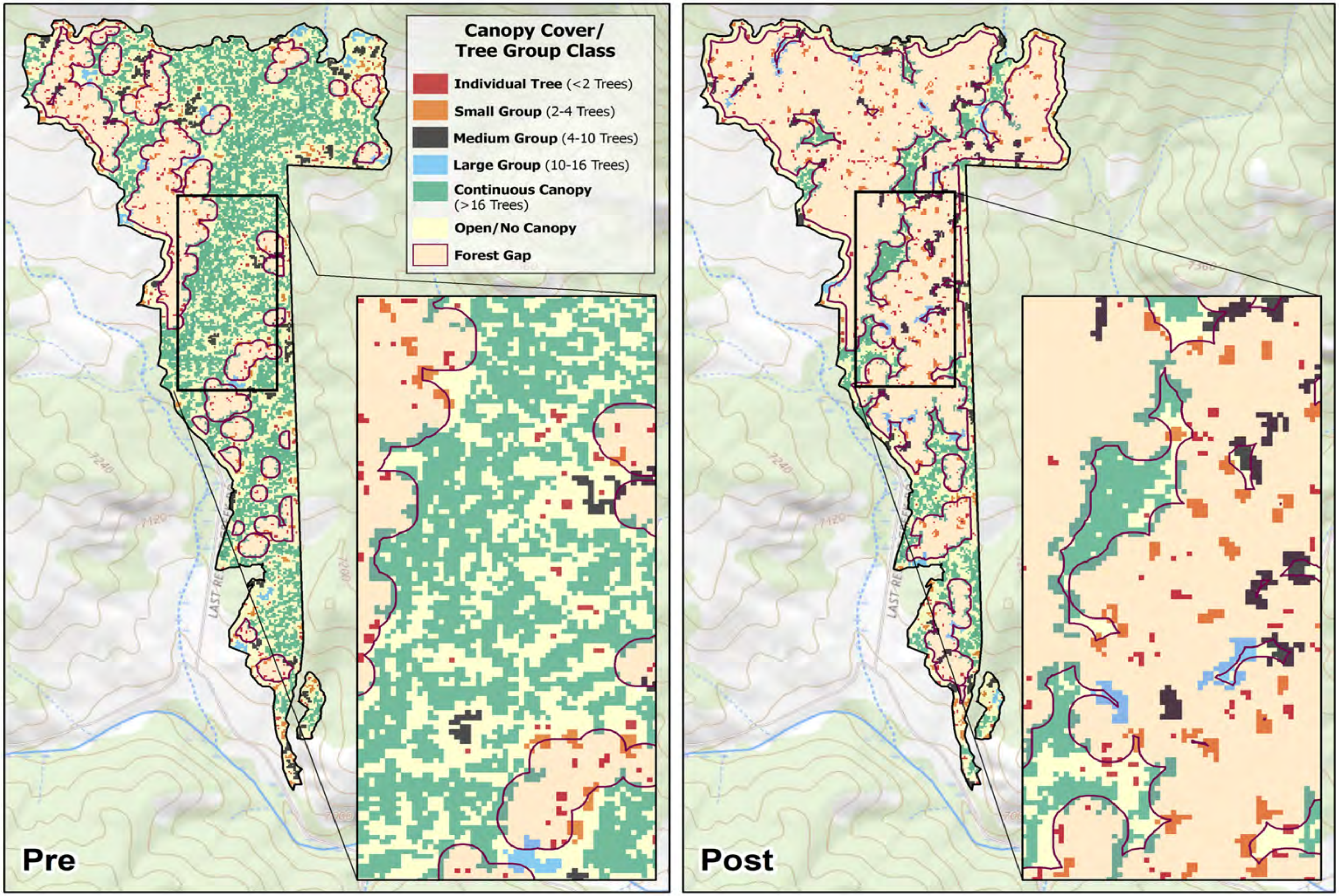
Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	40.3	0.06	5.9	79.0
Post	21.0	0.03	10.3	54.4

**Percent of total canopy cover*

Table 4. Changes in forest gaps pre- and post-treatment (remote sensed data).

Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	27.6	0.84	0.10 – 6.91	0.34	0.98
Post	69.0	10.90	0.10 – 49.64	4.41	1.40

Spatial Heterogeneity



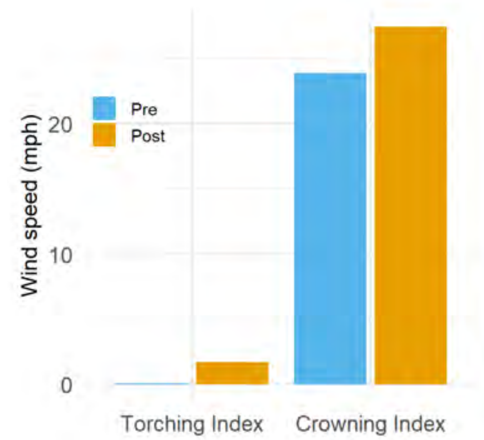
Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
Pre	0.62 ± 0.14	0.61 ± 0.25	0.84 ± 0.11	0.57 ± 0.18	8.6 ± 1.9
Post	1.87 ± 0.48	1.38 ± 0.72	0.52 ± 0.11	0.45 ± 0.15	5.4 ± 1.6

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Surface	Passive	Surface	Passive
Total flame length (feet)	0.4	11.2	0.3	13.1
Surviving tree basal area (%)	51	1	77	4



The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

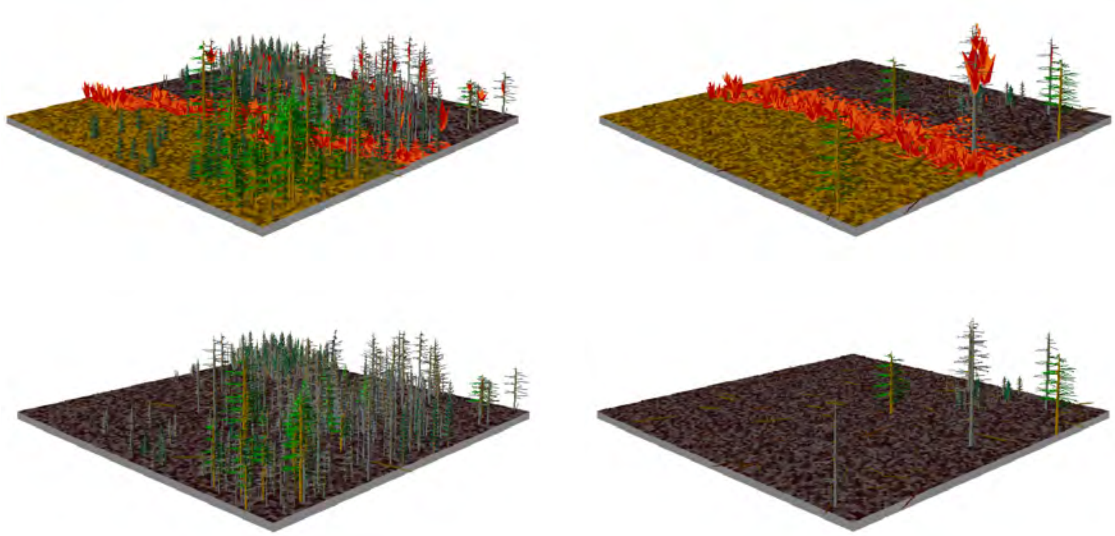
Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS).

Highlights: Surface fuel loading was considerably increased, and could lead to isolated torching of individual trees. However, extreme wind speeds would be needed to carry an active crown fire following treatment.

Pre-Treatment ***1 Year Post-Treatment***

During Fire

After Fire



March, 2021
Monitoring methods and more information are available at cfri.colostate.edu
Contact: Andrew Slack
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Resort Valley Ranch Phase 3

COLORADO FOREST RESTORATION INSTITUTE

FOREST AND RANGELAND STEWARDSHIP
COLORADO STATE UNIVERSITY

Upper South Platte Partnership Monitoring Summary
Resort Valley Ranch Phase 3

Goals and Objectives:

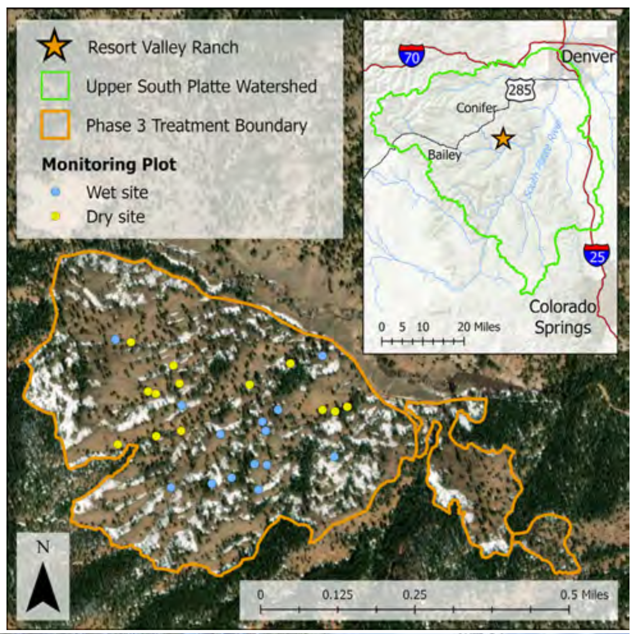
Forest restoration treatments at Resort Valley Ranch aimed to: reduce canopy cover below 50%; reduce basal area to less than 50 ft2; increase the presence of irregularly shaped gaps; and reduce the risk of widespread high severity crown fire. The landscape resilience management objectives for the Upper South Platte Partnership include: reducing mean canopy cover; maintaining a complex mosaic of forest canopy; increasing the ratio of ponderosa pine to other conifers; and creating conditions that support the future use of prescribed fire. **Analysis separated dry and wet sites, as defined by topographic wetness index, to highlight topographic differences in the treatment.** More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu

Highlights:

Overall, trees per acre, basal area, and canopy cover were substantially reduced below the project goals. Furthermore, the ratio of ponderosa pine nearly doubled, and the forest canopy became more complex with an increase in smaller tree groups. Following treatment, wet sites were more open, with lower tree density. Potential reference conditions determined by topographic wetness would guide prescriptions to leave more trees at wetter sites. Using spatial tools such as topographic wetness index can encourage higher variability in thinning intensity, which can result in greater spatial heterogeneity. Gap size, variability in gap size, and the coverage of gaps all increased, but the complexity of gap shape remained the same. When thinning intensity is high, additional analyses of forest groups may be required to fully assess treatment effect on spatial heterogeneity. Fire risk was reduced, and there is now potential for the use of prescribed fire at the site, which could reduce surface fuel loading.

Table 1. Project Information

Implementation Agency	Jefferson Conservation District
Ownership	Private
Year Completed	2018
Acres Treated	150
Acres Monitored	134
Forest Type	Dry mixed conifer
Implementation Method	Mechanical thinning
Slash Treatment	Product removal, lop and scatter, mastication

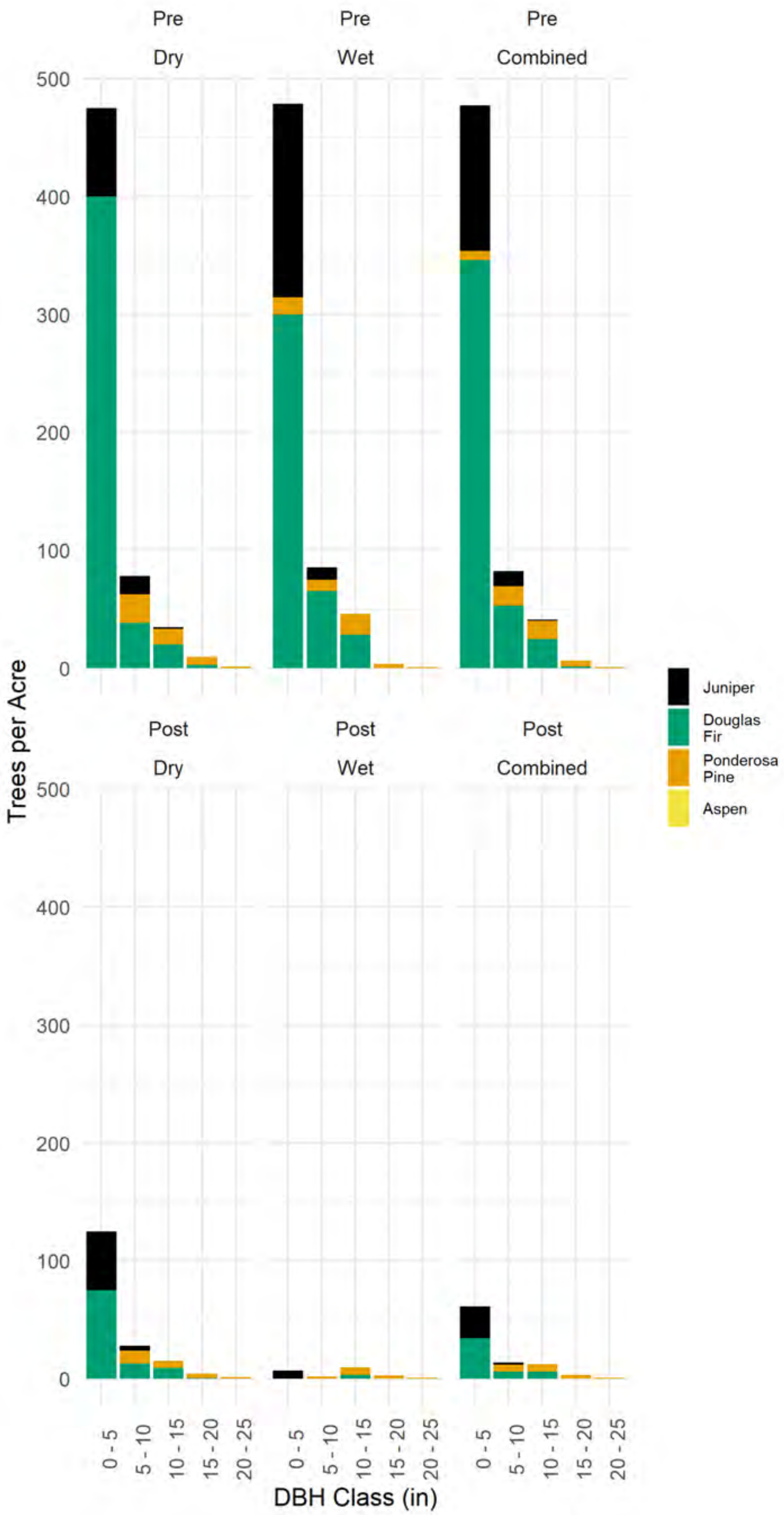


Pre-treatment

1 year post-treatment

Stand Structure and Composition

Change in tree size distribution



Methods: Data was collected on the ground from 26 total plots (14 wet, 12 dry) to assess the changes in stand structure and composition.

Highlights: Treatments were successful in promoting larger ponderosa pine, and greater size diversity. Treatment conditions at dry and wet sites were similar prior to treatment; however, forest structure metrics show that thinning intensity was approximately 25% higher at wet sites. This led to wet sites having lower tree density and being more dominated by ponderosa pine than dry sites. Smaller diameter Douglas-fir and juniper still dominate tree density at drier sites. Prescribed fire could be used in the future to knock back the smaller diameter Douglas-fir and juniper and promote ponderosa pine regeneration. Wetter sites potentially allow for higher tree density and a different species composition. Reducing thinning intensity at wet sites and increasing thinning intensity at dry sites could help maintain forest diversity.

Stand Structure and Composition

Change in basal area by species

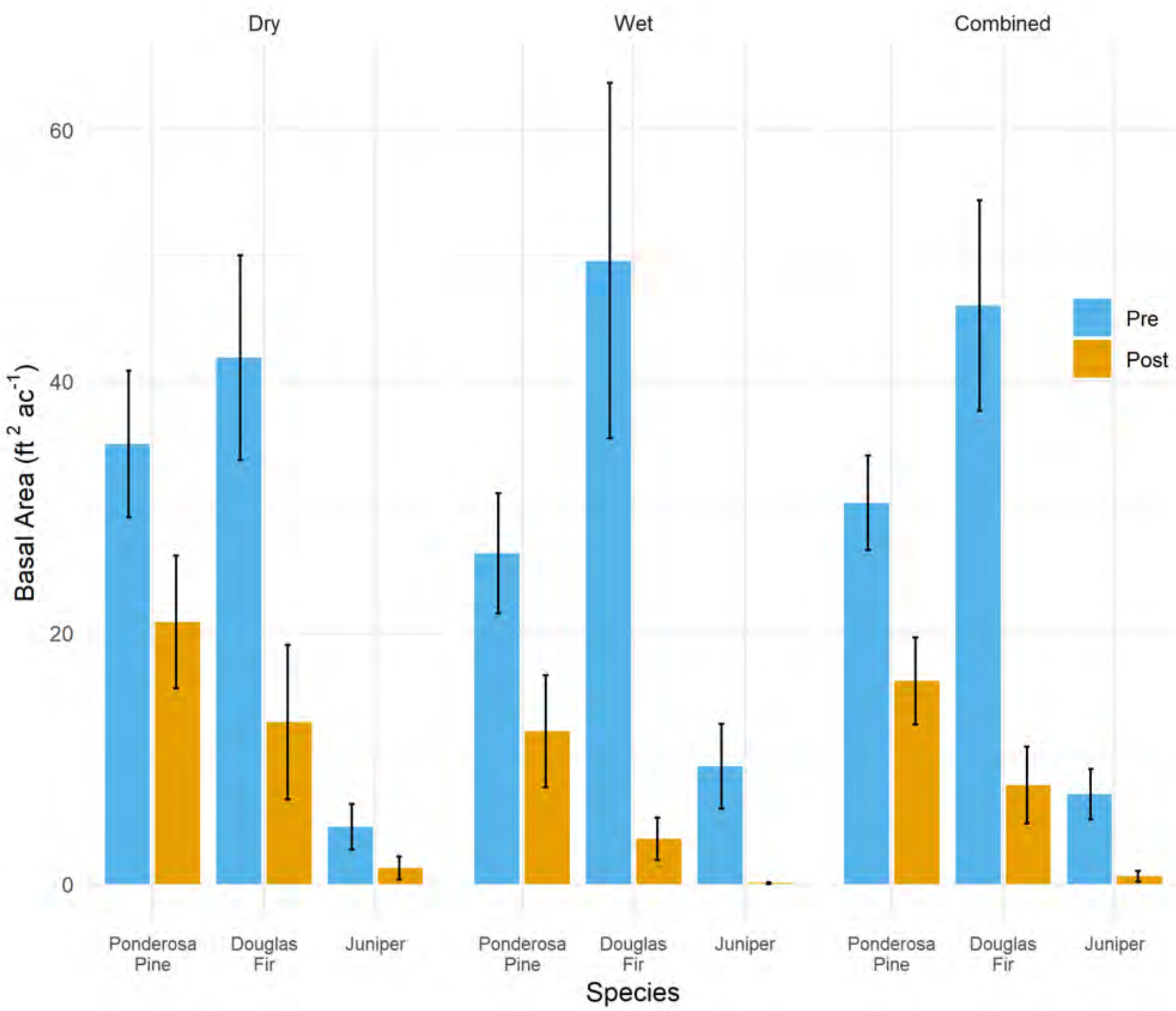


Table 2. Stand characteristics pre- and 1 year post-treatment

Site conditions	Phase	Trees per acre	Basal area (ft^2/ac)	Canopy cover (%)	Seedlings per acre	Percent ponderosa by BA (%)	Quadratic mean diameter (in)	Crown base height (ft)
Dry	Pre	600 ± 150	81 ± 11	43.7 ± 6.2	2078 ± 765	43.0	7.3 ± 1.3	7.7 ± 1.5
	Post	175 ± 99	35 ± 10	19.0 ± 6.4	157 ± 78	59.6	10.9 ± 1.6	10.5 ± 2.2
Wet	Pre	615 ± 200	85 ± 16	43.6 ± 8.9	2267 ± 567	30.9	7.8 ± 1.0	7.5 ± 1.1
	Post	23 ± 9	16 ± 6	9.3 ± 3.3	1408 ± 450	76.9	12.4 ± 0.9	14.9 ± 2.6
Combined	Pre	608 ± 125	83 ± 10	43.6 ± 5.5	2165 ± 479	36.3	7.6 ± 0.8	7.6 ± 0.9
	Post	93 ± 47	25 ± 6	13.7 ± 3.5	735 ± 242	65.6	11.5 ± 0.9	11.5 ± 0.9

Spatial Heterogeneity

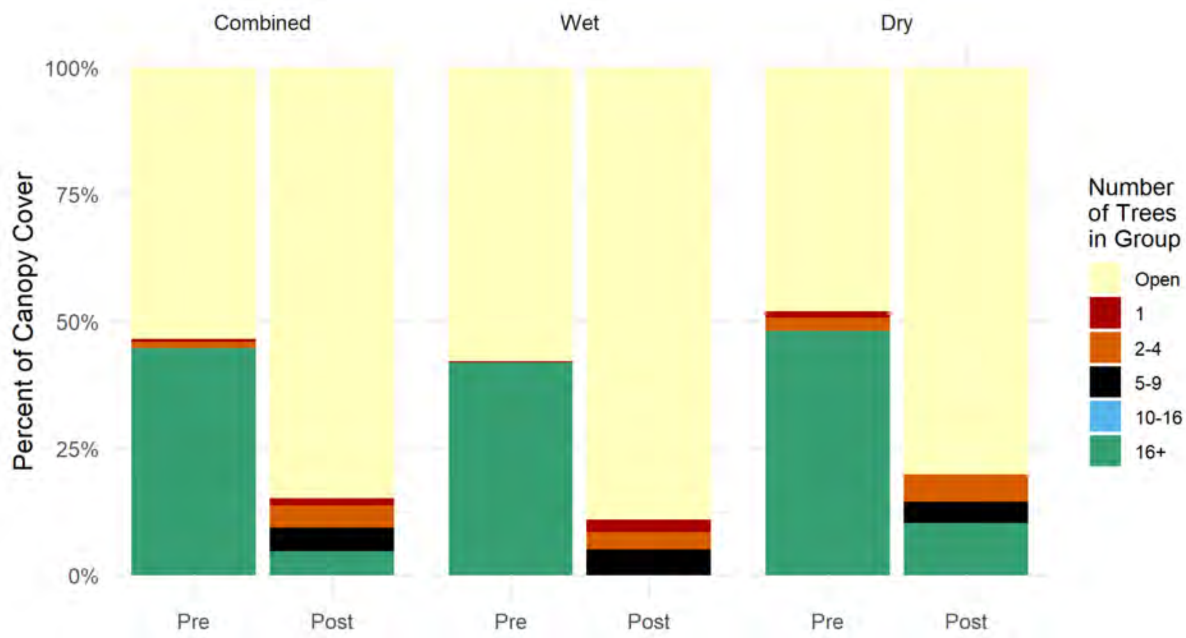


Table 3. Changes in tree groups pre- and post-treatment

Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	52.6	0.11	3.5	90.0
Post	28.5	0.04	7.5	63.5

