NEWTON PARK MONITORING REPORT

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COLORADO FOREST RESTORATION INSTITUTE
COLORADO STATE UNIVERSITY

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CSU Land Acknowledgment: Colorado State University acknowledges, with respect, that the land we are on today is the traditional and ancestral homelands of the Arapaho, Cheyenne, and Ute Nations and peoples. This was also a site of trade, gathering, and healing for numerous other Native tribes. We recognize the Indigenous peoples as original stewards of this land and all the relatives within it. As these words of acknowledgment are spoken and heard, the ties Nations have to their traditional homelands are renewed and reaffirmed. CSU is founded as a land-grant institution, and we accept that our mission must encompass access to education and inclusion. And, significantly, that our founding came at a dire cost to Native Nations and peoples whose land this University was built upon. This acknowledgment is the education and inclusion we must practice in recognizing our institutional history, responsibility, and commitment.

Document Development: This report was developed following CFRI's monitoring efforts at Newton Park, a property owned by Denver Mountain Parks. Monitoring was conducted on behalf of the Upper South Platte Partnership (USPP), a collaborative group dedicated to cross-boundary forest management in the Upper South Platte watershed. The aim of this report is to evaluate forest management outcomes in the context of treatment goals and USPP landscape resilience management objectives.

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Executive Summary

Forest thinning efforts at Newton Park were designed to improve ecological resilience by restoring historical forest structure and composition and mitigate wildfire hazard and intense wildfire behavior through fuels reduction. Funding for implementation and project planning was collaboratively developed through the Upper South Platte Partnership (USPP). This report summarizes changes to forest structure and composition, spatial heterogeneity, surface fuel loading, and modeled fire behavior resulting from mechanical thinning treatments. Thinning met several project objectives: (1) increased the ratio of ponderosa pine to other conifers while retaining existing spruce, (2) created gaps and more open forest conditions, and (3) reduced ladder fuels. However, Newton Park's treatments fell short of canopy cover goals, and further treatment is likely needed to create conditions that support the future use of prescribed fire. Forest management positively impacted Newton Park by moving forest conditions closer to desired conditions, but additional treatments are likely needed and future projects could benefit from more aggressive thinning in the overstory.

Introduction

Many Colorado forests are experiencing more frequent and higher intensity wildfires compared to historical conditions due in part to a century of fire suppression (Sherriff & Veblen, 2006) and climate change (Schoennagel et al., 2017). Additionally, human development in the wildland-urban interface increases wildfire risk to values such as homes and infrastructure. Mechanical thinning is an essential tool for forest managers, and when implemented properly, can moderate wildfire behavior and the subsequent impacts while also providing numerous ecological benefits (Hessburg et al., 2021). Forest thinning and fuels reduction treatments generally aim to readjust tree density, forest spatial heterogeneity, and surface fuel loading in a way that promotes desired conditions. Strategically targeting forest thinning and fuels reduction treatments to mitigate risk to values can promote the desired conditions needed for fire adapted ecosystems and communities. Thinning treatments can also provide ecological benefits by increasing heterogeneity, understory diversity, and wildlife habitat (Addington et al., 2018).

The Upper South Platte Partnership (USPP) was created to increase collaborative efforts across forested areas of the Upper South Platte watershed to improve ecological resilience and reduce wildfire risk (Slack et al., 2021). Newton Park, owned by Denver Mountain Parks, is located within the Upper South Platte watershed and is part of the wildland urban interface surrounding the town of Conifer, Colorado (Figure 1). This area is of particular interest to the USPP due to a large number of buildings, structures, and recreation opportunities. Newton Park has several forest types, with ponderosa pine and mixed conifer forests covering the greatest area. Meadows and aspen stands dispersed throughout the property provide additional ecosystem services such as water storage and wildlife habitat. The impacts from the forest thinning at Newton Park provide learning opportunities about forest management in areas where numerous vegetation types and social factors are intermixed, complicating management.

Thinning treatments were collaboratively planned and funded through the USPP. Colorado Forest Restoration Institute was engaged as a partner to conduct monitoring of pre- and post-treatment conditions. Data collection and analysis sought to answer the following research questions:

1. How did stand structure and composition respond to forest thinning?
2. How did spatial heterogeneity of tree groups and forest gaps change following thinning?
3. How did surface fuel conditions and modeled fire behavior change following thinning?