**Percent of total canopy cover*

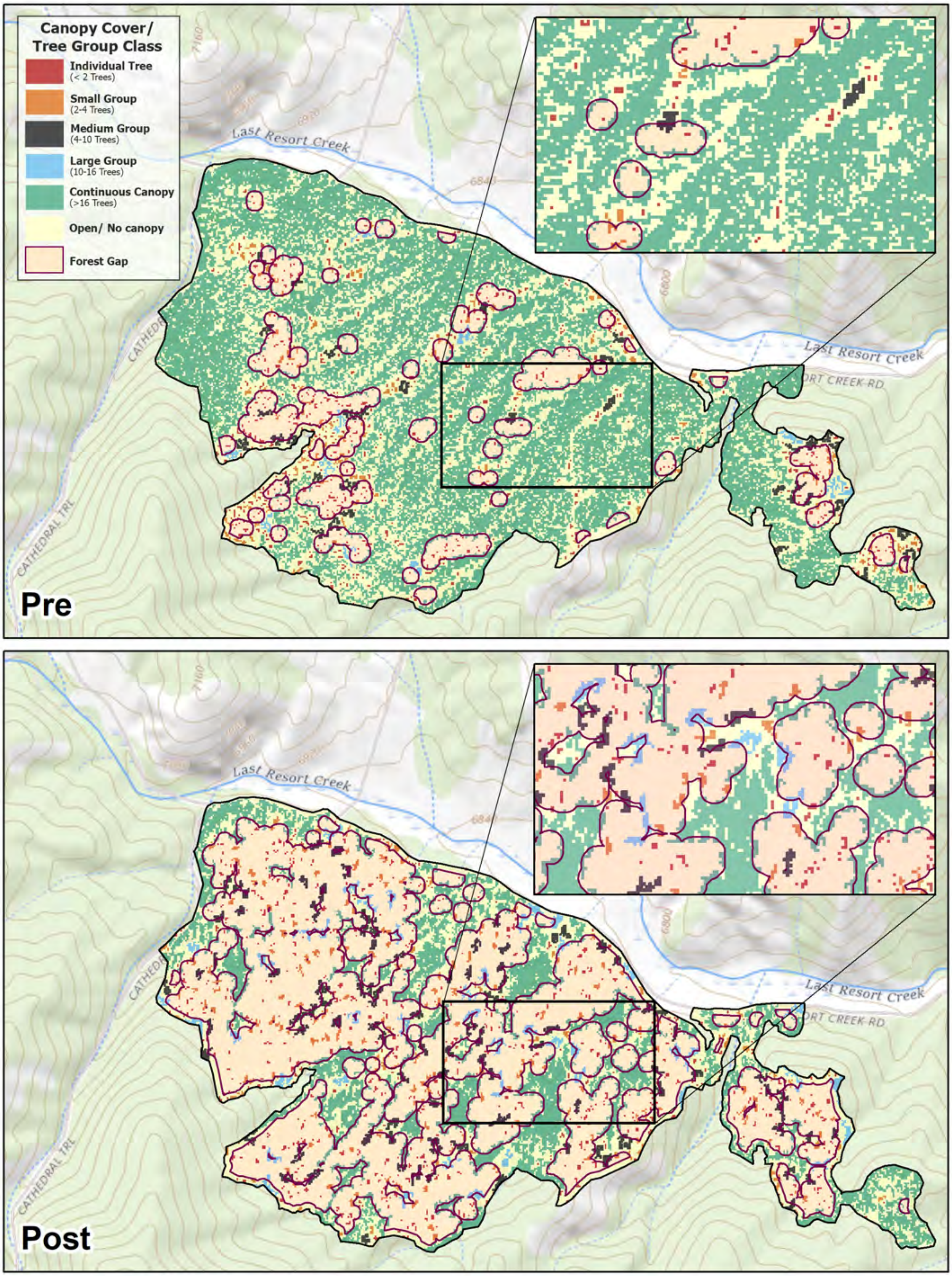
Table 4. Changes in forest gaps pre- and post-treatment.

Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	15.5	0.54	0.07 - 3.48	1.25	0.97
Post	64.5	3.83	0.05 - 41.12	2.77	1.01

Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: Thinning treatments created smaller tree groups, and increased the presence of isolated trees. Thinning also resulted in more gaps that were bigger, more variable in size, and slightly more irregular in shape.

Spatial Heterogeneity



Surface Fuel Conditions and Potential Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

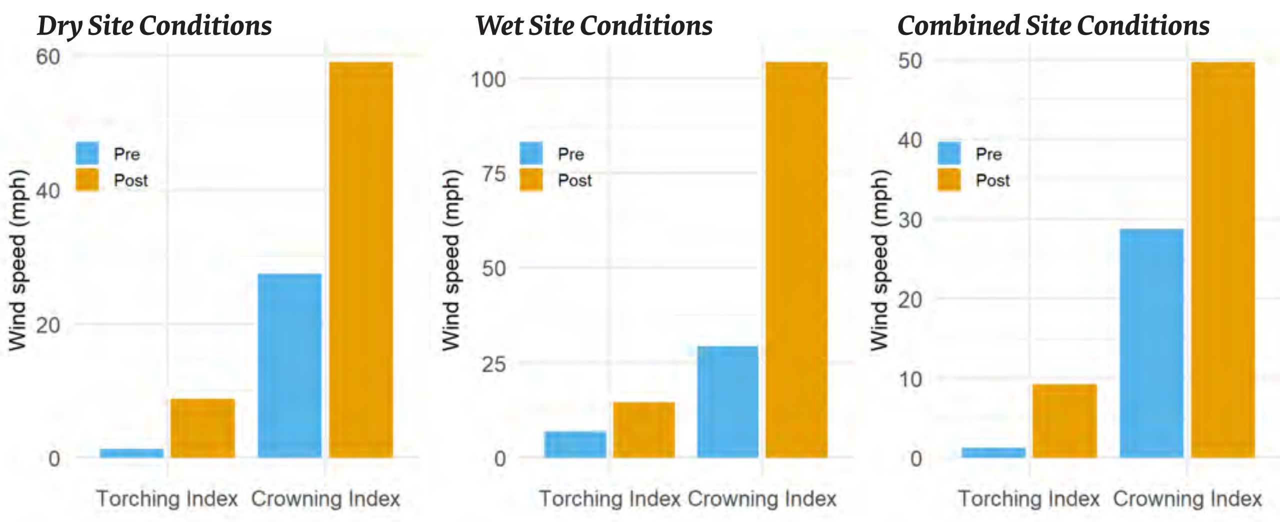
Site conditions	Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
Dry	Pre	0.99 ± 0.23	0.79 ± 0.18	0.80 ± 0.10	0.52 ± 0.10	12.5 ± 3.0
	Post	2.44 ± 0.77	1.11 ± 0.23	0.67 ± 0.14	0.52 ± 0.17	6.1 ± 2.0
Wet	Pre	0.94 ± 0.20	1.11 ± 0.33	0.97 ± 0.14	0.70 ± 0.18	6.3 ± 2.9
	Post	2.27 ± 0.40	1.93 ± 0.53	0.95 ± 0.52	0.52 ± 0.13	1.1 ± 0.3
Combined	Pre	0.97 ± 0.14	0.96 ± 0.20	0.89 ±0.09	0.61 ± 0.11	9.5 ± 2.2
	Post	2.35 ± 0.41	1.55 ± 0.31	0.81 ± 0.27	0.52 ± 0.10	5.0 ± 1.7

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Site Conditions	Dry				Wet			
Phase	Pre		Post		Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe	Moderate	Severe	Moderate	Severe
Fire type	Surface	Passive	Surface	Passive	Surface	Passive	Surface	Passive
Total flame length (feet)	0.3	18.3	0.5	7.5	0.4	14.1	0.4	13.1
Surviving tree basal area (%)	71	1	79	7	66	1	84	4

Combined Wet and Dry				
Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Surface	Active	Surface	Passive
Total flame length (feet)	0.4	16.6	0.5	7.7
Surviving tree basal area (%)	68	0	81	4

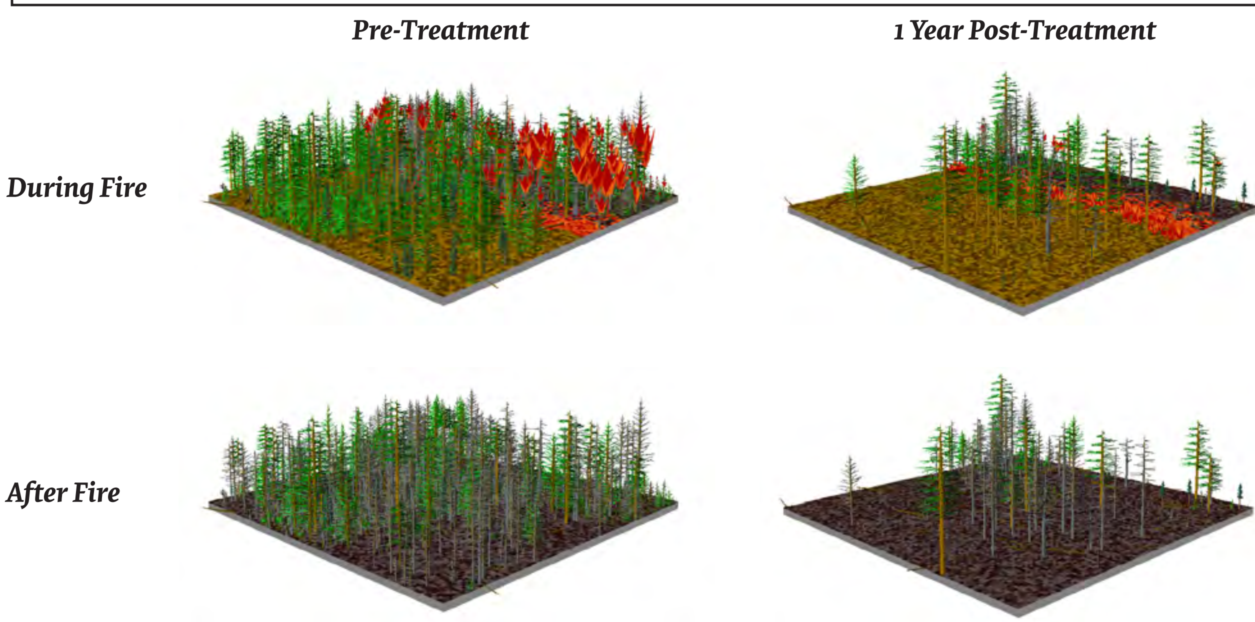
Surface Fuel Conditions and Potential Fire Behavior



The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator.

Highlights: Change in surface fuel conditions was similar between dry and wet sites, with slightly larger increases in fuel loading at wet sites due to higher thinning intensity. Woody fuel loading nearly doubling across the project area, and the potential for individual tree torching remained high. Breaking up the forest canopy likely reduced the risk of an active crown fire, and the wind speed need to carry an active crown fire more than doubled. Future fuels treatments, such as prescribed fire, could reduce the risk of tree torching and fire-related tree mortality.



March, 2021
Monitoring methods and more information are available at cfri.colostate.edu
Contact: Andrew Slack
Andrew.W.Slack@colostate.edu

Ridge Road 1

COLORADO FOREST RESTORATION INSTITUTE

FOREST AND RANGELAND STEWARDSHIP
COLORADO STATE UNIVERSITY

Upper South Platte Partnership Monitoring Summary
Ridge Road 1

Goals and Objectives:

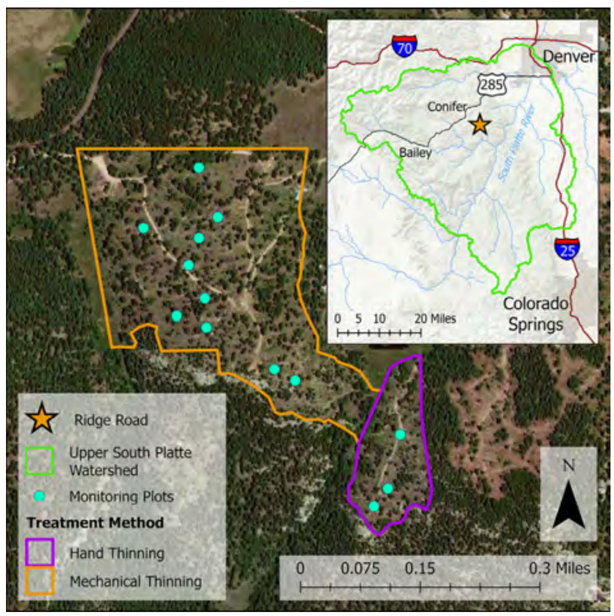
Phase 1 treatments were designed to: reduce tree crown cover below 50%; reduce basal area to less than 50 ft2 per acre; reduce homogeneity in tree groups and openings; favor ponderosa pine, aspen and older trees for retention; reduce the potential for high severity wildfire. The landscape resilience management objectives for the Upper South Platte Partnership include: reducing mean canopy cover; maintaining a complex mosaic of forest canopy; increasing the ratio of ponderosa pine to other conifers; and creating conditions that support the future use of prescribed fire. More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu

Highlights:

The intensity of thinning was likely higher in the hand-thinned unit; however, because there were only three plots in the hand-thinned unit, our analysis combined the mechanical and hand-thinned treatment units. One year following treatment canopy cover was substantially reduced to less than 20%, and basal area was reduced by over 70% to 51 ft2 per acre. The ratio of ponderosa to other conifers increased by 17% to over 60%, and the average tree size increased by 21% indicating that thinning retained older trees. Treating slash by pile burning effectively limited increases in surface fuel. Pile burning in combination with breaking up the forest canopy reduced the potential for high severity fire. Forest gap size and size variability increased, but median gap shape was unchanged. Post-treatment conditions support future use of prescribed fire to maintain ponderosa pine and a lower risk of high severity fire. Prescribed fire could also be effective in further increasing heterogeneity in tree groups and forest gaps.

Table 1. Project Information

Implementation agency	Jefferson Conservation District
Ownership	Private
Year completed	2016
Acres treated	60
Acres monitored	60
Forest type	Dry mixed conifer
Implementation method	Mechanical thinning (50 acres), hand thinning (10 acres)
Slash treatment	Burn piles




Pre-treatment

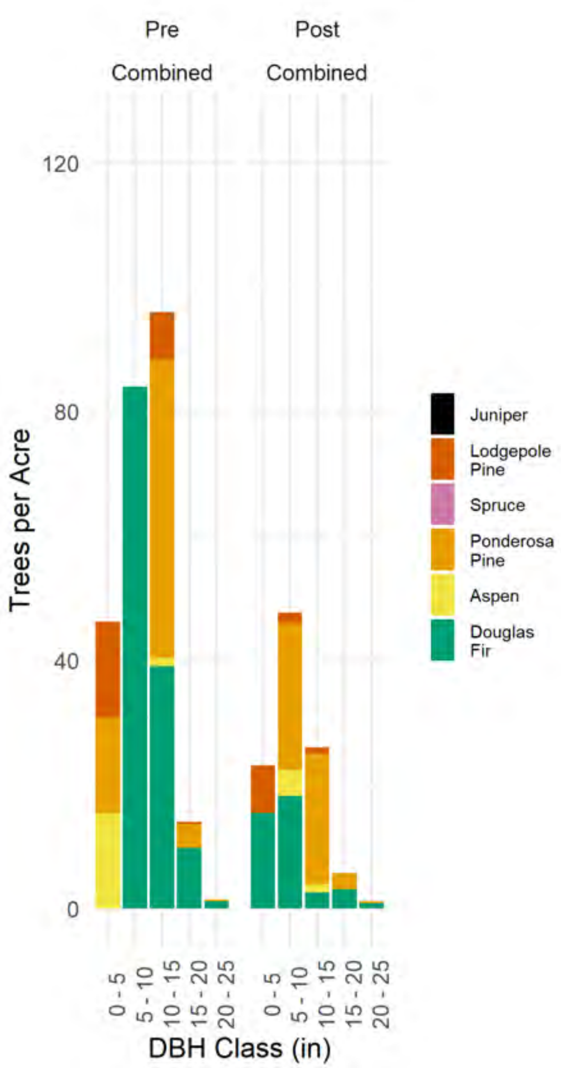

1 year post-treatment

Stand Structure and Composition

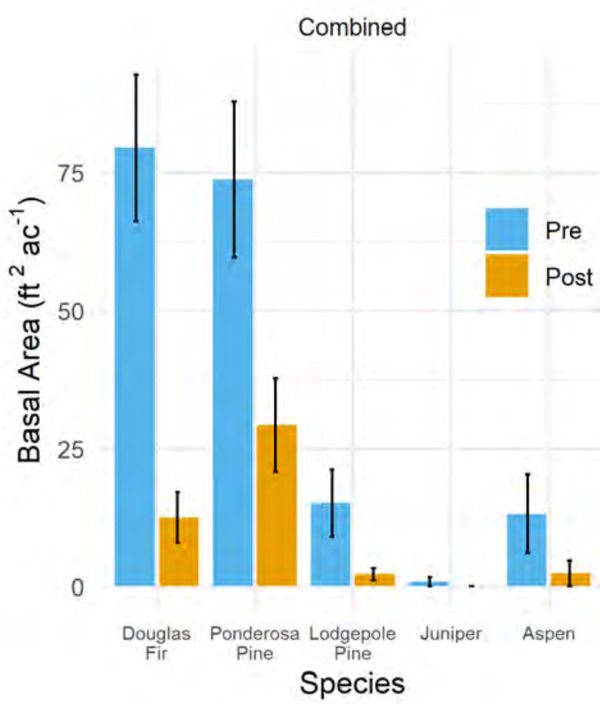
Table 2. Stand characteristics pre- and post-treatment

Phase	Trees per Acre	Basal Area (ft^2/ac)	Canopy Cover (%)	Seedlings per Acre	Percent Ponderosa by BA	Quadratic Mean Diameter	Crown Base Height (ft)
Pre	564 ± 107	183 ± 19	73.5 ± 4.3	679 ± 327	43.4	8.5 ± 0.6	18.0 ± 2.3
Post	181 ± 82	51 ± 13	18.6 ± 7.3	1207 ± 573	60.4	10.3 ± 1.1	21.5 ± 3.0

Stand characteristics pre- and 1 year post-treatment



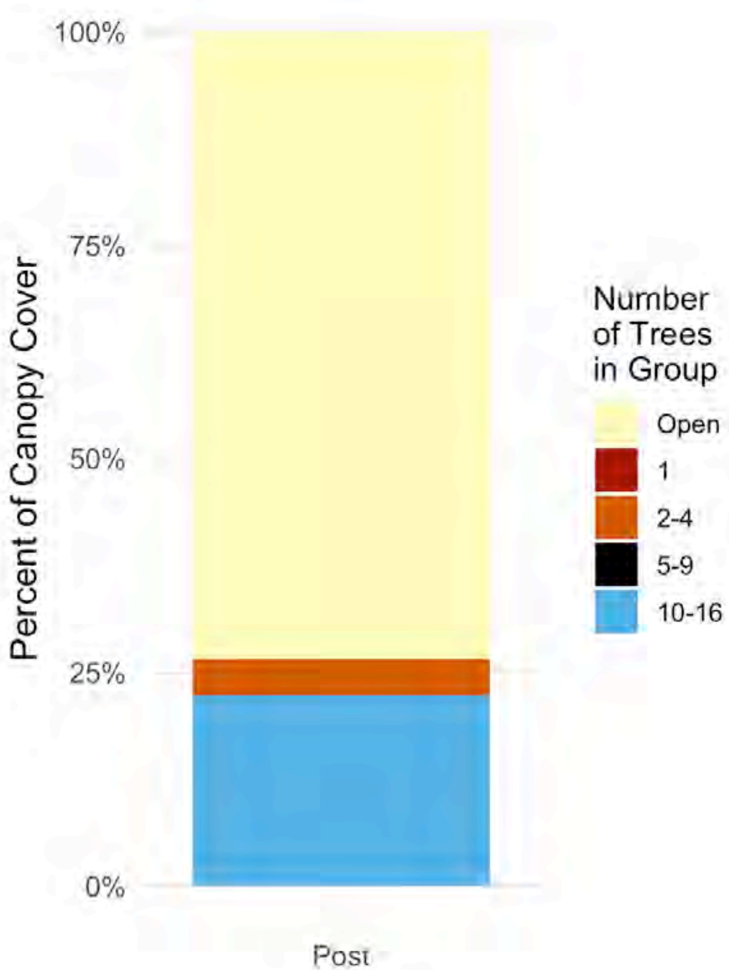
Change in basal area by species



Methods: Data was collected on the ground from 13 plots to assess the changes in stand structure and composition.

Highlights: One year following treatment thinning was effective in removing mostly Douglas-fir and lodgepole pine to meet project goals for reducing canopy cover and promoting ponderosa pine. Tree size distribution was relatively unchanged.

Spatial Heterogeneity



Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: Tree group data was not collected pre-treatment, but given that only two classes of tree groups were recorded after treatment, there may be a need for more variability in tree groups. Gap coverage and size variability increased considerably, but the median shape index was unchanged. This is likely because in our analysis, smaller gaps were equally weighted with one large and visually complex gap. Shape complexity could increase by focusing on creating more irregularity in smaller gaps.

Table 3. Changes in tree groups pre- and post-treatment (remote sensed data).

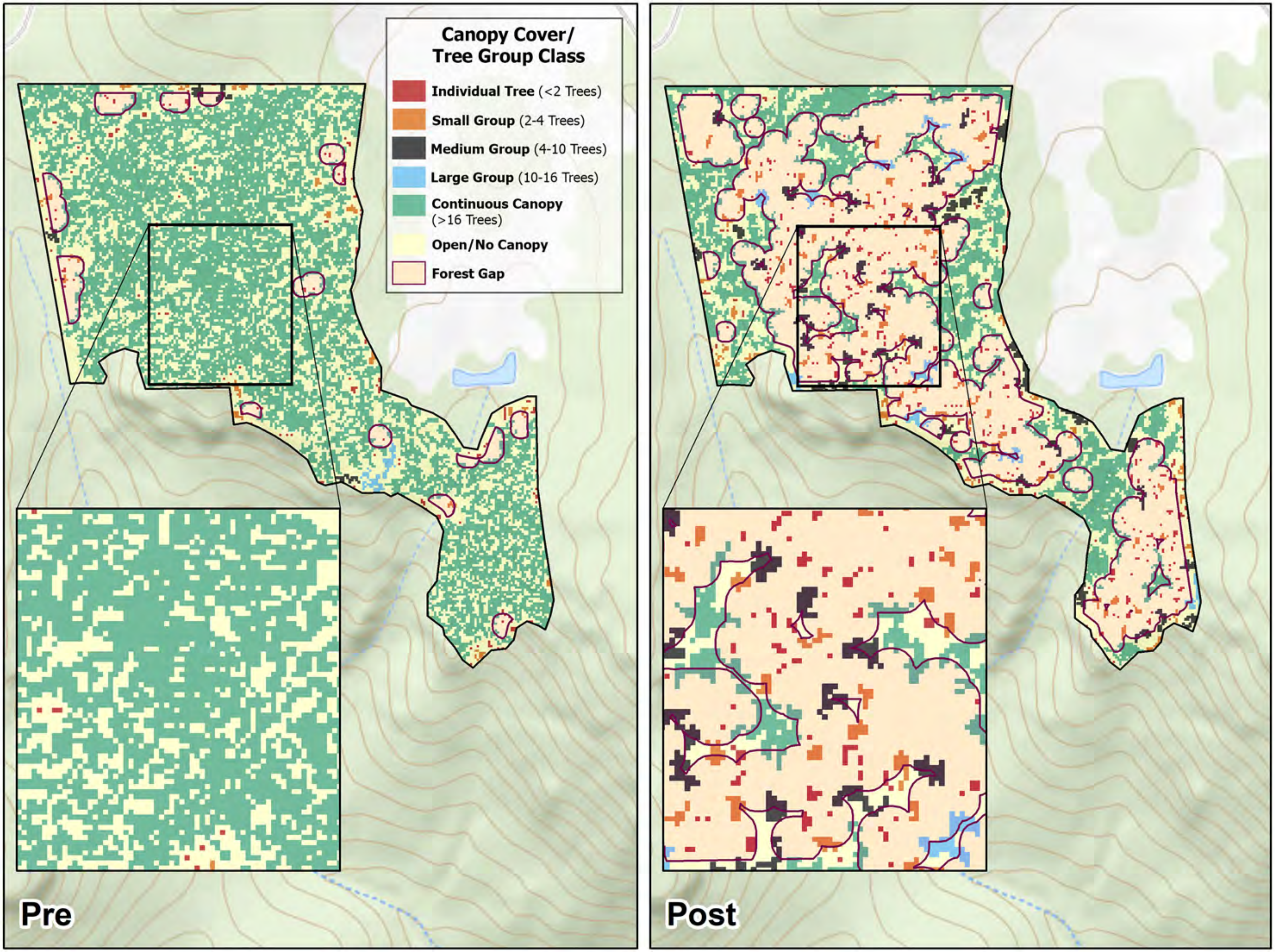
Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	57.1	0.27	1.3	96.5
Post	31.6	0.05	7.0	68.5

**Percent of total canopy cover*

Table 4. Changes in forest gaps pre- and post-treatment (remote sensed data).

Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	5.4	0.22	0.07 – 0.54	0.55	1.01
Post	58.9	3.51	0.14 – 26.91	2.39	0.99

Spatial Heterogeneity



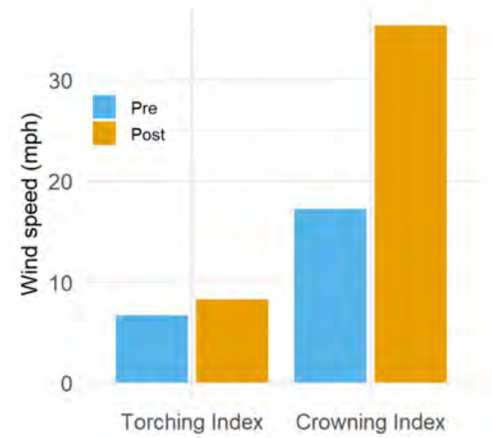
Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
Pre	2.01 ± 0.32	4.13 ± 1.08	0.97 ± 0.12	1.12 ± 0.19	9.27 ± 2.43
Post	2.24 ± 0.31	3.67 ± 0.77	1.14 ± 0.18	0.80 ± 0.15	5.96 ± 1.93

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Surface	Active	Surface	Passive
Total flame length (feet)	1.5	52.7	2.1	12.7
Surviving tree basal area (%)	66	0	64	2



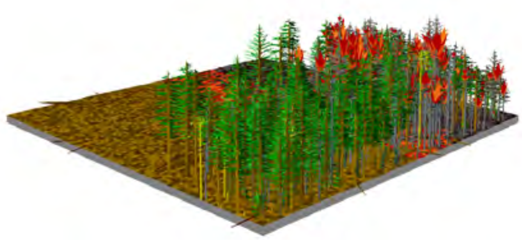
The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS).

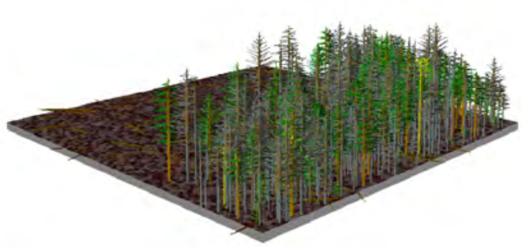
Highlights: One year following treatment pile burning successfully limited fine woody fuel loading to an increase of only 11%, and course woody fuel loading decreased. The potential for high severity fire was substantially reduced following treatment. Predicted fire behavior changed from active to passive crown fire under severe weather conditions, the total flame length fell by 76%, and the wind speed needed to carry a crown fire doubled.

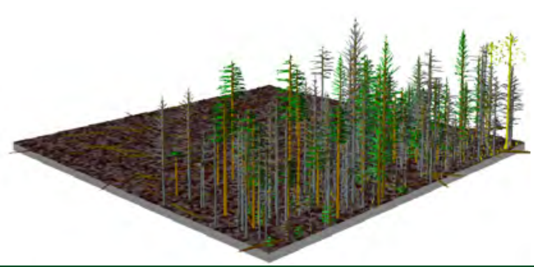
Pre-Treatment ***1 Year Post-Treatment***

During Fire



After Fire





Ridge Road 2

COLORADO FOREST RESTORATION INSTITUTE

FOREST AND RANGELAND STEWARDSHIP
COLORADO STATE UNIVERSITY

Upper South Platte Partnership Monitoring Summary
Ridge Road 2

Goals and Objectives:

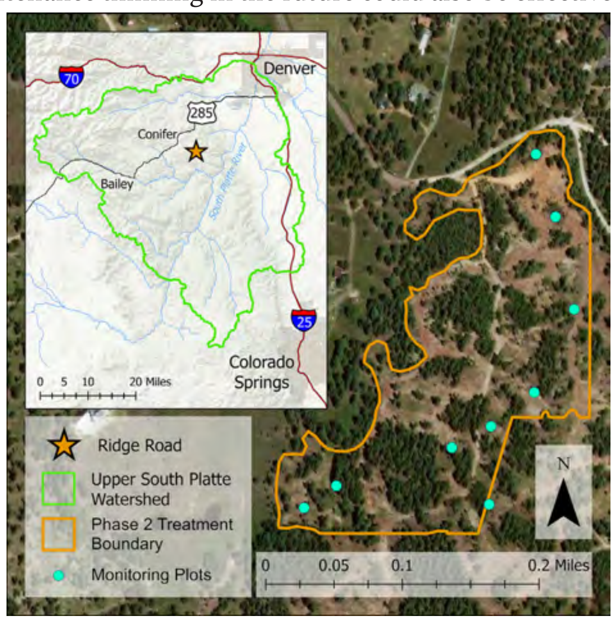
Phase 2 treatments expanded on neighboring projects to protect the community from high intensity fire by creating a contiguous treated ridgeline. Specific goals included: reduce tree crown cover to 10-60% with an average around 30%; promote ponderosa pine and aspen; create irregular forest gaps up to 3 acres in size; reduce widespread crown fire potential and increase surface fire potential. The landscape resilience management objectives for the Upper South Platte Partnership include: reducing mean canopy cover; maintaining a complex mosaic of forest canopy; increasing the ratio of ponderosa pine to other conifers; and creating conditions that support the future use of prescribed fire. More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu

Highlights:

One year after treatment, forest thinning reduced basal area by 60% to 52 ft2 per acre, and canopy cover was reduced to 33.8%, meeting canopy cover reduction goals. Field data only recorded two classes of tree group size after treatment, and increasing the presence of smaller tree groups (1-5 trees) would improve variability in tree group size. The ratio of ponderosa pine and average tree size increased slightly. Lower surface fuel loading in combination with breaking up the forest canopy reduced the potential for high severity fire, even under severe weather conditions. Forest gaps increased in average size, size variability, and shape complexity. Post-treatment conditions support the future use of prescribed fire to maintain a lower risk of high severity fire, complex forest gaps, and further promote larger ponderosa pine. Light intensity or maintenance thinning in the future could also be effective to increase canopy diversity.

Table 1. Project Information

Implementation agency	Jefferson Conservation District
Ownership	Private
Year completed	2017
Acres treated	25
Acres monitored	25
Forest type	Dry mixed conifer
Implementation method	Mechanical thinning
Slash treatment	Burn piles



Pre-treatment

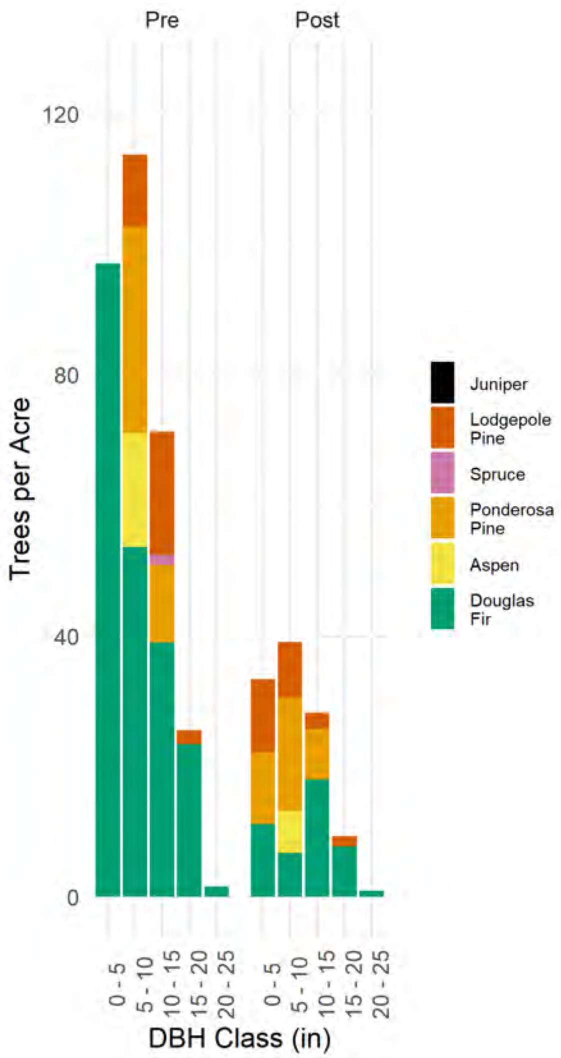
1 year post-treatment

Stand Structure and Composition

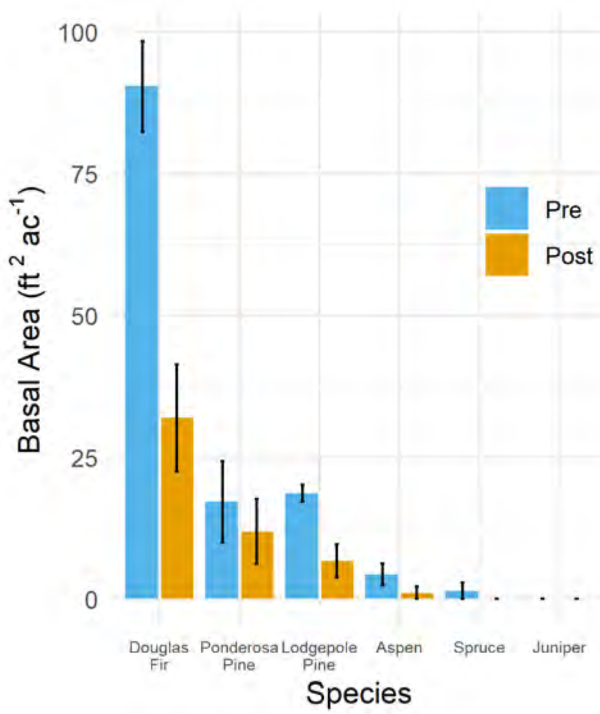
Table 2. Stand characteristics pre- and post-treatment

Phase	Trees per Acre	Basal Area (ft^2/ac)	Canopy Cover (%)	Seedlings per Acre	Percent Ponderosa by BA	Quadratic Mean Diameter	Crown Base Height (ft)
Pre	395 ± 110	132 ± 10	69.4 ± 6.1	2071 ± 800	13.4	9.2 ± 1.4	17.2 ± 2.5
Post	111 ± 38	52 ± 14	33.8 ± 9.5	1975 ± 755	23.6	10.2 ± 1.1	17.2 ± 1.4

Stand characteristics pre- and 1 year post-treatment



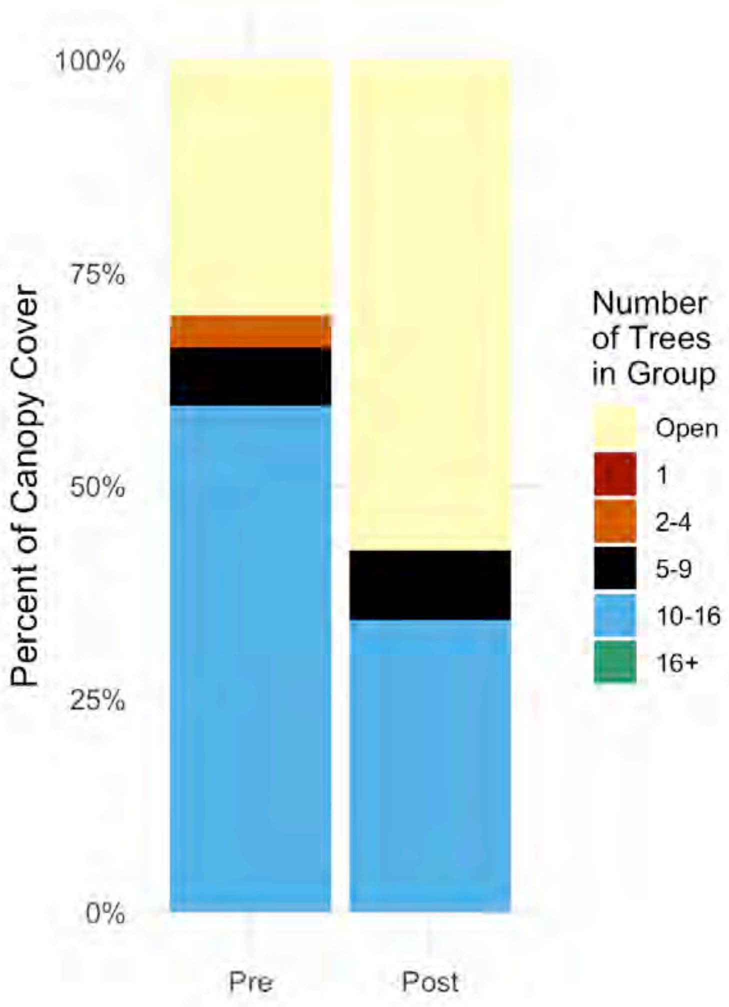
Change in basal area by species



Methods: Data was collected on the ground from 13 plots to assess the changes in stand structure and composition.

Highlights: One year following treatment Douglas-fir and lodgepole pine had the greatest reduction in basal area. Diameter distribution was relatively unchanged, but ponderosa pine made up a larger portion of each size class when present. Canopy cover met project goals and was reduced by more than half.

Spatial Heterogeneity



Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: One year after treatment there were fewer tree group size classes following treatment, and smaller tree groups (1-5 trees) were not recorded. However, there were more gaps with higher size variability and more shape irregularity. Despite the high intensity of thinning the treatment avoided creating a single large gap, and the largest gap was limited to 4.5 acres.

Table 3. Changes in tree groups pre- and post-treatment (remote sensed data).

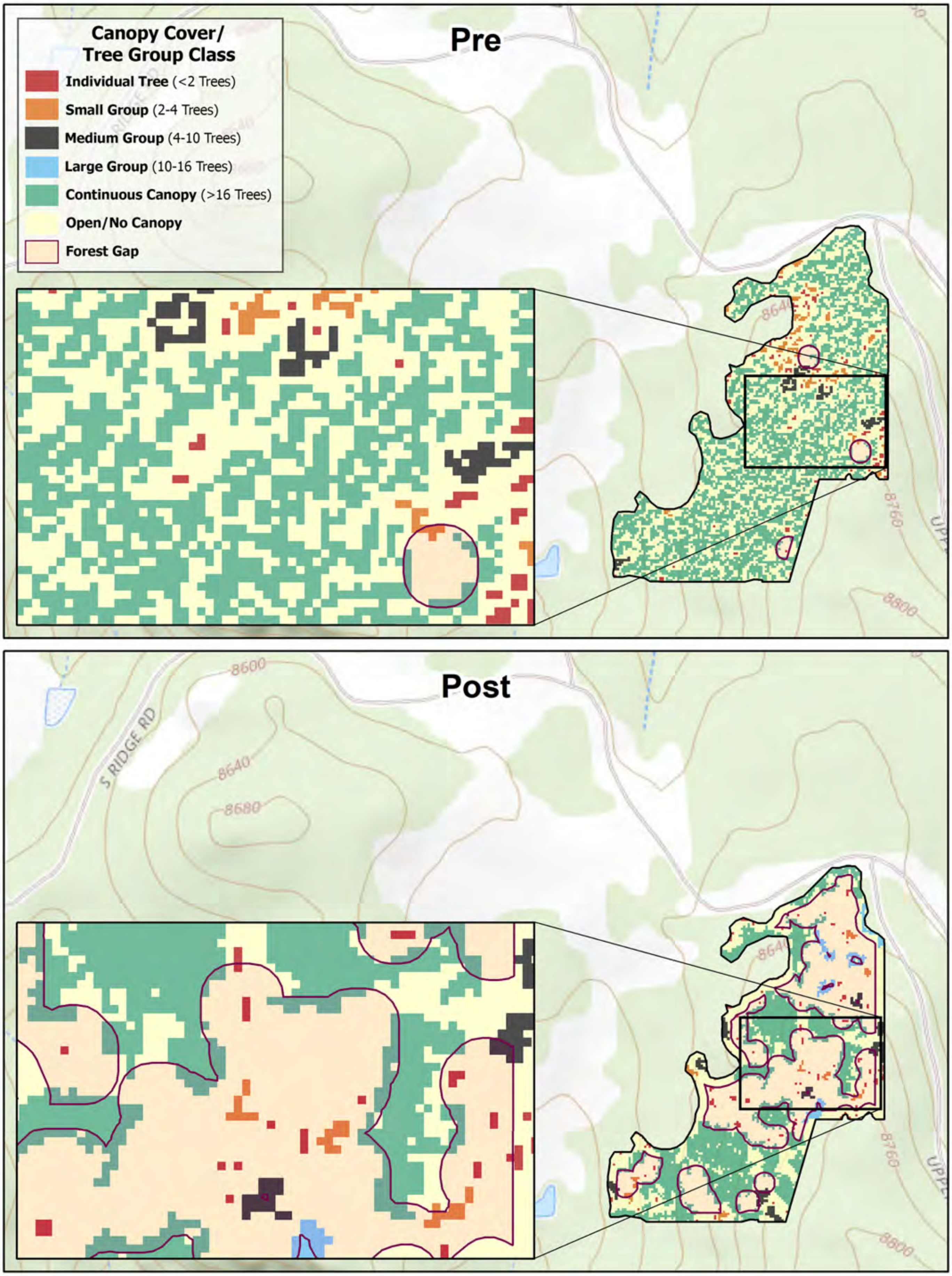
Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	50.9	0.12	3.0	90.7
Post	36.9	0.08	4.2	82.3

**Percent of total canopy cover*

Table 4. Changes in forest gaps pre- and post-treatment (remote sensed data).

Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	2.0	0.15	0.12 – 0.12	0.22	0.89
Post	48.0	1.53	0.15 – 4.50	1.26	1.17

Spatial Heterogeneity



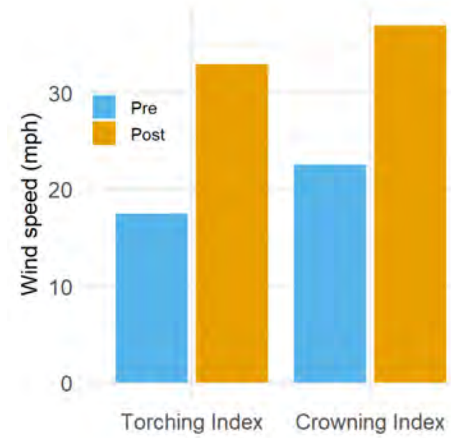
Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
Pre	2.45 ± 0.49	1.46 ± 0.55	0.65 ± 0.08	0.64 ± 0.12	22.24 ± 0.35
Post	1.98 ± 0.59	1.37 ± 0.37	0.84 ± 0.20	0.96 ± 0.22	4.92 ± 2.43

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Surface	Passive	Surface	Surface
Total flame length (feet)	1.2	14.9	1.5	3.8
Surviving tree basal area (%)	74	2	73	65



The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

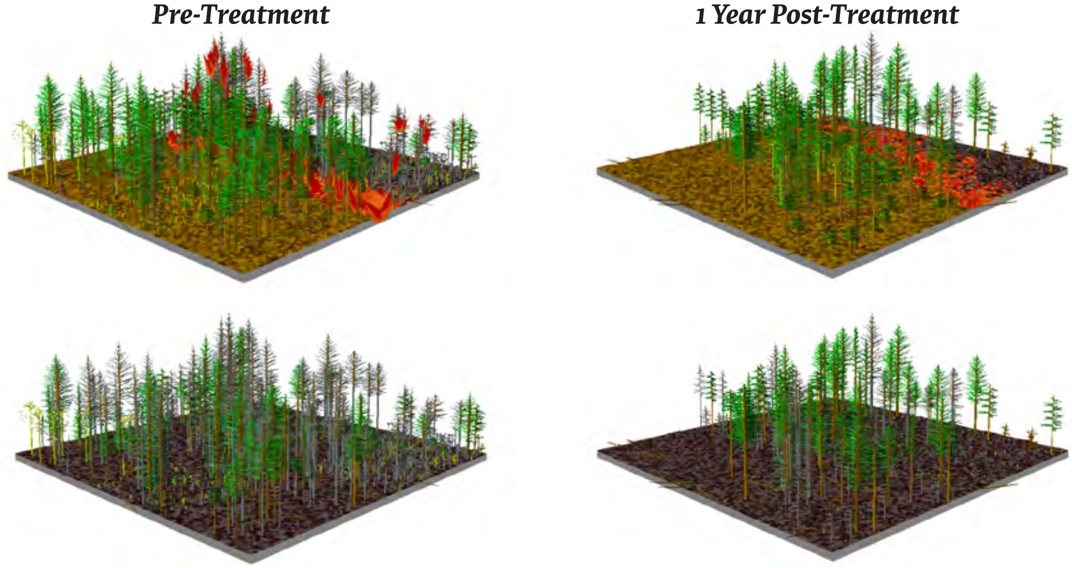
Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS).