To answer these questions and evaluate the outcomes of forest thinning at Newton Park, we compared post-treatment conditions to a reference site at the neighboring Staunton State Park. This reference site is part of the Forest Reconstruction Network (FRNet), a project that recreated historical reference conditions from around 1860 (i.e. before fire suppression) at numerous sites along the Front Range (Battaglia et al., 2018). We compared treatment outcomes at Newton Park to historical reference conditions because the desired conditions and treatment goals are generally aimed to restore historical conditions that are often associated with greater forest resiliency to wildfire and drought. While we acknowledge that information about historic conditions is important, other factors such as climate change may be altering the target conditions for current and future treatments.

Project Background

Thinning treatments were designed to restore desired conditions, specifically by: increasing the ratio of ponderosa pine to Douglas-fir and lodgepole pine; retaining quaking aspen and spruce; maintaining a complex forest mosaic by leaving a higher density of trees at the bottom of slopes, in ravines, and on north-facing slopes while reducing tree density on ridgetops and south-facing slopes; reducing ladder fuels while maintaining native understory plant communities; and creating conditions that support the future use of prescribed fire. These treatment goals parallel the USPP's landscape resilience management objectives. For more information on these objectives see Slack et al., 2021.

Table 1. Project Information.

Implementation Agency	Denver Mountain Parks
Ownership	Denver Mountain Parks
Year Completed	2019
Acres Treated	315
Acres Monitored	273
Forest Type	Mixed Conifer
Implementation Method	Mechanical Thinning
Slash Treatment	Product Removal & Mastication
Years Monitored	2017 & 2019

Methods

In 2017, CFRI installed 39 long-term monitoring plots in the Newton Park treatment area. Most plots were remeasured in 2019, following thinning (Figure 1). One plot could not be relocated, as mechanical thinning treatments removed plot markers and nearby landmarks. At each plot and during pre- and post-treatment sampling visits, a series of pictures were taken, topographical information was recorded, and a fire behavior fuel model was assigned (Figure 2; Colorado Forest Restoration Institute, 2019). Variable radius plots using a 10 basal area factor prism were used to measure overstory trees. Each tree's species, diameter, height, crown base height, and decay class (if dead) were recorded. Tree regeneration (<5 inches diameter) was measured in 1/100th acre fixed radius plots. All pieces of coarse wood (>3 inches diameter) within the 1/100th acre fixed radius plot were measured, and three 1m2 quadrats were used to assess fine wood loading (<3 inches diameter) using the photoload sampling technique (Keane & Dickinson, 2007). Litter and duff depths were taken at the corners of each quadrat. Although the three herbaceous plant species covering the greatest area of each quadrat were recorded, we did not collect data to assess thinning's impact on understory plant diversity and abundance. Shrubs were measured along a 50 foot transect; species, height, and transect intercept distance were recorded (Colorado Forest Restoration Institute, 2019).