Highlights: One year following treatment fine woody fuel loading decreased by 19%, and coarse woody fuel loading by 6%. Fewer surface fuels and a less contiguous canopy changed predicted fire behavior. Total flame length fell by 74% and both the torching and crowning index substantially increased. The potential for high severity fire was reduced and post-treatment conditions support the future use of prescribed fire. This project highlights the impact of treating slash with pile burning to meet goals for desirable fire behavior.

Pre-Treatment ***1 Year Post-Treatment***

During Fire

After Fire



Payne Gulch

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Upper South Platte Partnership Monitoring Summary Payne Gulch

Goals and Objectives:

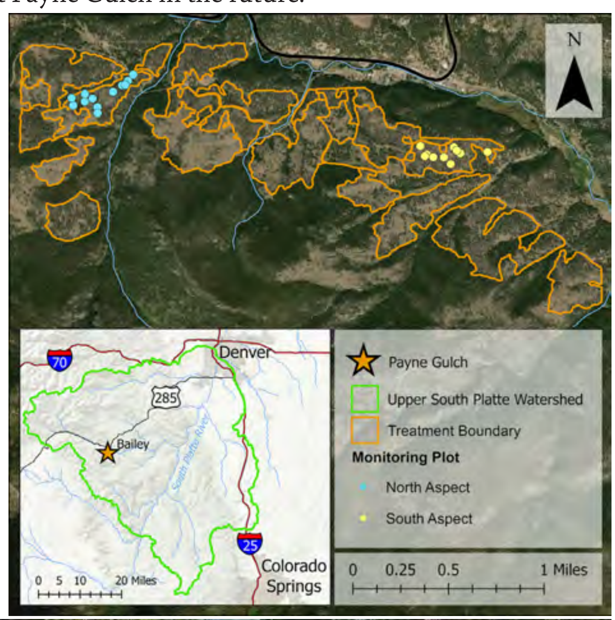
The main objective of the Forests to Faucets partnership between Denver Water and the U.S. Forest Service is to reduce wildfire risk to Denver's critical watersheds and improve forest conditions across the Front Range. Forest restoration treatments in the Upper South Platte were designed to create a mosaic pattern across the landscape that promotes wildlife habitat and resilience to fire, insects and disease. To achieve the mosaic pattern, stand prescriptions aimed to reduce overall canopy cover and tree density, while increasing variability in stand age and forest openings. Targets for Payne Gulch included reducing basal area to an average 50 ft^2 and tree density to 50-60 trees per acre, while maintaining diversity of tree sizes and density across the treatment area. Ponderosa pine and larger trees of all species were favored for retention in varying group sizes from 2 trees to 50+ trees in reserves. **Analysis separated sites of north and south aspects to highlight topographic differences in the treatment.** More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu

Highlights:

Forest thinning at Payne Gulch achieved many project objectives by targeting smaller diameter trees for removal. The treatment substantially reduced tree density, and created a stand dominated by larger ponderosa pine. Fire hazard was relatively low prior to treatment, and remained low following thinning. Surface fuel loading only increased slightly, and surface fire was predicted to occur under most weather conditions across monitored sites. Following treatment, there were more gaps that have greater size variability; a mosaic pattern of forest cover and gaps emerged within the project boundary. There is high potential for the use of prescribed fire at Payne Gulch in the future.

Table 1. Project Information

Implementation agency	Pike San Isabel National Forest, South Platte Ranger District
Ownership	U.S. Forest Service
Funding	Forests to Faucets
Year completed	2017
Acres treated	545
Acres monitored	75
Forest type	Ponderosa Pine
Implementation method	Mechanical Thinning
Slash treatment	Product removal, Mastication

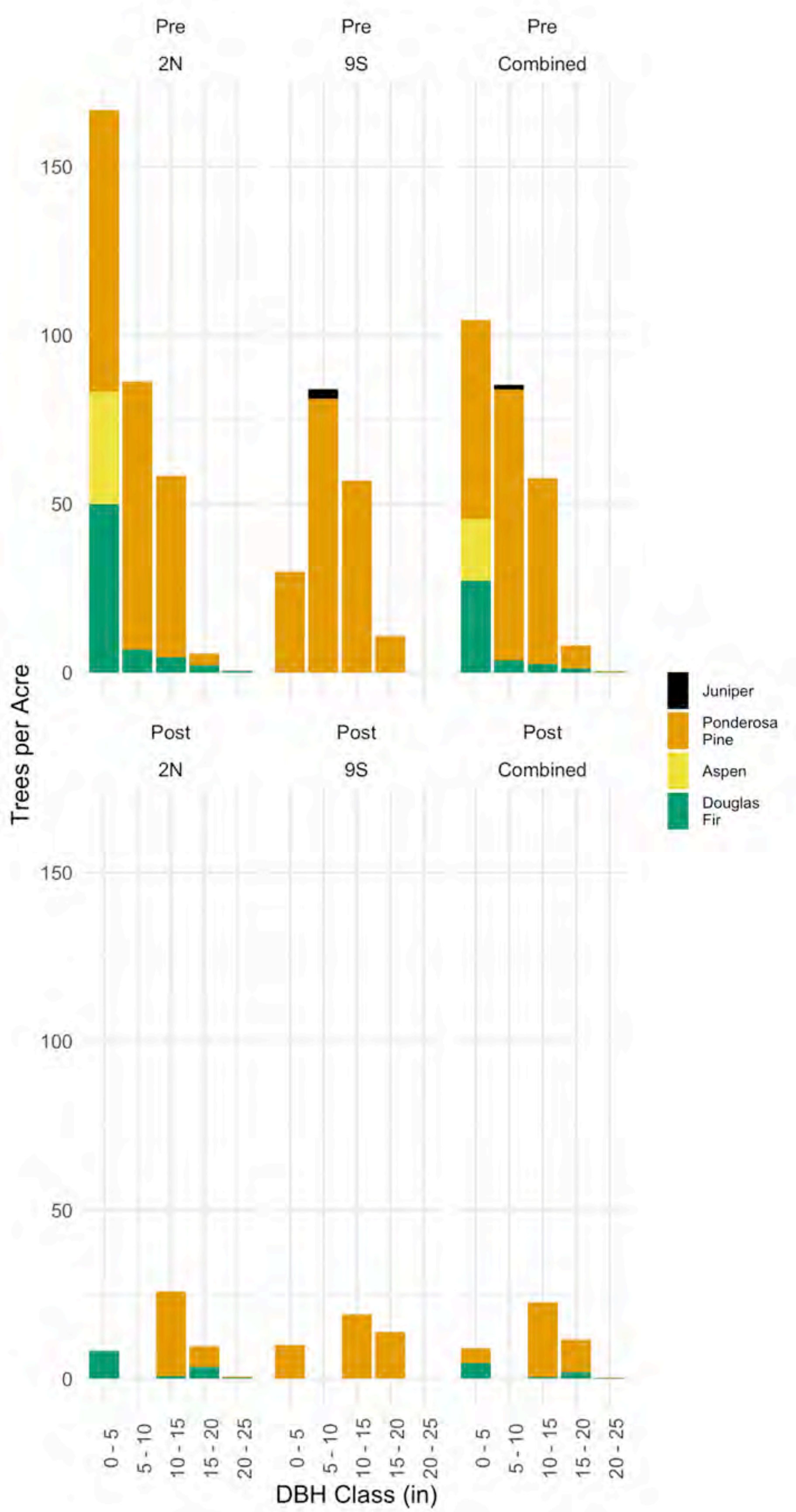



Pre-treatment


1 year post-treatment

Stand Structure and Composition

Change in tree size distribution



Methods: Data was collected on the ground from 21 plots (11 north aspect, 10 south aspect) to assess the changes in stand structure and composition.

Highlights: Thinning treatments in the north aspect unit mostly removed ingrowth of small diameter ponderosa pine and Douglas-fir. Tree density was reduced by 86%, canopy cover dropped by 32%, and average tree size increased by 64%. The south aspect unit mostly removed small diameter ponderosa pine to maintain a stand that had already been dominated by ponderosa.

Stand Structure and Composition

Change in basal area by species

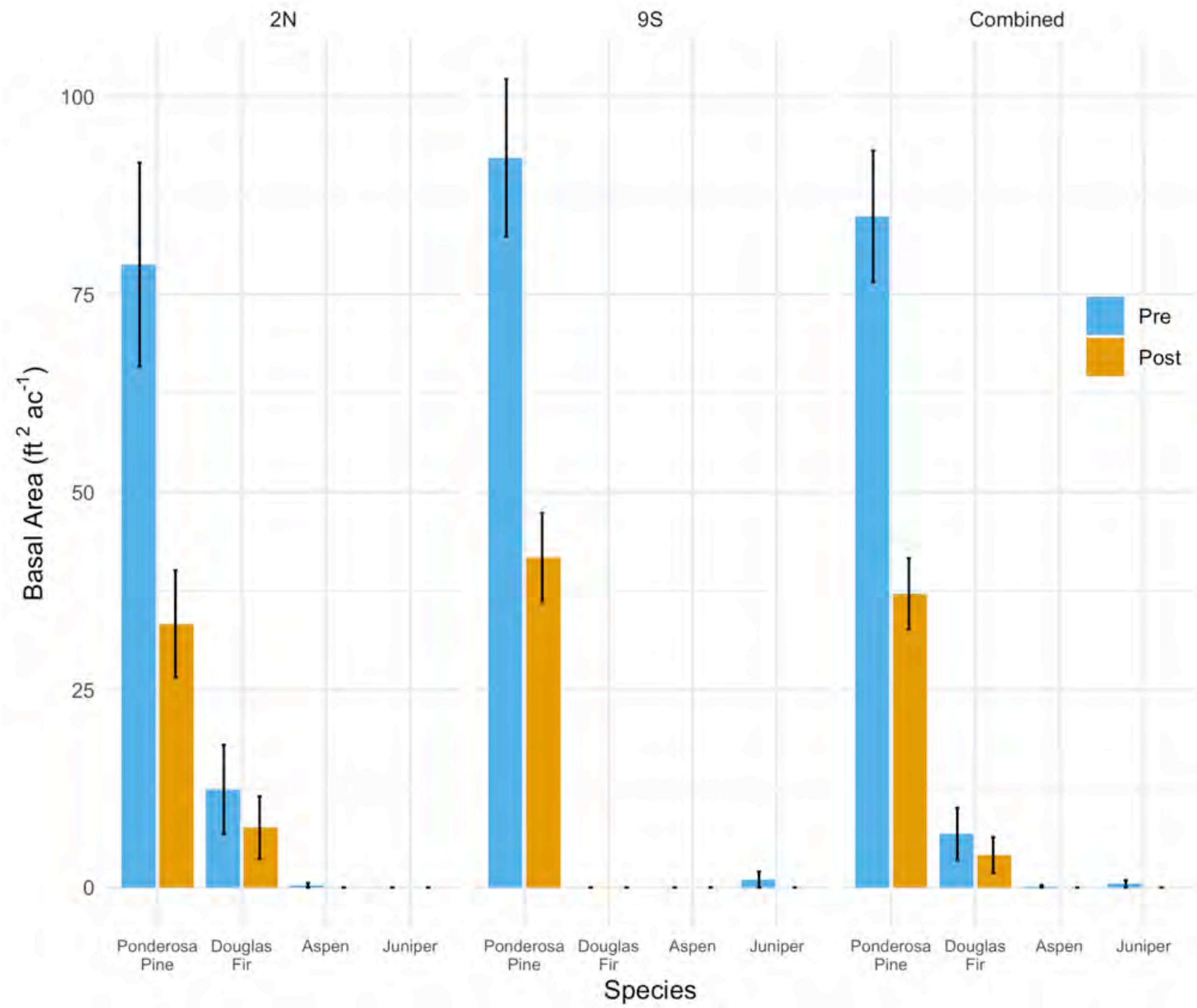


Table 2. Stand characteristics pre- and 1 year post-treatment

Aspect	Phase	Trees per acre	Basal area (ft²/ac)	Canopy cover (%)	Seedlings per acre	Percent ponderosa by BA (%)	Quadratic mean diameter (in)	Crown base height (ft)
North	Pre	318 ± 64	91 ± 10	50 ± 7	1675 ± 458	86	8.3 ± 0.9	14.2 ± 1.7
	Post	45 ± 9	41 ± 6	18 ± 5	558 ± 245	81	13.6 ± 0.7	17.6 ± 2.6
South	Pre	182 ± 42	93 ± 10	43 ± 5	50 ± 34	99	10.9 ± 0.8	12.5 ± 0.8
	Post	43 ± 9	42 ± 6	19 ± 6	30 ± 21	100	14.3 ± 0.9	13.3 ± 2.1
Combined	Pre	256 ± 41	92 ± 7	47 ± 4	936 ± 302	85	9.5 ± 0.6	13.4 ± 1.0
	Post	44 ± 6	41 ± 4	19 ± 4	318 ± 143	84	13.9 ± 0.5	15.6 ± 1.7

Spatial Heterogeneity

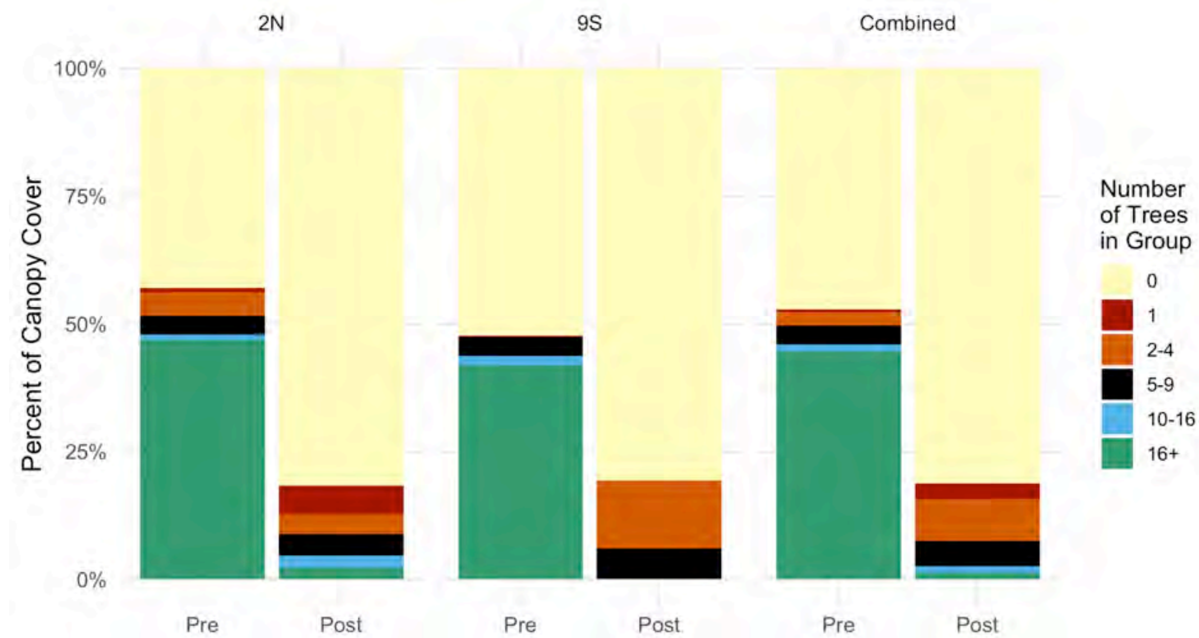


Table 3. Changes in tree groups pre- and post-treatment

Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	67.2	0.26	1.4	96.5
Post	33.1	0.04	9.4	59.4

**Percent of total canopy cover*

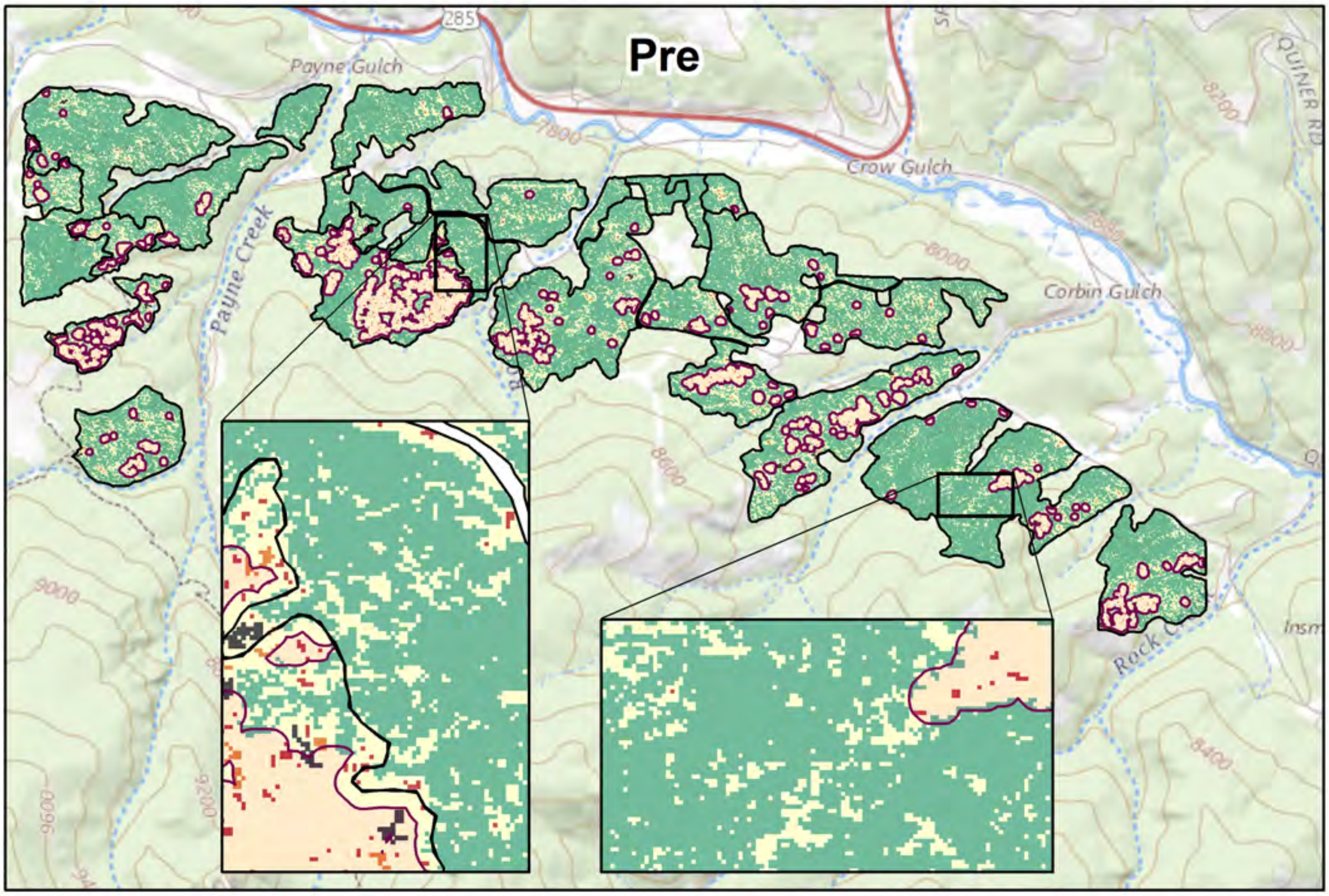
Table 4. Changes in forest gaps pre- and post-treatment.

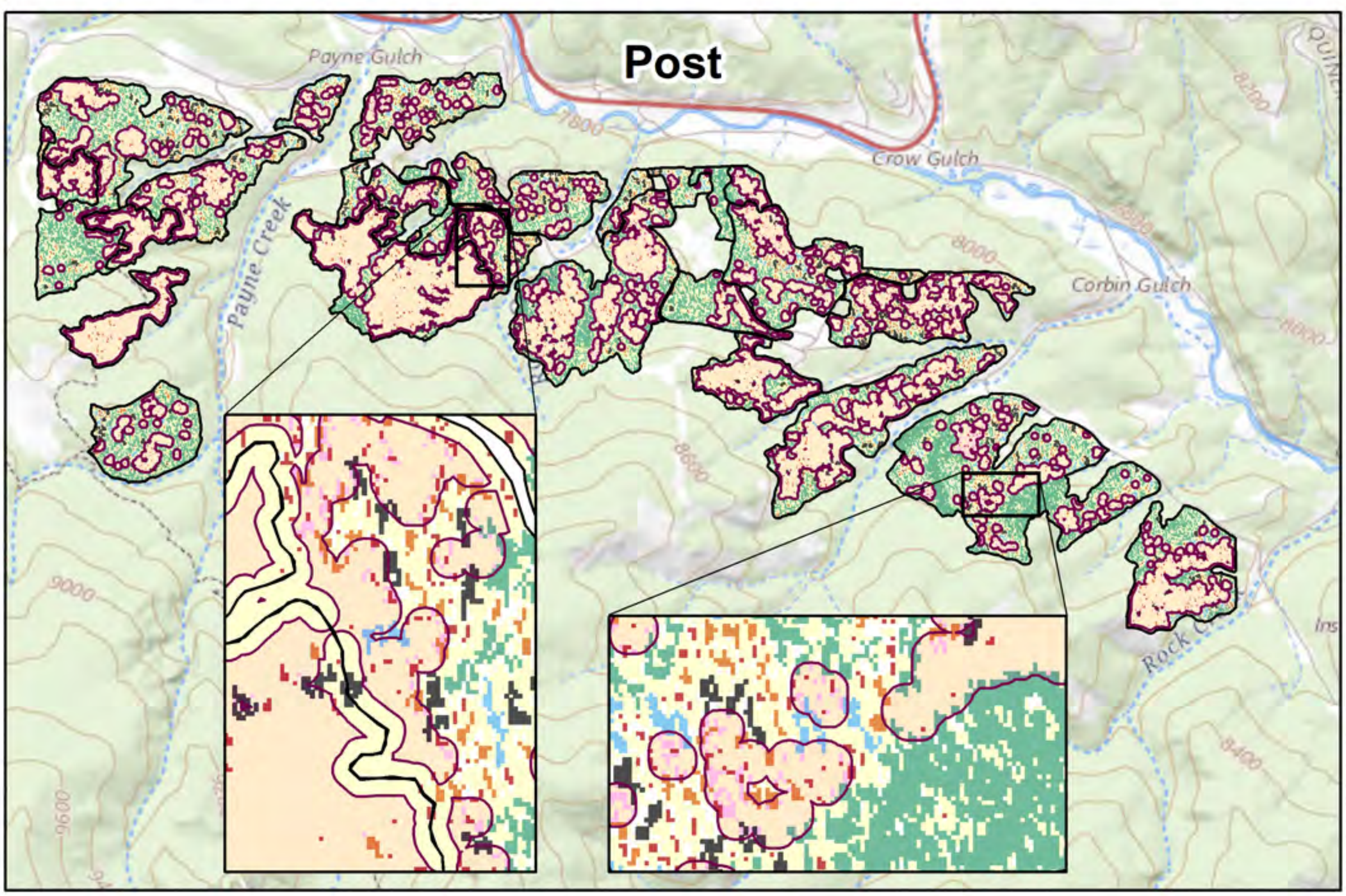
Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	12.6	0.69	0.07 - 6.27	2.80	0.97
Post	40.0	1.24	0.07 - 23.60	2.88	1.01

Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: The gap coverage increased tripled to 40% and average gap size nearly doubled following thinning. Variability in forest gap size and shape remained relatively the same. Tree groups with more than 16 trees were heavily reduced across the project, and there was more group size diversity in the north aspect unit.