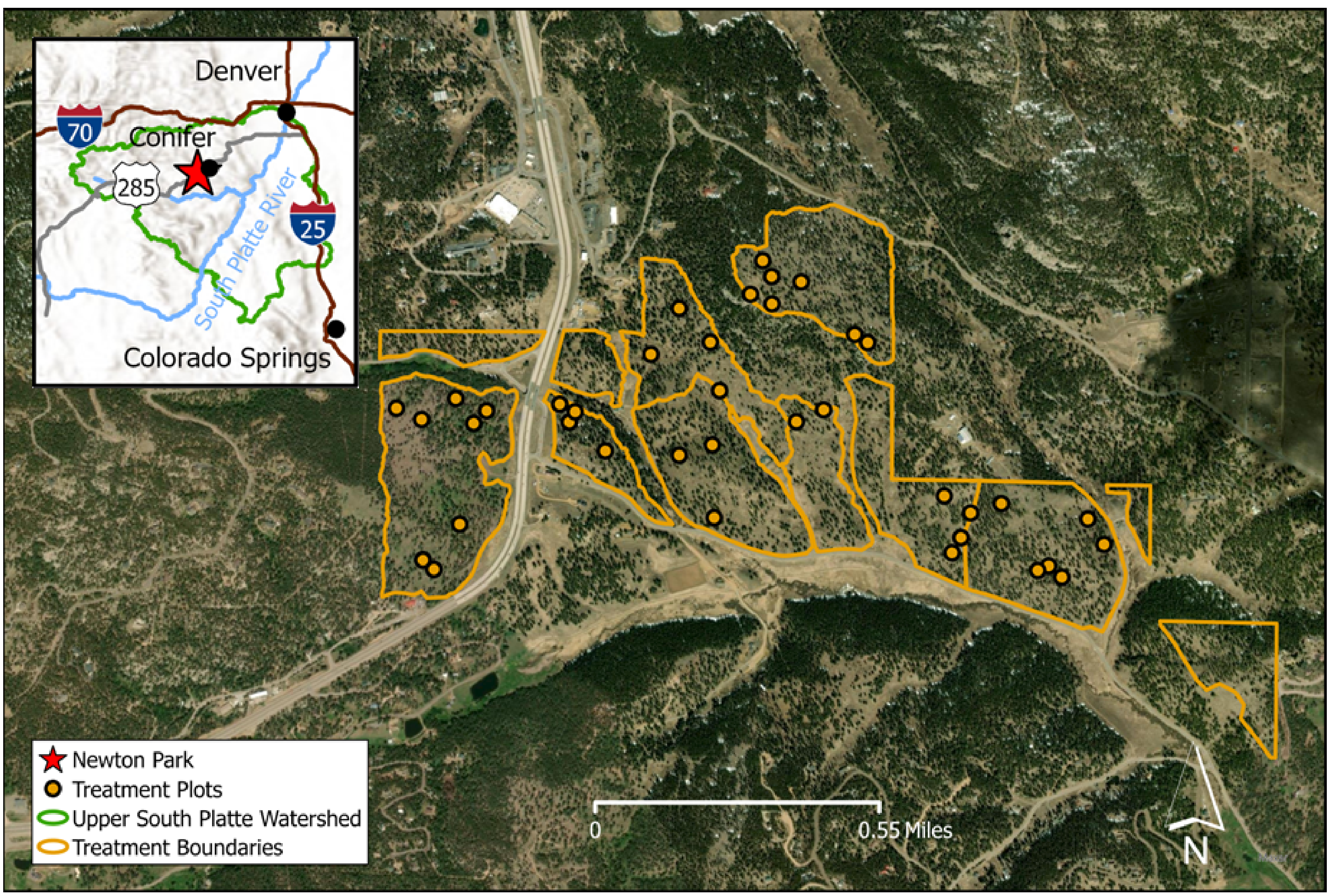


Figure 1. Map of Newton Park's location, unit boundaries, and monitoring plots.

We put field data through a series of quality control checks and analyzed the data in R (R Development Core Team, 2021). A total 36 plots are included in this analysis. We used the Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS; Reinhardt & Crookston, 2003) to model potential fire behavior under moderate and severe fire weather conditions. Regional default values used in FFE-FVS are very similar to RAWS outputs for 97th percentile fire weather conditions; temperature, wind speed, and live herbaceous fuel moisture are adjusted in the model to represent moderate and severe conditions (Table 2). The regional default values are used for all other metrics.

Table 2. Values used to model potential fire behavior under moderate and severe fire weather conditions.

Weather metric	Moderate Fire Weather	Severe Fire Weather
Temperature (°F)	77	90
20-Foot Wind Speed (mph)	6	20
Live Herbaceous Fuel Moisture (%)	70	30

Statistical differences between pre- and 1-year-post-treatment for stand structure, composition, and fuel loading metrics were analyzed using pairwise t-tests. Extreme outliers were only removed if they did not accurately characterize the conditions at Newton Park. Some datasets did not meet the assumption for a normal distribution; however, t-tests have been shown to be robust against type I error when the normality assumption is not met (Blanca Mena et al., 2017); therefore, data transformations and nonparametric test options were not used.

LiDAR (light detection and ranging) point cloud data were used to evaluate the project's effect on tree canopy cover and spatial heterogeneity. Point clouds of the treatment area in 2013 (pre-treatment) and 2020 (post-treatment) were downloaded in LAS format from USGS and processed into DEMs (Digital Elevation Models) and DSMs (Digital Surface Models) in ArcGIS Pro. Raster functions were used to create 1m resolution canopy height models. Focal statistics were applied to create pre- and post-treatment canopy cover rasters identifying tree groups and openings (i.e., forest gaps). Parts of the raster with less than 5% canopy cover in an area larger than 0.11 acres were defined as forest gaps. Canopy cells sharing an edge or corner were compiled into tree groups and assigned to size classes based on the assumption that a single tree occupies approximately 305 ft2 of canopy, the 33rd percentile of ponderosa pine canopy diameter (Cannon et al., 2018). These rasters were then used to calculate variability in canopy cover, forest gaps, and tree group size.

Figure 2. Examples of forest conditions before and after forest thinning.

Results and Discussion

Stand Structure and Composition

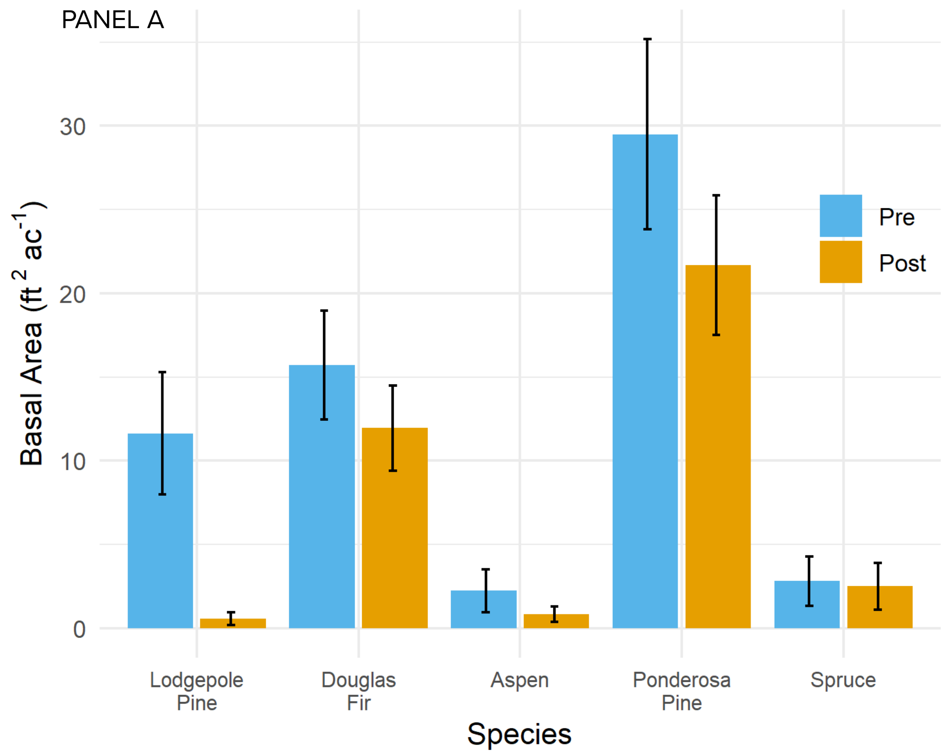
Forest thinning at Newton Park successfully removed small-diameter trees, which act as ladder fuels (Figure 3). The project significantly reduced tree density from 210 to 35 trees per acre (P=0.008; Table 3), and basal area by roughly a third to 38 ft2/acre (P<0.001). However, post-treatment tree density at Newton Park was lower than the historical estimate of 57 trees per acre at Staunton State