Spatial Heterogeneity





Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

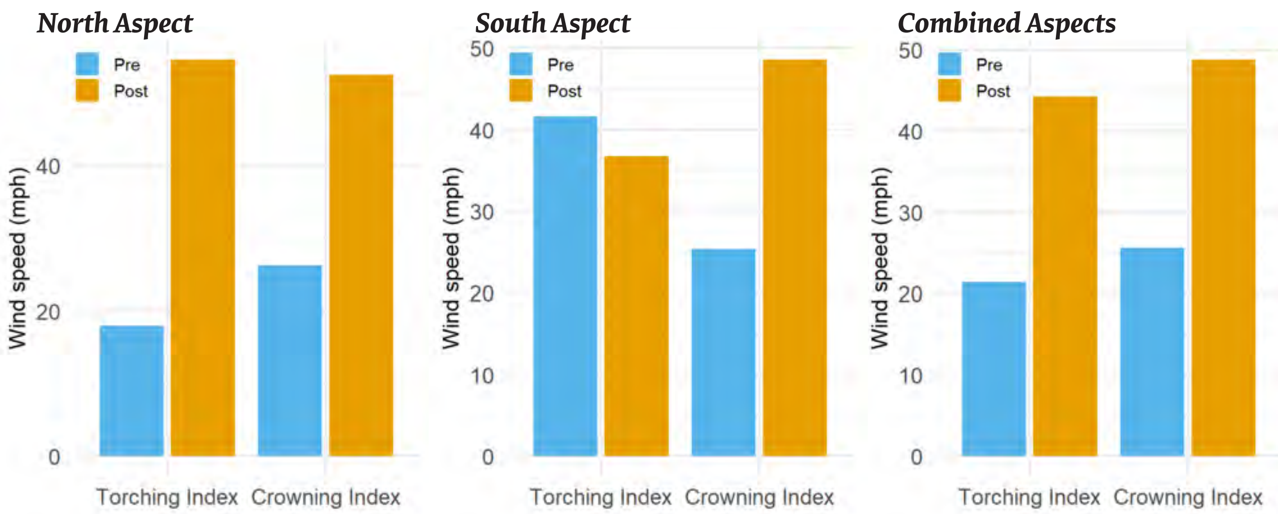
Aspect	Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
North	Pre	1.87 ± 0.88	1.15 ± 0.48	0.98 ± 0.12	0.59 ± 0.09	11.95 ± 2.96
	Post	0.86 ± 0.16	1.70 ± 0.34	0.62 ± 0.08	0.42 ± 0.09	3.22 ± 1.49
South	Pre	0.71 ± 0.08	0.14 ± 0.82	0.82 ± 0.09	0.64 ± 0.12	4.68 ± 1.49
	Post	1.14 ± 0.26	1.48 ± 0.25	1.03 ± 0.18	0.42 ± 0.09	1.68 ± 0.89
Combined	Pre	1.34 ± 0.49	0.69 ± 0.28	0.92 ± 0.08	0.61 ± 0.07	8.65 ± 1.89
	Post	0.99 ± 0.15	1.60 ± 0.21	0.78 ± 0.09	0.42 ± 0.06	2.52 ± 0.90

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Aspect	North				South			
Phase	Pre		Post		Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe	Moderate	Severe	Moderate	Severe
Fire type	Surface	Passive	Surface	Surface	Surface	Surface	Surface	Surface
Total flame length (feet)	1.6	7.6	1.4	3.4	1.1	2.6	1.8	4.5
Surviving tree basal area (%)	75	2	86	85	77	72	86	66

Combined North and South				
Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Surface	Surface	Surface	Surface
Total flame length (feet)	1.4	3.2	1.4	3.5
Surviving tree basal area (%)	75	66	87	85

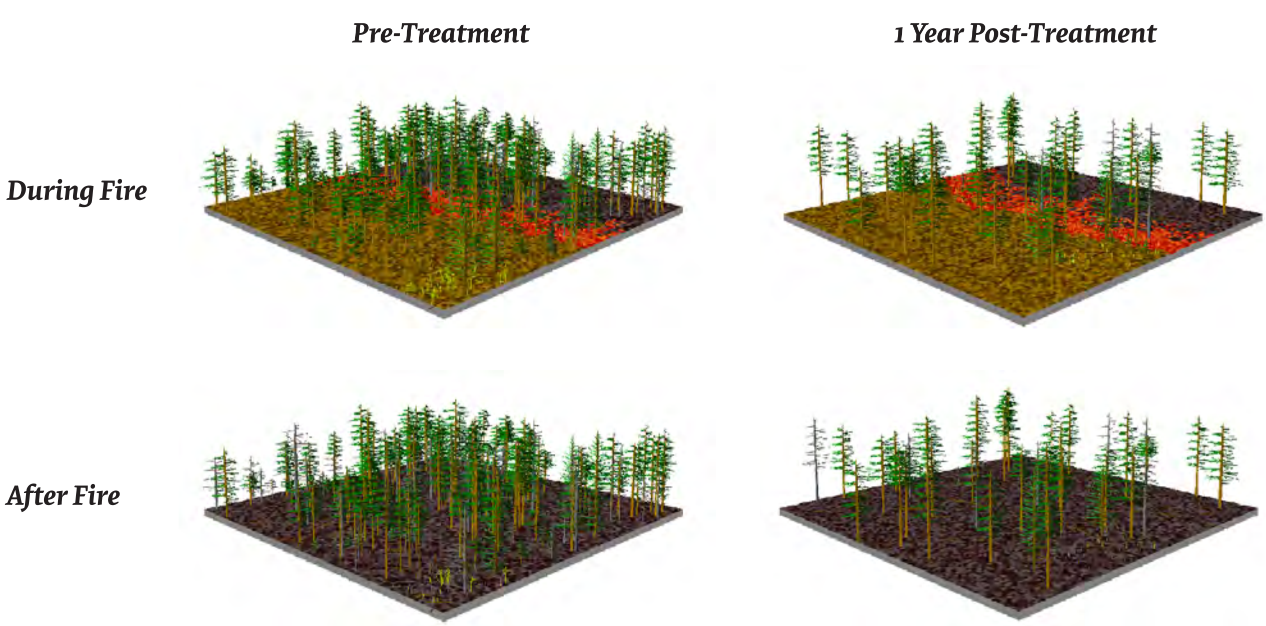
Fuels and Fire Behavior



The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator.

Highlights: Accumulations of surface fuels were limited following thinning, and fine fuel loading decreased by 26%. Across both the north and south aspect units the risk of active crown fire was low prior to treatment and was slightly reduced following thinning. Torching index was lower after treatment on south aspects and there could be a higher potential for group and individual tree torching in the south aspect unit. Surface fire was predicted under severe weather conditions for both units, and conditions strongly support the use of prescribed fire in the future.



March, 2021
Monitoring methods and more information are available at cfri.colostate.edu
Contact: Andrew Slack
AndrewW.Slack@colostate.edu

COLORADO FOREST RESTORATION INSTITUTE

FOREST AND RANGELAND STEWARDSHIP
COLORADO STATE UNIVERSITY

Upper South Platte Partnership Monitoring Summary
Nighthawk, Osprey, Long Scraggy (NOS)

Goals and Objectives:

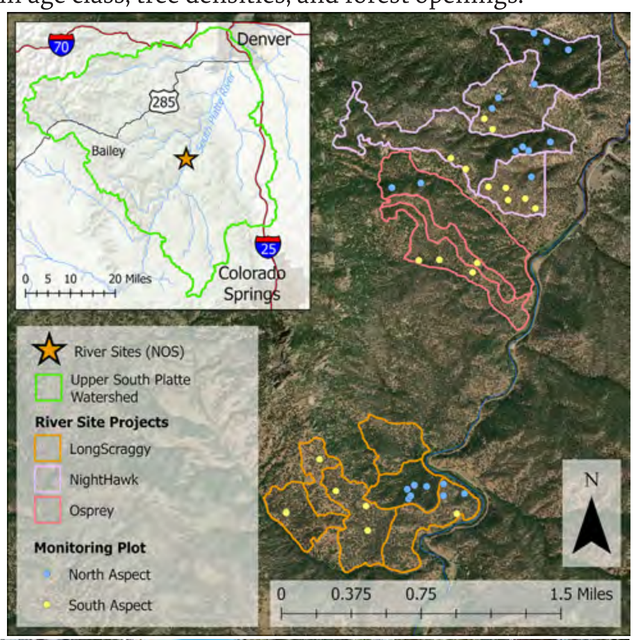
The main objective of the Forests to Faucets partnership between Denver Water and the U.S. Forest Service is to reduce wildfire risk to Denver's critical watersheds and improve forest conditions across the Front Range. Forest restoration treatments in the Upper South Platte were designed to create a mosaic pattern across the landscape that promotes wildlife habitat and resilience to fire, insects and disease. To achieve the mosaic pattern, stand prescriptions aimed to reduce overall canopy cover and tree density, while increasing variability in stand age and forest openings. Targets for Nighthawk, Osprey, and Long Scraggy (NOS) include reducing basal area to an average 50 ft^2, and tree density to 50-60 trees per acre, while maintaining diversity of tree sizes and density across the treatment area. Ponderosa pine and larger trees of all species were to be favored for retention in varying group sizes from 2 trees to 50+ trees in reserves. **Analysis separated sites of north and south aspects to highlight topographic differences in the treatment.** More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu

Highlights:

Most metrics suggested that stand conditions were closer to desired conditions following treatment. Thinning created more forest gaps that were more variable in size. Analysis of potential fire behavior also suggested less risk of crown fire activity following treatment. However, because thinning intensity at NOS was relatively light, future management may be needed to ensure treatment longevity. Prescribed fire at NOS has the potential to allow for mixed-severity fire that supports the development of a mosaic pattern with variations in age class, tree densities, and forest openings.

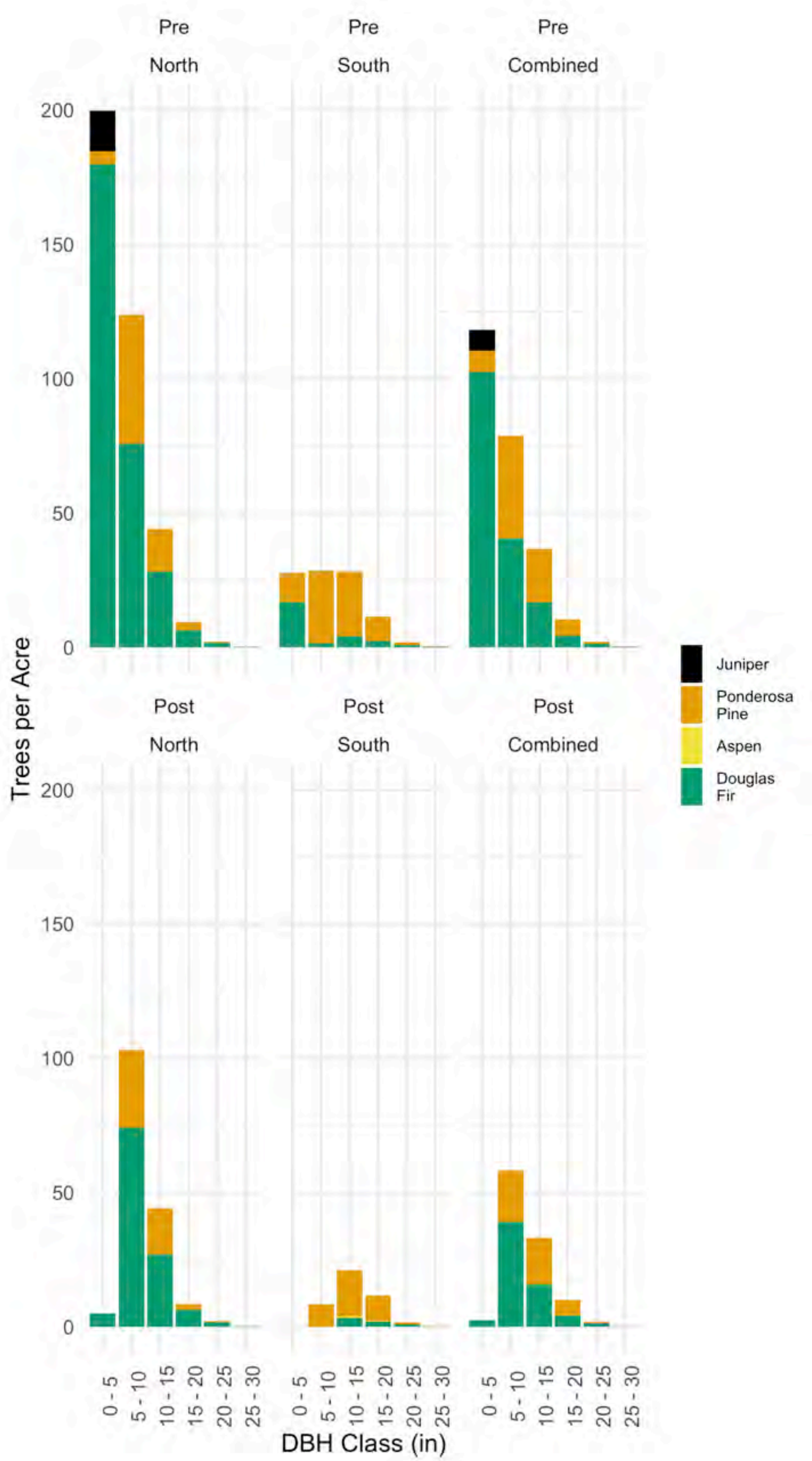
Table 1. Project Information

Implementation agency	Pike San Isabel National Forest, South Platte Ranger District
Ownership	U.S. Forest Service
Funding	Forests to Faucets
Year completed	2017
Acres treated	834
Acres monitored	787
Forest type	Ponderosa Pine Mixed Conifer
Implementation method	Hand Thinning
Slash treatment	Lop and scatter, pile burn



Stand Structure and Composition

Change in tree size distribution



Methods: Data was collected on the ground from 40 plots (21 north aspect, 19 south aspect) to assess the changes in stand structure and composition.

Highlights: Tree density was cut in half across the project, and thinning intensity was similar on north and south aspects. Because mostly smaller diameter trees were cut, there was only slight reduction in basal area and canopy cover. Species composition remained unchanged after treatment.

Stand Structure and Composition

Change in basal area by species

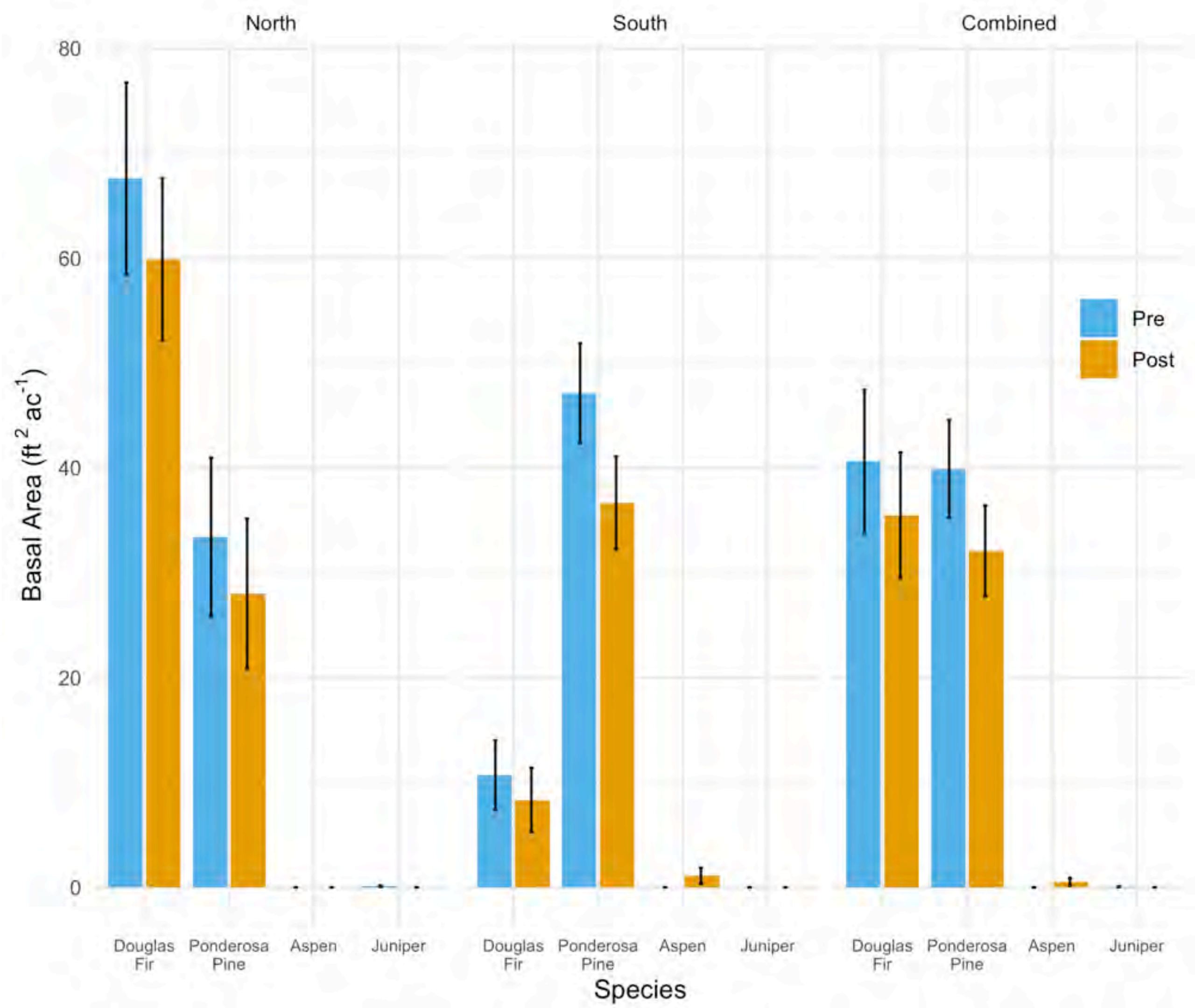


Table 2. Stand characteristics pre- and 1 year post-treatment

Aspect	Phase	Trees per acre	Basal area (ft^2/ac)	Canopy cover (%)	Seedlings per acre	Percent ponderosa by BA (%)	Quadratic mean diameter (in)	Crown base height (ft)
North	Pre	380 ± 79	102 ± 10	50.8 ± 6.4	956 ± 330	33	8.2 ± 0.5	9.4 ± 0.9
	Post	163 ± 23	88 ± 8	42.7 ± 4.7	355 ± 225	32	10.4 ± 0.4	11.5 ± 0.7
South	Pre	98 ± 25	58 ± 5	48.8 ± 7.1	307 ± 96	82	12.3 ± 0.7	9. ± 1.3
	Post	43 ± 4	46 ± 5	36.6 ± 5.4	157 ± 49	81	14.1 ± 0.4	10.7 ± 1.0
Combined	Pre	246 ± 49	81 ± 7	49.5 ± 4.7	467 ± 156	49	10.2 ± 0.5	9.5 ± 0.8
	Post	106 ± 16	68 ± 6	39.7 ± 3.6	262 ± 130	48	12.2 ± 0.4	11.1 ± 0.6

Spatial Heterogeneity

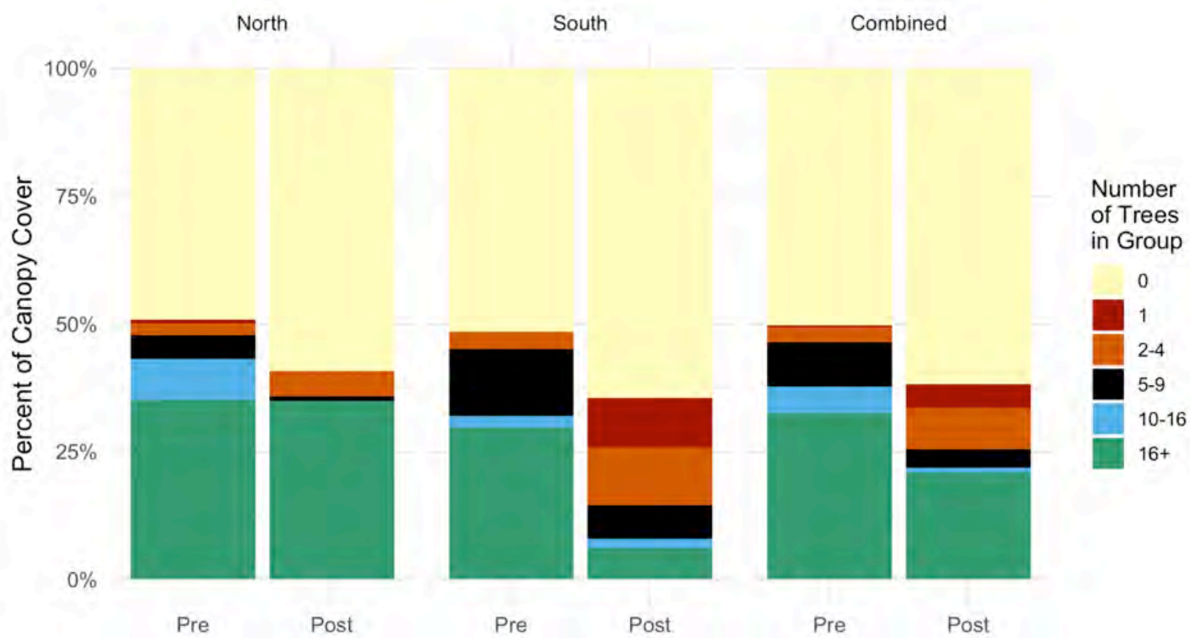


Table 3. Changes in tree groups pre- and post-treatment

Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	69.8	0.59	0.6	97.7
Post	52.2	0.13	2.9	88.3

**Percent of total canopy cover*

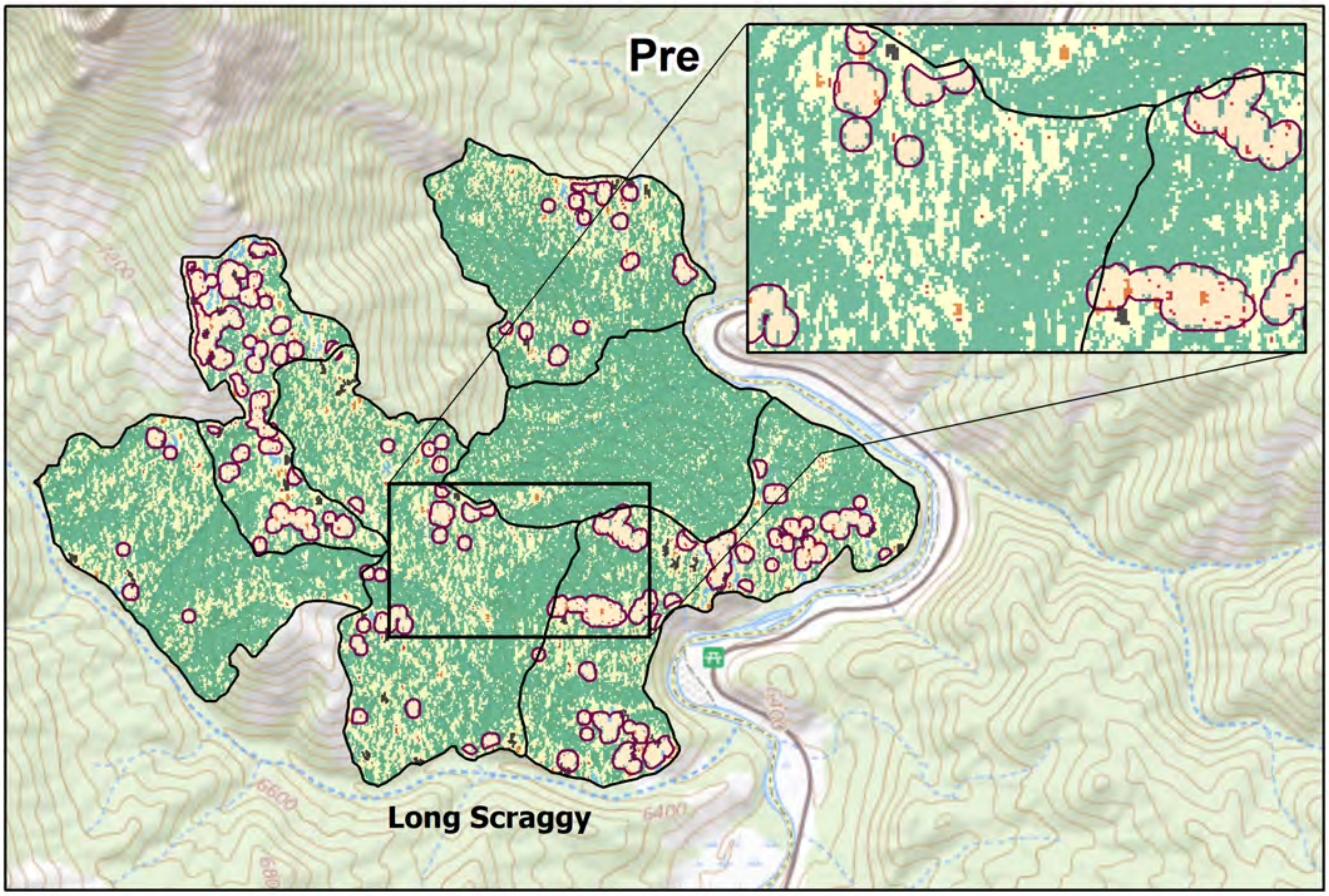
Table 4. Changes in forest gaps pre- and post-treatment.

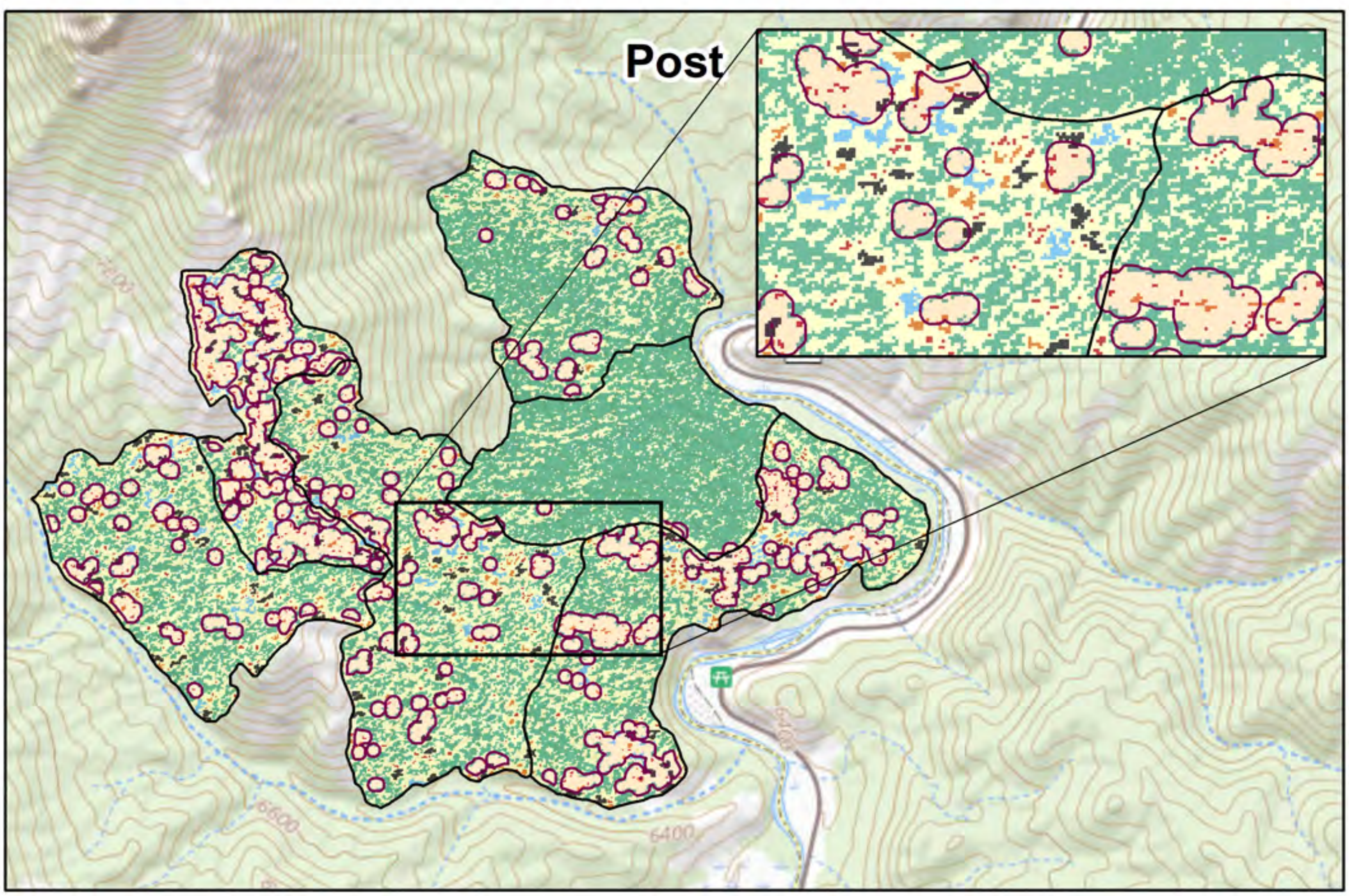
Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	5.8	0.34	0.03 - 2.08	1.01	0.91
Post	18.4	0.64	0.03 - 30.94	3.29	0.94

Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: Forest thinning resulted in larger gaps that maintained shape complexity and were more variable in size. On south facing slopes treatments were effective in breaking up a contiguous canopy into small tree groups (<16 trees), which contributed to diverse mosaic pattern in the canopy. Small tree groups and individual trees made up more of the canopy on southern aspects, and larger groups of more than 16 trees persist on northern aspects.

Spatial Heterogeneity





Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

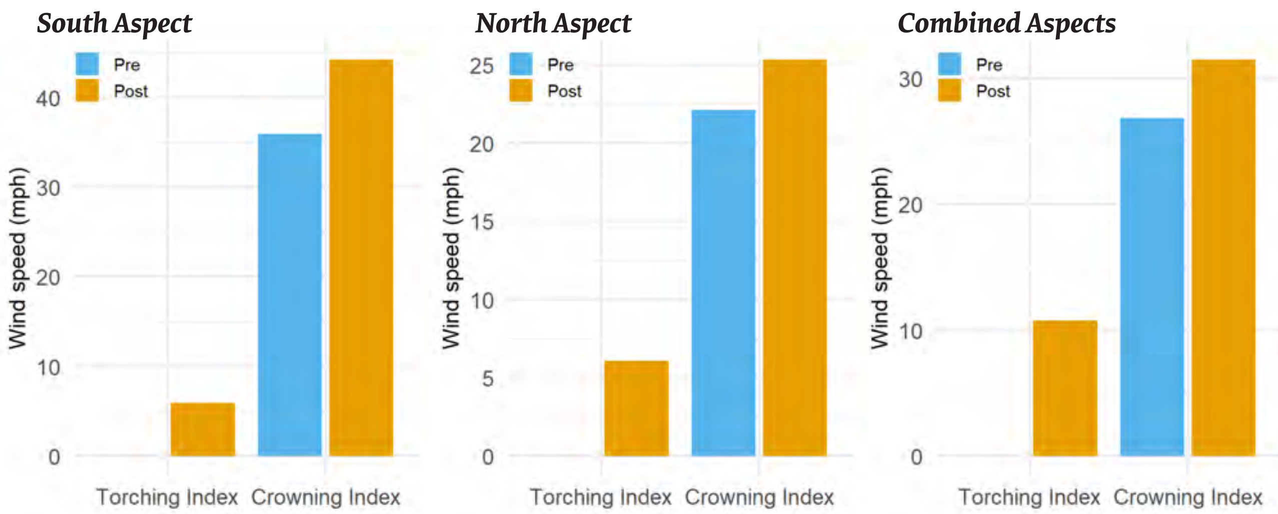
Aspect	Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
South	Pre	0.58 ± 0.10	2.08 ± 0.74	0.70 ± 0.08	0.25 ± 0.06	0.53 ± 0.34
	Post	0.82 ± 0.31	5.18 ± 0.71	0.85 ± 0.11	0.29 ± 0.09	2.97 ± 1.42
North	Pre	1.15 ± 0.15	1.53 ± 0.41	0.62 ± 0.07	0.46 ± 0.07	3.15 ± 1.19
	Post	1.01 ± 0.22	2.82 ± 0.69	0.91 ± 0.21	0.47 ± 0.07	2.73 ± 1.41
Combined	Pre	0.88 ± 0.10	1.79 ± 0.41	0.66 ± 0.05	0.36 ± 0.05	1.91 ± 0.67
	Post	0.92 ± 0.18	3.94 ± 0.52	0.88 ± 0.12	0.39 ± 0.06	2.84 ± 0.99

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Aspect	**South**				**North**			
Phase	Pre		Post		Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe	Moderate	Severe	Moderate	Severe
Fire type	Passive	Passive	Surface	Passive	Passive	Passive	Surface	Passive
Total flame length (feet)	3.5	17.6	4.0	15.0	3.3	40.6	3.2	28.5
Surviving tree basal area (%)	40	2	37	3	32	1	45	1

Combined South and North				
Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Passive	Passive	Surface	Passive
Total flame length (feet)	3.1	26.3	0.8	15.8
Surviving tree basal area (%)	41	1	80	2

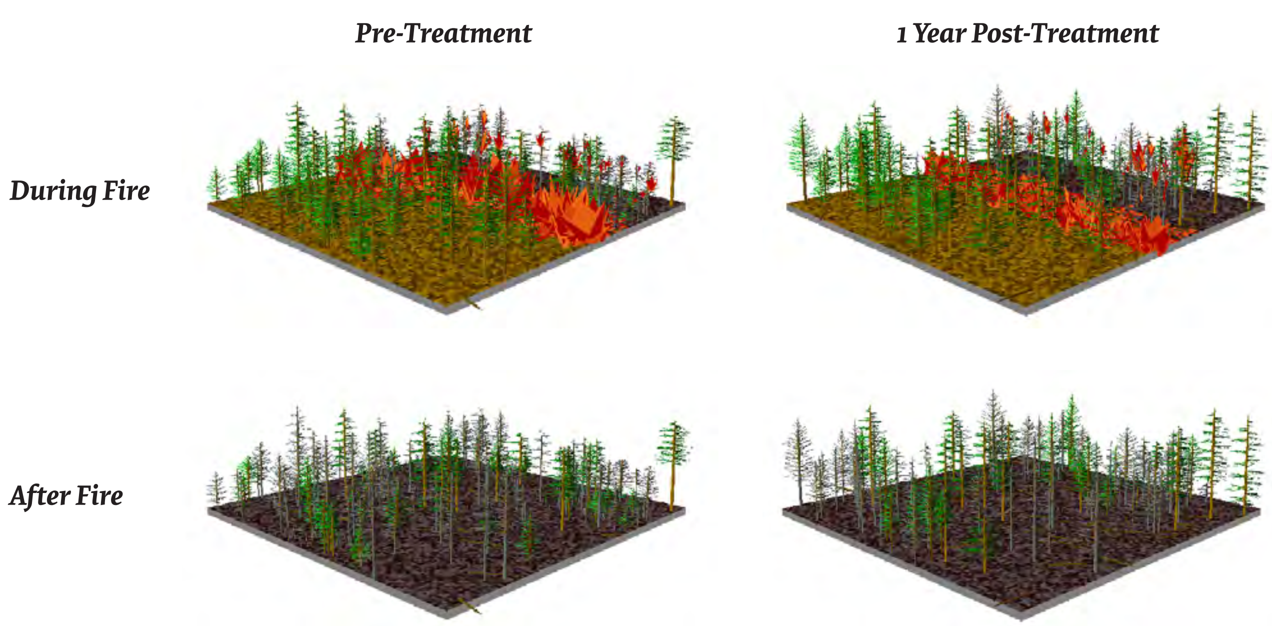
Fuels and Fire Behavior



The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator.

Highlights: Treatments were effective in limiting the accumulations of fine woody fuels. Total flame lengths were 40% lower following thinning, and surface fire was predicted under moderate weather conditions. For the most part modeled fire behavior following treatment was only slightly changed, and there was a marginally lower potential for crown fire activity.



COLORADO FOREST RESTORATION INSTITUTE | FOREST AND RANGELAND STEWARDSHIP, COLORADO STATE UNIVERSITY

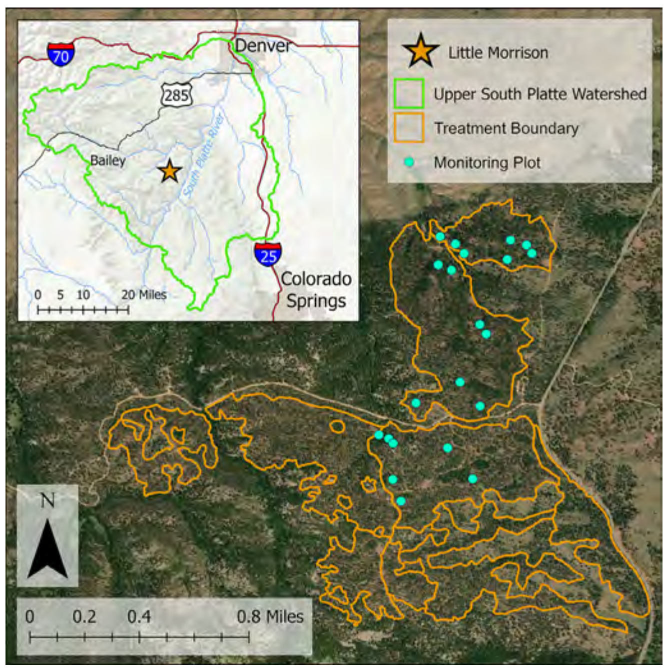
Forests to Faucets Monitoring Summary
Little Morrison

Goals and Objectives:
The main objective of the Forests to Faucets partnership between Denver Water and the U.S. Forest Service is to reduce wildfire risk to Denver's critical watersheds and improve forest conditions across the Front Range. Forest restoration treatments in the Upper South Platte were designed to create a mosaic pattern across the landscape that promotes wildlife habitat and resilience to fire, insects and disease. To achieve the mosaic pattern, stand prescriptions aimed to reduce overall canopy cover and tree density, while increasing variability in stand age and forest openings. Targets for Little Morrison include reducing basal area to an average of 25 - 50 ft^2, and tree density to 50-60 trees per acre. Ponderosa pine and larger trees of all species were to be favored for retention in varying group sizes from 2 trees to 50+ trees in reserves.

Highlights:
Most metrics suggested that stand conditions were closer to desired conditions following treatment. However, because thinning intensity at Little Morrison was relatively light, future treatments may be needed to achieve desired conditions and ensure treatment longevity. It should be noted that the project was mostly on a gentle, north facing slope. Thinning created more forest gaps, but there was no change in gap size variability. While the potential for high intensity crown fire was slightly reduced, passive crown fire was still predicted under moderate weather conditions following treatment.

Table 1. Project Information

Implementation agency	Pike San Isabel National Forest, South Platte Ranger District
Ownership	U.S. Forest Service
Funding	Collaborative Forest Landscape Restoration Program
Year completed	2018
Acres treated	615
Acres monitored	290
Forest type	Ponderosa Pine/Mixed Conifer
Implementation method	Mechanical thinning
Slash treatment	Product removal and pile burning




Pre-treatment

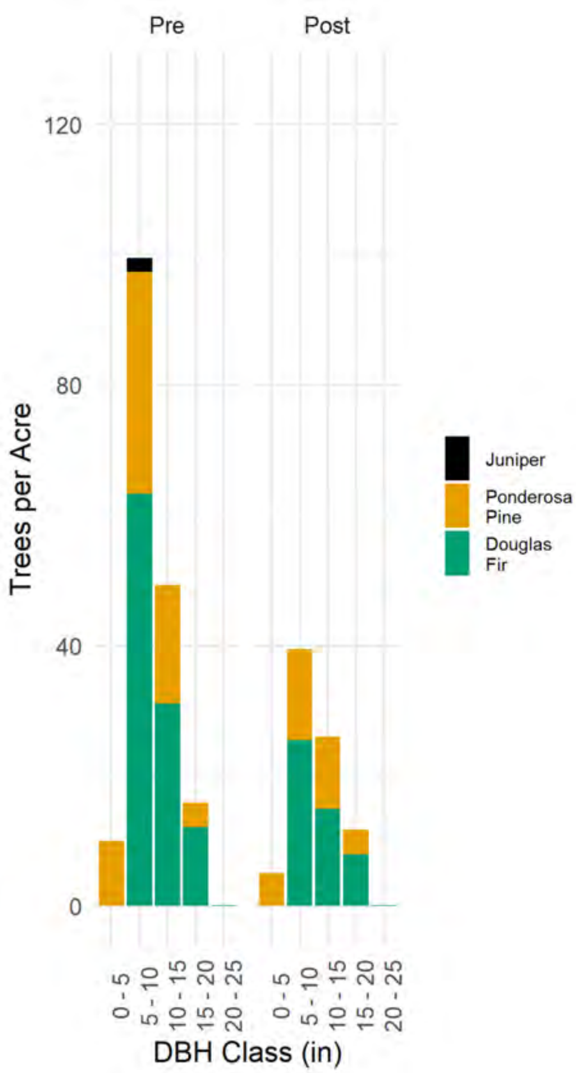

1 year post-treatment

Stand Structure and Composition

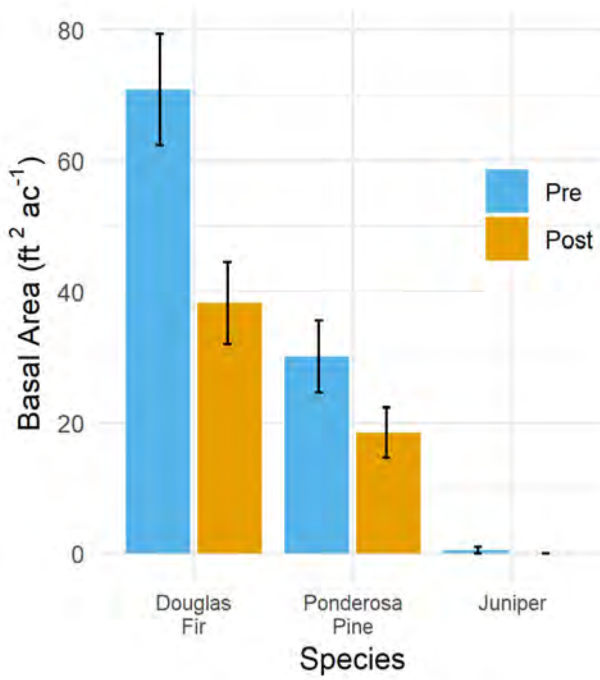
Table 2. Stand characteristics pre- and post-treatment

Phase	Trees per Acre	Basal Area (ft²/ac)	Canopy Cover (%)	Seedlings per Acre	Percent Ponderosa by BA	Quadratic Mean Diameter	Crown Base Height (ft)
Pre	504 ± 156	101 ± 5	49 ± 4	1815 ± 485	20	7.7 ± 0.6	12.5 ± 1.1
Post	322 ± 128	57 ± 6	32 ± 5	1485 ± 454	33	9.0 ± 1.0	13.3 ± 1.1

Stand characteristics pre- and 1 year post-treatment



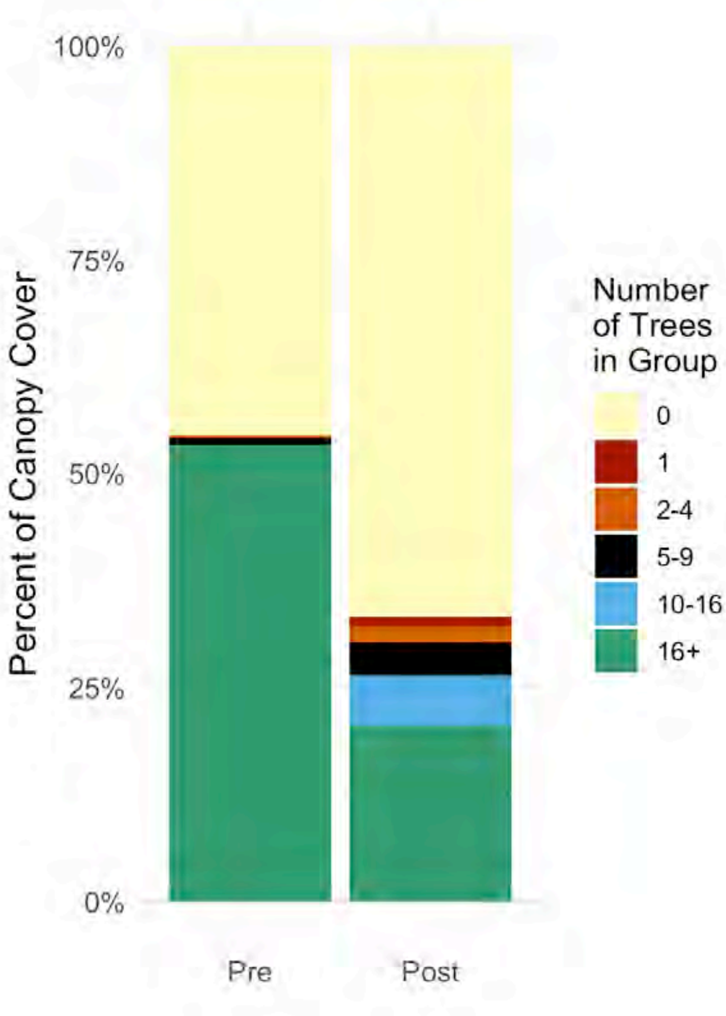
Change in basal area by species



Methods: Data was collected on the ground from 22 plots to assess the changes in stand structure and composition.

Highlights: Forest thinning reduced tree density by 37%, basal area by 44%, and canopy cover by 17%. Stand composition shifted marginally to favor ponderosa pine and larger trees.

Spatial Heterogeneity



Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: Gap coverage increased following thinning, but there are still relatively few gaps and the variability in gap size and shape was unchanged. There were more small and medium tree groups after treatment, and future thinning could break up residual large tree groups to further increase heterogeneity and reach targets for tree density and basal area.

Table 3. Changes in tree groups pre- and post-treatment (remote sensed data).

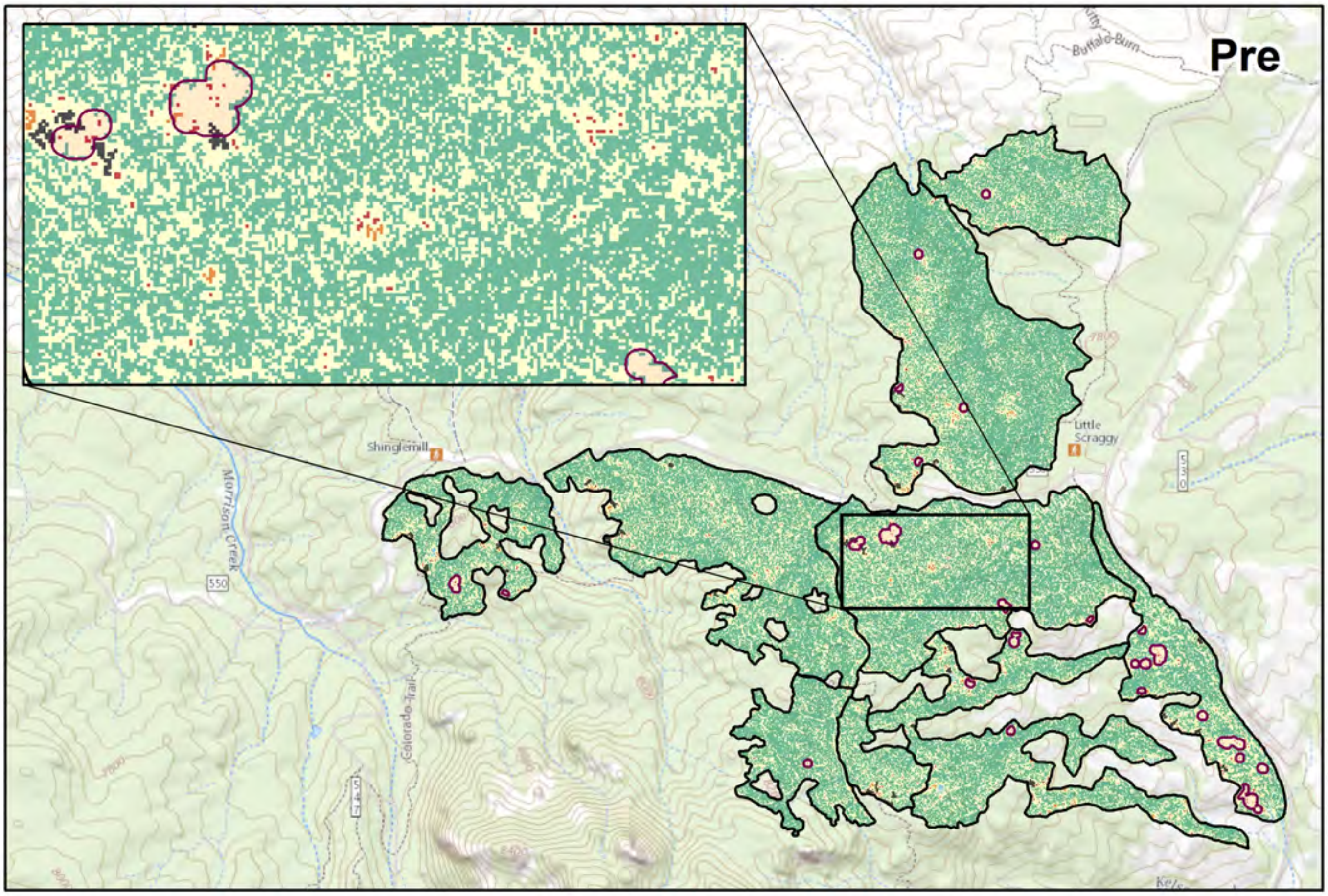
Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	63.9	0.42	0.9	98.2
Post	40.4	0.05	7.2	76.3

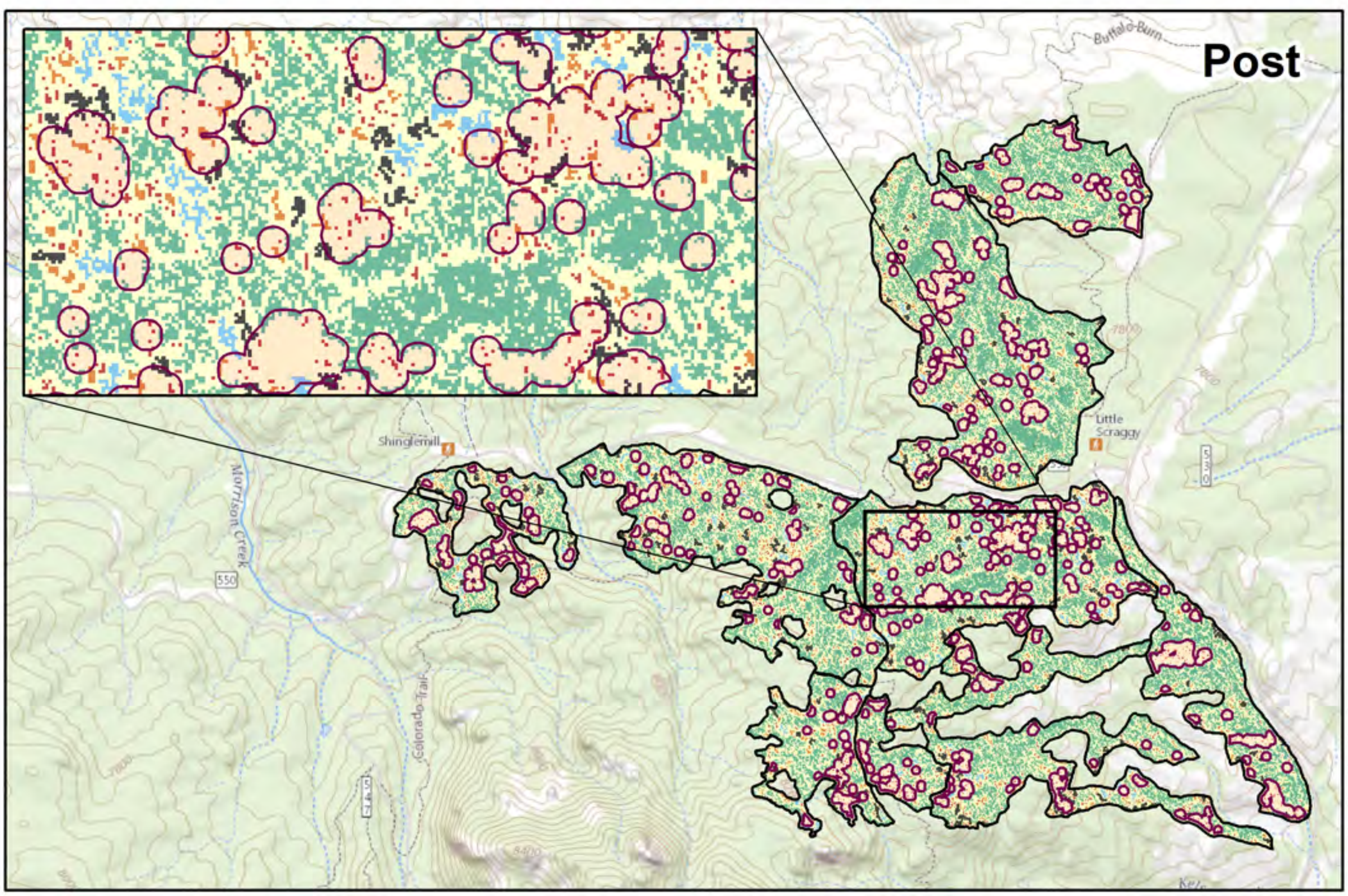
Percent of total canopy cover

Table 4. Changes in forest gaps pre- and post-treatment (remote sensed data).

Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	1.2	0.30	0.07 - 0.91	0.88	0.98
Post	16.4	0.42	0.07 - 3.36	1.13	0.97

Spatial Heterogeneity





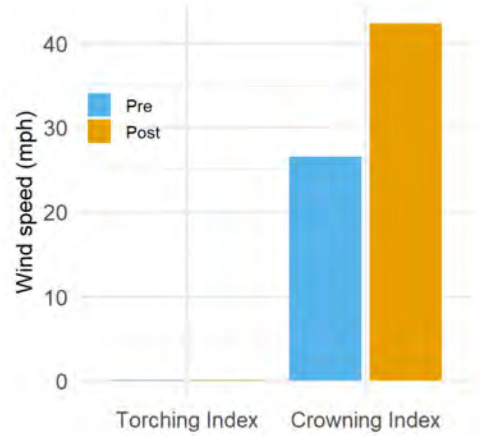
Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
Pre	1.07 ± 0.17	1.92 ± 0.68	9.03 ± 1.22	0.83 ± 0.07	0.92 ± 0.09
Post	1.12 ± 0.17	3.06 ± 0.76	4.95 ± 1.06	1.13 ± 0.16	0.57 ± 0.08

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Passive	Passive	Passive	Passive
Total flame length (feet)	3.5	29.8	3.4	15.0
Surviving tree basal area (%)	45	1	57	2



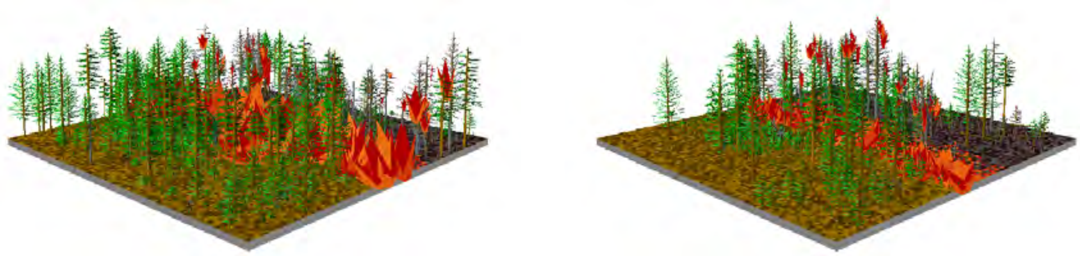
The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS).

Highlights: Surface fuel accumulations were limited following treatments and fine fuels were unchanged. The crowning index increased by 62% and the predicted total flame length was cut in half under severe weather conditions. However, following treatment passive crown fire was predicted to occur under moderate weather conditions, the torching index did not increase from zero, and the potential for high intensity fire behavior remains high. Additional treatment may be required to support the use of prescribed fire at Little Morrison.

Pre-Treatment | ***1 Year Post-Treatment***

During Fire



After Fire

Spring Creek

COLORADO FOREST RESTORATION INSTITUTE

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COLORADO STATE UNIVERSITY

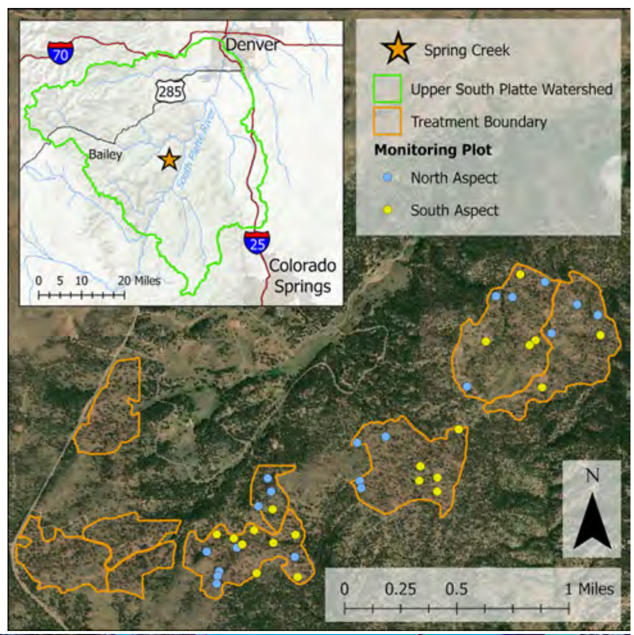
Upper South Platte Partnership Monitoring Summary
Spring Creek

Goals and Objectives:
The main objective of the Forests to Faucets partnership between Denver Water and the U.S. Forest Service is to reduce wildfire risk to Denver's critical watersheds and improve forest conditions across the Front Range. Forest restoration treatments in the Upper South Platte were designed to create a mosaic pattern across the landscape that promotes wildlife habitat and resilience to fire, insects and disease. To achieve the mosaic pattern, stand prescriptions aimed to reduce overall canopy cover and tree density, while increasing variability in stand age and forest openings. Targets for Spring Creek include reducing basal area to an average of 50 ft^2 and tree density to 50-60 trees per acre Ponderosa pine and larger trees of all species were to be favored for retention in varying group sizes from 2 trees to 50+ trees in reserves. **Analysis separated sites of north and south aspects to highlight topographic differences in the treatment.** More information on the project, monitoring methods and adaptive management can be found here – www.cfri.colostate.edu

Highlights:
Treatments successfully reduced basal area, tree density, and canopy cover by over 50%, well below prescription targets. This thinning supported an increase in average tree size, and the ratio of ponderosa pine to other conifers. Increased gap coverage and variability in forest gaps improved heterogeneity across the landscape. Higher variability in tree group size following treatment indicates that a mosaic pattern is beginning to emerge. Predicted fire intensity was low to begin with, but the risk of crown fire was further reduced.

Table 1. Project Information

Implementation agency	Pike San Isabel National Forest, South Platte Ranger District
Ownership	U.S. Forest Service
Funding	Forests to Faucets
Year completed	2018
Acres treated	578
Acres monitored	414
Forest type	Ponderosa Pine
Implementation method	Mechanical Thinning
Slash treatment	Burn Pile, Lop and Scatter, Product Removal

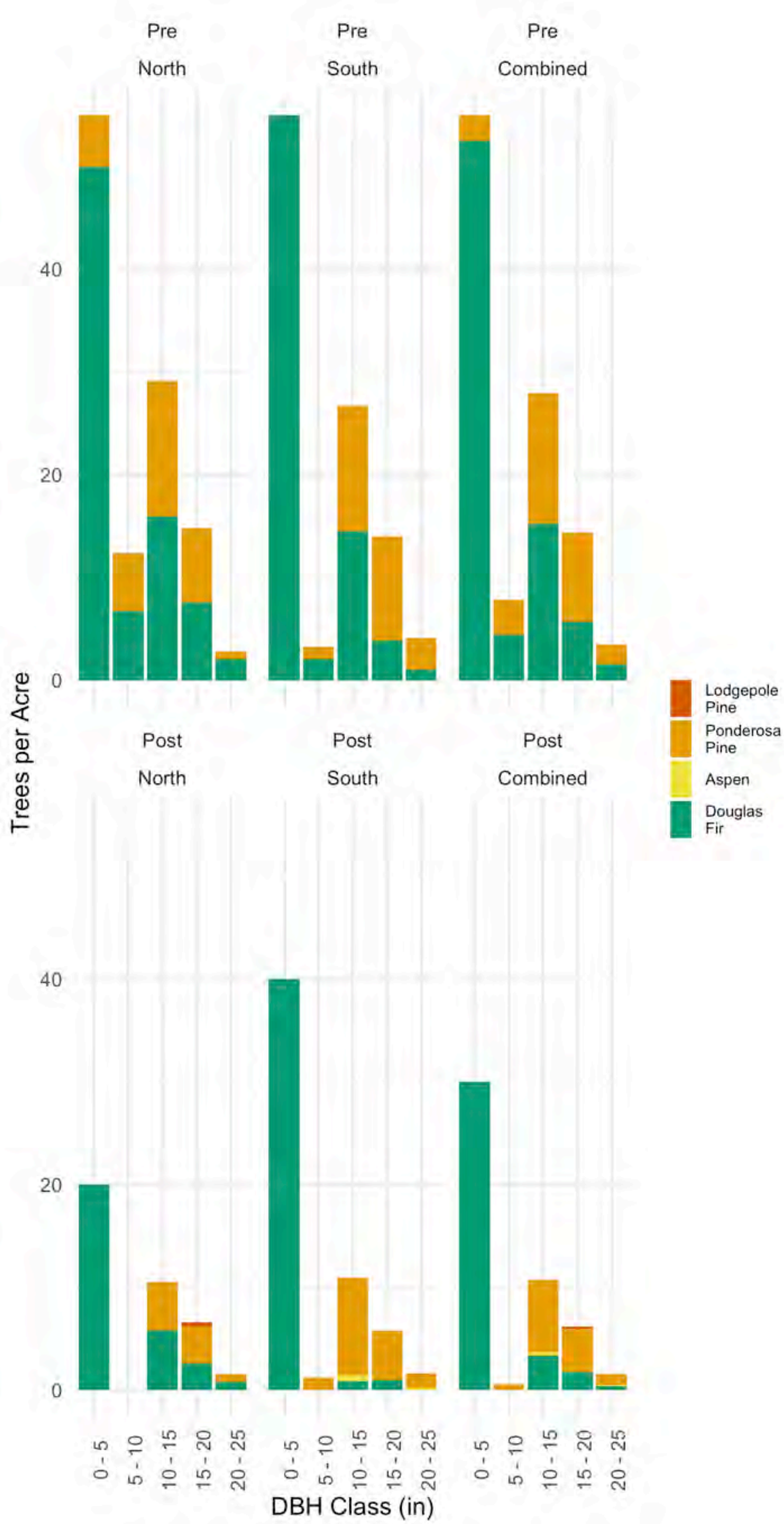



Pre-treatment


1 year post-treatment

Stand Structure and Composition

Change in tree size distribution



Methods: Data was collected on the ground from 40 plots (20 north aspect, 20 south aspect) to assess the changes in stand structure and composition.

Highlights: Treatments on south facing slopes mostly removed Douglas-fir to favor a ponderosa pine dominated forest post-treatment and into the future. Thinning on north facing slopes removed more small-diameter trees and retained large Douglas-fir. This resulted in a 40% increase in average tree size, but the ratio of ponderosa pine was only slightly changed.

Stand Structure and Composition

Change in basal area by species

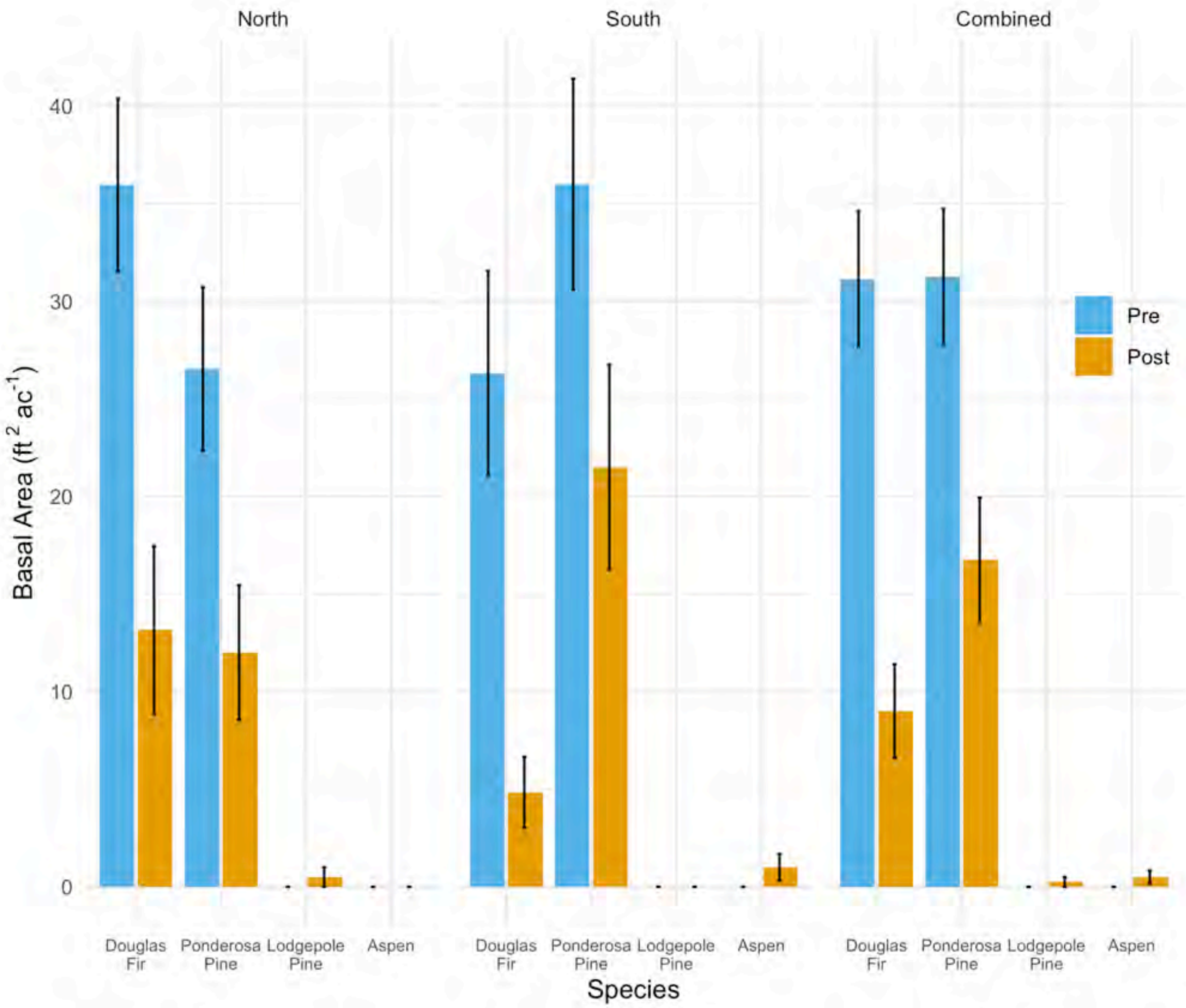


Table 2. Stand characteristics pre- and 1 year post-treatment

Aspect	Phase	Trees per acre	Basal area (ft^2/ac)	Canopy cover (%)	Seedlings per acre	Percent ponderosa by BA (%)	Quadratic mean diameter (in)	Crown base height (ft)
South	Pre	104 ± 46	62 ± 6	39 ± 6	580 ± 216	57	14.6 ± 0.9	13.8 ± 1.5
	Post	60 ± 27	26 ± 4	17 ± 5	440 ± 155	81	15.7 ± 1.3	13.3 ± 2.0
North	Pre	114 ± 19	62 ± 4	29 ± 6	1570 ± 536	42	11.6 ± 0.9	14.1 ± 1.3
	Post	39 ± 15	26 ± 4	11 ± 5	795 ± 251	47	16.2 ± 1.2	14.6 ± 1.9
Combined	Pre	109 ± 24	62 ± 4	34 ± 4	1075 ± 296	50	13.0 ± 0.6	14.0 ± 1.0
	Post	50 ± 16	27 ± 3	14 ± 3	618 ± 148	64	16.0 ± 0.9	14.0 ± 1.4

Spatial Heterogeneity

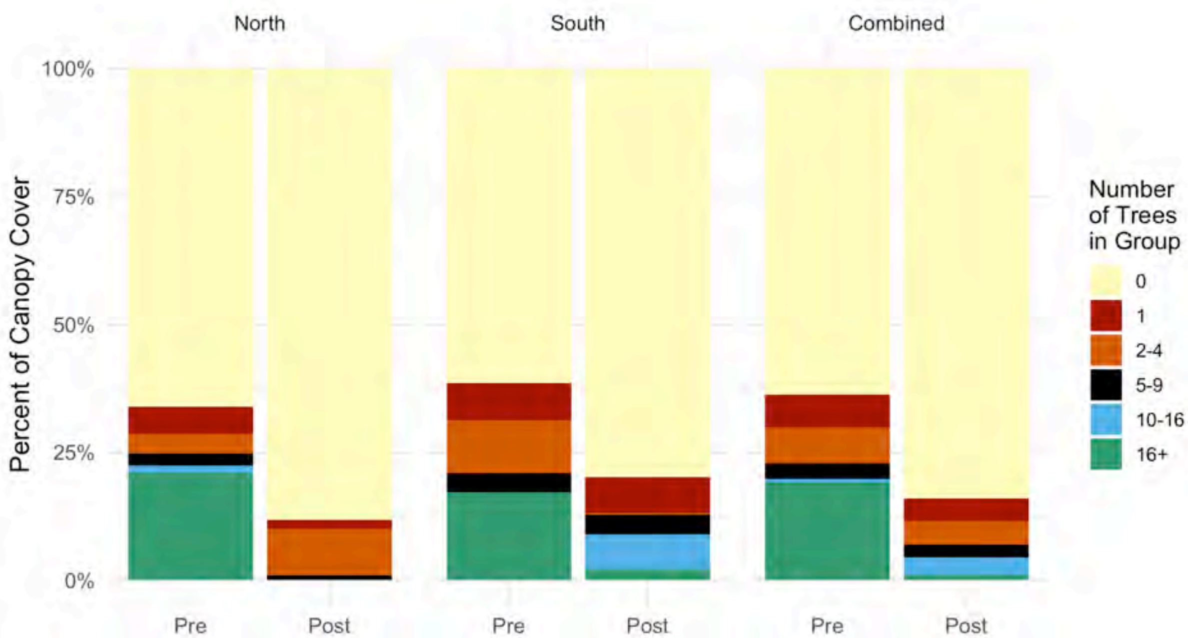


Table 3. Changes in tree groups pre- and post-treatment

Phase	Canopy cover (%)	Mean tree group size (acres)	Isolated tree cover (%)*	Continuous canopy tree group cover (%)*
Pre	53.6	0.18	1.9	93.2
Post	17.6	0.02	24.6	27.4

**Percent of total canopy cover*

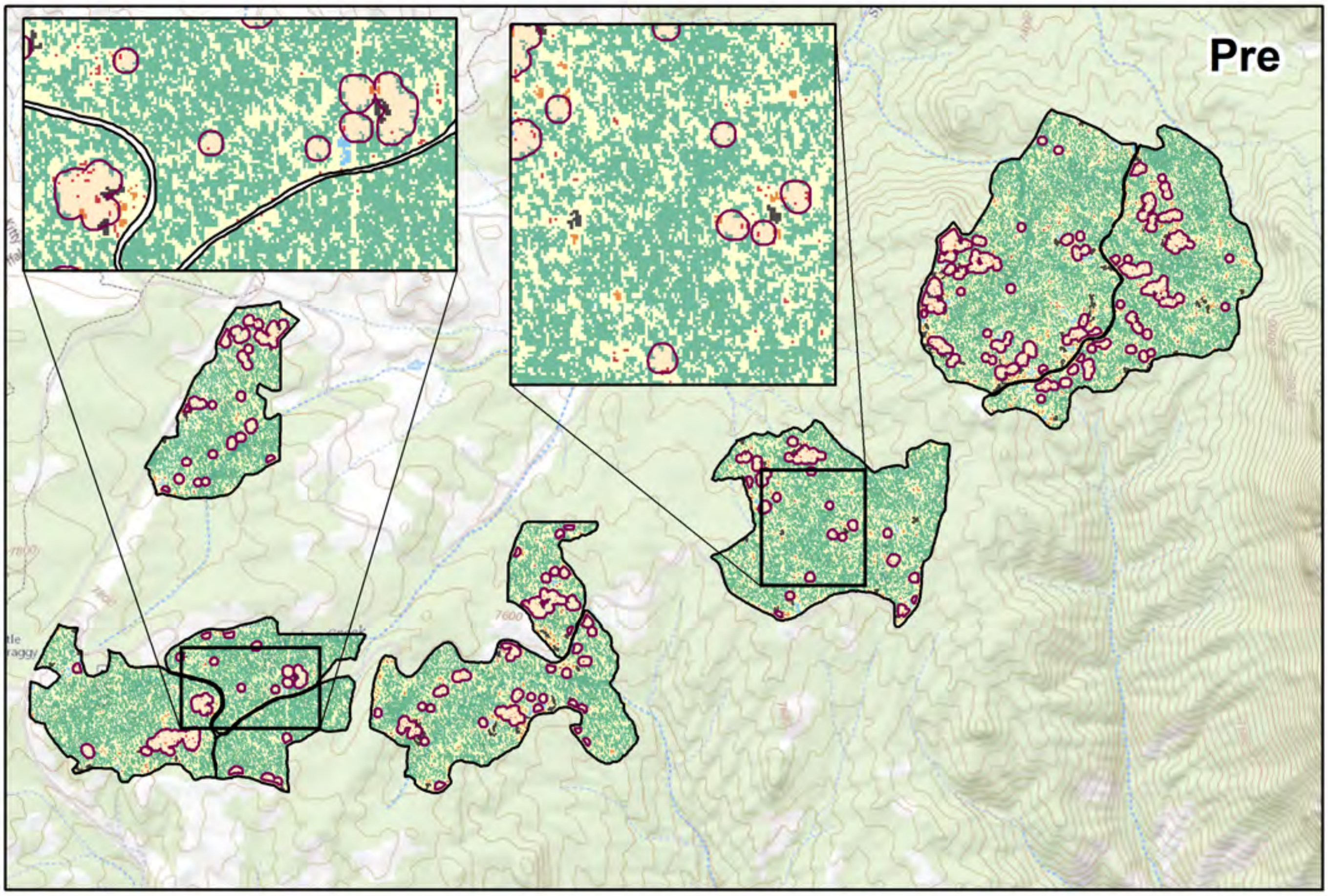
Table 4. Changes in forest gaps pre- and post-treatment.

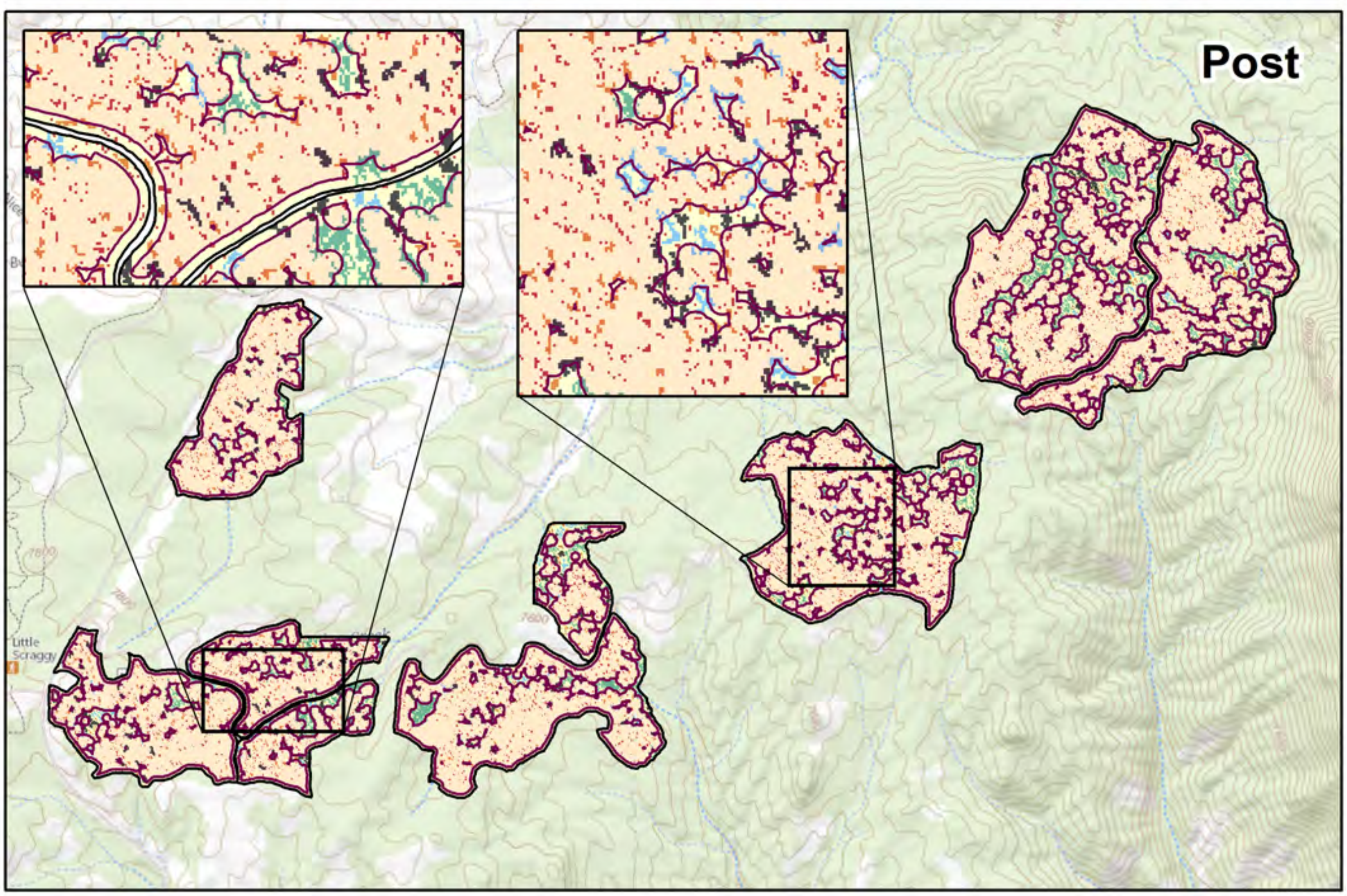
Phase	Gap cover (%)	Mean gap size (acres)	Gap size range (acres)	Gap size variability (CV)	Median gap shape index
Pre	10.0	0.42	0.07 - 2.87	1.15	0.95
Post	73.8	8.70	0.07 - 72.82	2.18	1.00

Methods: Spatial heterogeneity included analysis of tree groups and forest gaps using data from the field and satellite imagery. Satellite imagery was acquired before and after treatment and classified into a canopy raster to identify tree groups and forest gaps. Contiguous canopy cells (i.e. share an edge or corner) were combined into tree groups and placed into group size classes based on the area of each group. Gaps were defined as an area larger than .11 acres with less than 5% canopy cover. Higher values for gap size variability indicted a greater diversity in the size of gaps, and higher values for gap shape index indicated more complexity in gap shape or more edge.

Highlights: Forest thinning resulted in larger gaps that covered substantially more area, and had higher variability in size while maintaining shape complexity. Smaller and medium-sized tree groups were more represented following treatment across the project. Large tree groups were effectively cut into smaller-sized tree groups, which increased group size variability.

Spatial Heterogeneity





Fuels and Fire Behavior

Table 5. Surface fuel conditions pre- and 1 year post-treatment

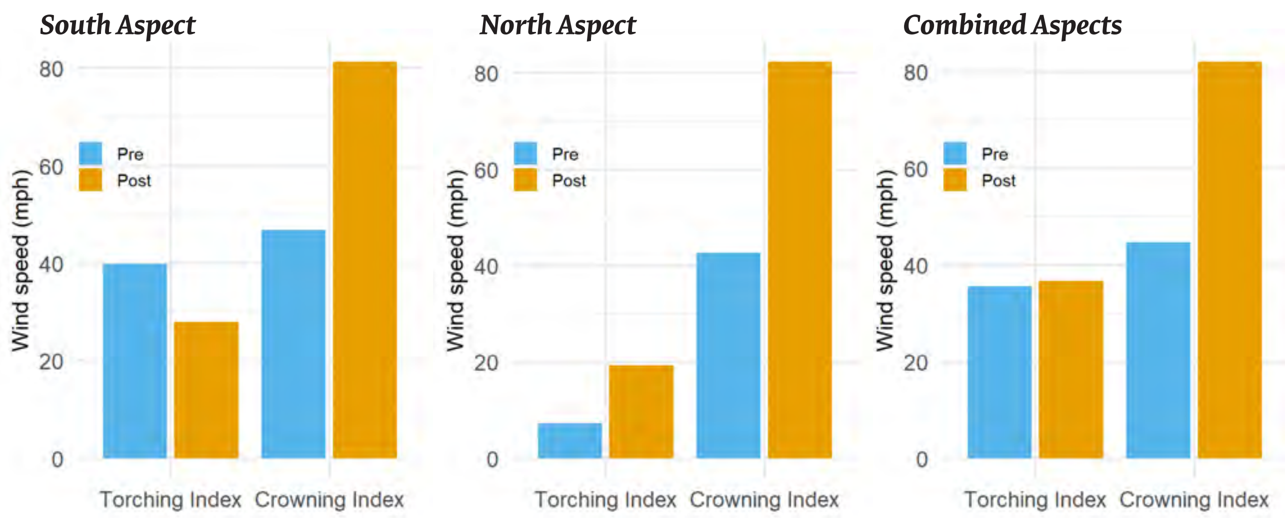
Aspect	Phase	Fine woody fuel loading (tons/acre)	Coarse woody fuel loading (tons/acre)	Litter depth (in)	Duff depth (in)	Shrub cover (%)
South	Pre	1.14 ± 0.19	3.82 ± 1.08	0.77 ± 0.09	0.86 ± 0.19	5.73 ± 1.80
	Post	1.19 ± 0.21	5.10 ± 1.33	1.23 ± 0.20	0.72 ± 0.13	3.49 ± 1.39
North	Pre	2.87 ± 0.87	3.06 ± 0.65	0.73 ± 0.08	1.00 ± 0.17	12.41 ± 3.53
	Post	1.05 ± 0.08	3.61 ± 0.59	0.89 ± 0.08	0.69 ± 0.09	2.80 ± 0.82
Combined	Pre	2.00 ± 0.46	3.46 ± 0.64	0.75 ± 0.06	0.93 ± 0.12	9.07 ± 2.03
	Post	1.12 ± 0.11	4.40 ± 0.75	1.06 ± 0.11	0.70 ± 0.08	3.15 ± 0.80

Table 6. Modeled fire behavior pre- and 1 year post-treatment

Aspect	South				North			
Phase	Pre		Post		Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe	Moderate	Severe	Moderate	Severe
Fire type	Surface	Surface	Surface	Surface	Surface	Passive	Surface	Passive
Total flame length (feet)	1.3	3.2	2.9	7.5	1.9	12.6	2.4	8.3
Surviving tree basal area (%)	87	85	85	13	84	3	87	7

Combined South and North				
Phase	Pre		Post	
Fire weather conditions	Moderate	Severe	Moderate	Severe
Fire type	Surface	Surface	Surface	Surface
Total flame length (feet)	1.3	3.1	2.3	6.1
Surviving tree basal area (%)	86	84	88	51

Fuels and Fire Behavior

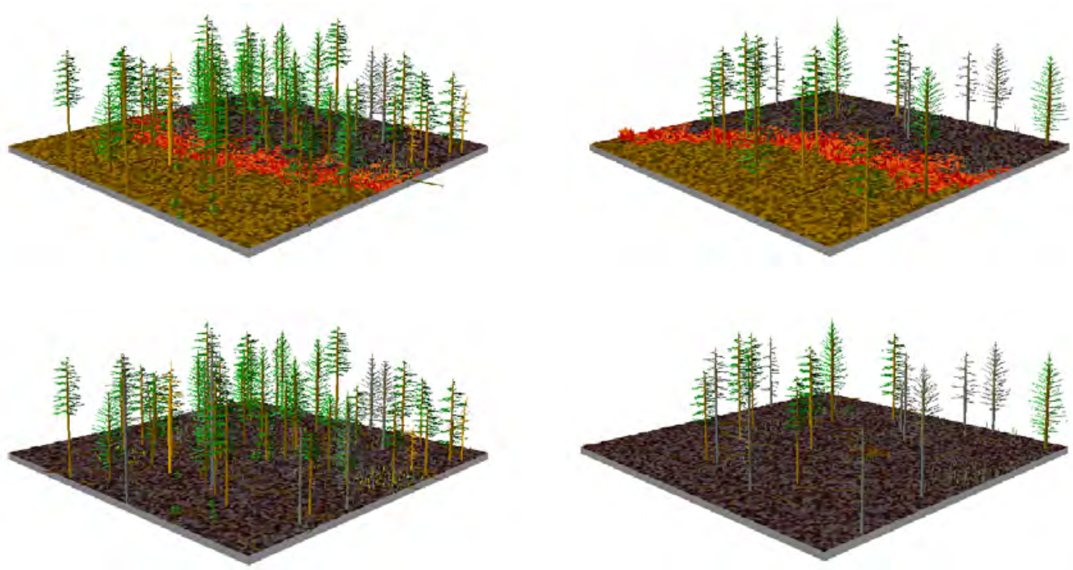


The figure above shows the wind speed needed to initiate crown fire activity or torching (torching index), and the wind speed needed to carry an active crown fire (crowning index).

Methods: To model the potential fire behavior pre- and post-treatment, field data was used with the Fire and Fuels Extension to the Forest Vegetation Simulator.

Highlights: Total fuel loading was relatively unchanged; however, reductions in fine fuels were offset by increases in course fuels. Crowing index was higher following treatment on both north and south aspects, suggesting a lower risk of crown fire across the project. Torching index was lower following treatment on south aspects. This could be related to the slight increase in surface fuel loading, and a lower canopy base height.

	Pre-Treatment	***1 Year Post-Treatment***
During Fire		
After Fire		



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Appendix 4: Adaptive Management Discussion Questions

Monitoring

1. Are we monitoring the right metrics?
2. What other metrics would you like to see?
3. What projects would like to see monitored in the future?

Project Planning and Implementation

1. What is your approach to developing goals and desired conditions for any given project?
2. How do you prioritize restoration across the landscape?
3. What factors do you consider when developing a prescription?
4. What methods have/have not been helpful for project layout?
5. What are the greatest difficulties with project implementation?

Climate Change Adaptation

1. How do you take climate change into consideration when developing a project?
2. What would you like to know or learn more about climate change adaptive silviculture?
3. What resources do you need that you don't currently have to make climate change adaptation decisions?
4. What are the barriers to implementing projects that prioritize climate adaptation?
    4a. Within your organization?
    4b. Outside of your organization?
5. What mandates and regulations within your organization do you have to adhere to that encourage or prevent climate change adaptation?
6. Would CSFS and landowners be open to the idea of experimenting with novel climate adaptation strategies?

Prescribed Fire

1. What are the greatest barriers to implementing prescribed fire in the Upper South Platte watershed?
2. Does CSFS have the ability to utilize pile burning on projects?
3. What would CSFS need to implement a prescribed fire project?

Improving applied science

1. What kinds of scientific information do you need to inform your work?
2. What information is the scientific community lacking about your work?
3. What factors influence your ability to implement scientific information on the ground?
    3a. What motivates or prevents you from incorporating into projects?
    3b. What are the biggest barriers to implementation?
4. What do you think scientists see as the biggest barriers to implementation?
5. What are the greatest opportunities for scientists and managers to learn from one another?
6. What is the biggest problem that, if solved, would lead to successful implementation of new scientific information?
7. How can outreach be improved?

GTR-373

1. Have you had any involvement or experience working with GTR-373? If so, can you tell me about your involvement?
2. Have you implemented any of the concepts from GTR-373?
3. Are there implementation challenges that are not addressed by GTR-373? How do you address these challenges?
4. Did authors come to you for technical or non-technical information about what should be included in GTR-373?

4a. Information you were hoping to see in GTR-373?
4b. Do you feel these conversations influenced the content of GTR-373?

5. Did you feel that communication about GTR-373 was effective both pre- and post-publication?
   5a. Effective means?
   5b. Ineffective?
   5c. Barriers/Opportunities?
   5d. Have we missed any groups?

Partnerships and Collaboration

1. What are the strengths of collaboration and partnerships?
2. Where could collaboration and partnerships improve?
3. How do you apply partnership goals and objectives to your projects?
4. Is there potential for cross-boundary projects in the future?
5. Is there anything you would change, add, or remove in the partnership goals, objectives, or desired conditions?
6. What zones of concern or areas in the Upper South Platte Watershed are the highest priority for your organization?
7. What additional values or risks would you incorporate into landscape scale prioritization?

POLLING RESULTS from Adaptive Management Presentation to USPP on 4/22/2020.

What values/factors are currently considered when prioritizing forest restoration across the landscape?

Wildlife	29% (5/17)
Departure from historical conditions	6% (1/17)
Wildfire risk or burn probability	100% (17/17)
Forest health	59% (10/17)
Climate change vulnerability	12% (2/17)
Community protection	65% (11/17)
Water quality/soil erosion	59% (10/17)
Recreation	6% (1/17)
Accessibility	12% (2/17)
Timber products	6% (1/17)

What values/factors do you think should be included that currently not considered or under consideration when prioritizing forest restoration across the landscape?

Wildlife	29%
Departure from historical conditions	6%
Wildfire risk or burn probability	35%
Forest health	35%
Climate change vulnerability	71%
Community protection	21%
Water quality/soil erosion	47%
Recreation	12%
Accessibility	12%
Timber products	6%

What is the most useful monitoring metric that will inform your next forestry treatment plan?

Stand structure and composition info	56% (9/16)
Tree group size by canopy cover	25% (4/16)
Canopy gap cover map	75% (12/16)
Surface fuel loading	38% (6/16)
Fire behavior modeling	69% (11/16)
Enjoyed your presentation, but probably won't use	0%