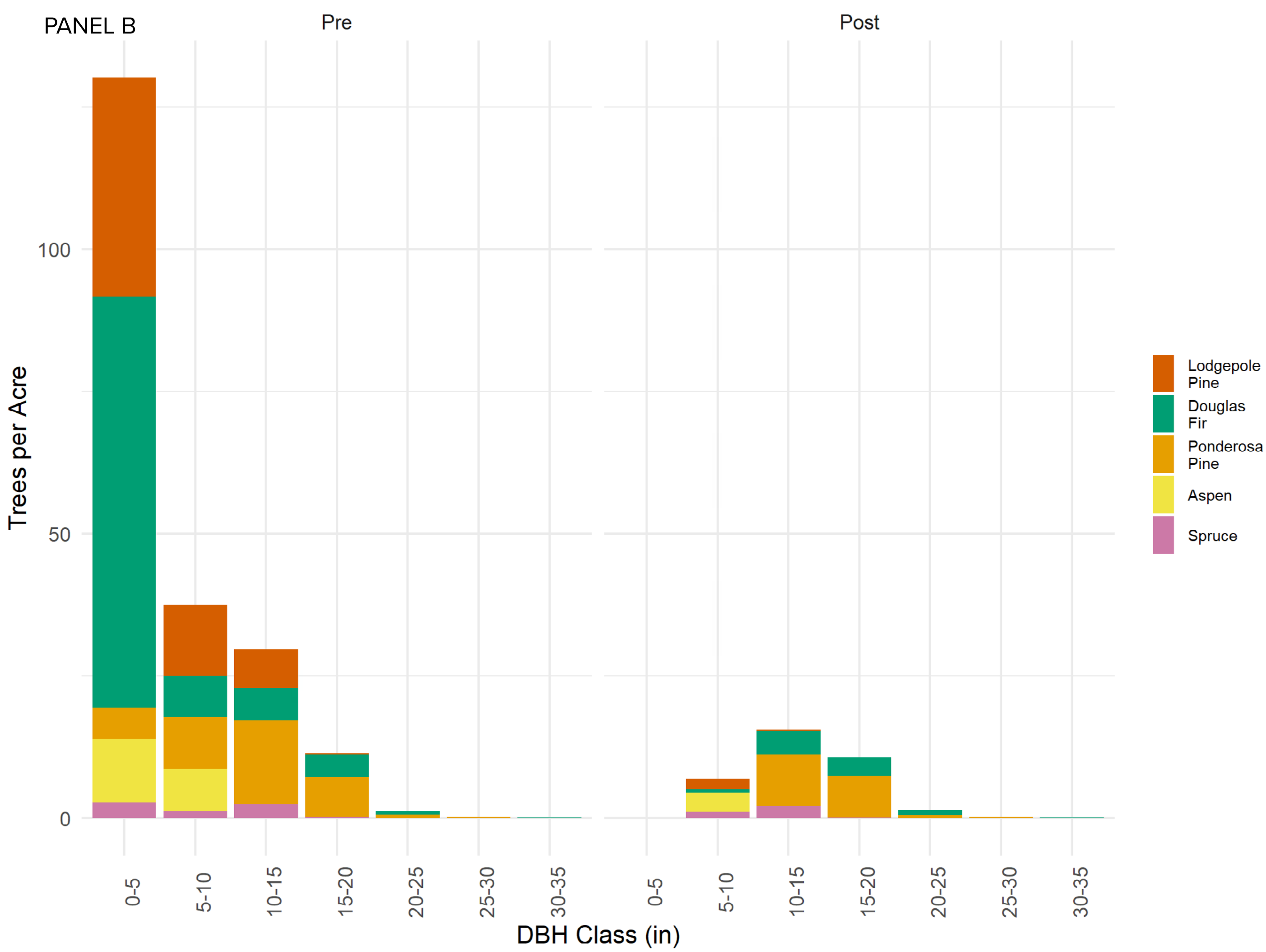
Table 3. Stand characteristics (mean ± standard deviation) pre- and post-forest thinning. Asterisks (*) denote a statistically significant difference at an α=0.05 level.

Phase	Trees per Acre	Basal Area (ft2/ac)	Seedlings per Acre	Ponderosa by BA (%)	Quadratic Mean Diameter (in)	Crown Base Height (ft)
Pre	*210 ± 372	*62 ± 30	*539 ± 1116	49 ± 42	*10.9 ± 4.8	8.3 ± 4.2
Post	*35 ± 24	*38 ± 24	*229 ± 444	59 ± 42	*14.9 ± 3.6	9.2 ± 4.2

Figure 3. Panel A (top). Species composition by basal area.

Panel B (bottom). Number of overstory trees and saplings by diameter class and species.





Park, and basal area at Newton Park was slightly higher. (Battaglia et al., 2018). Average tree size—quadratic mean diameter (QMD)—increased by four inches following thinning (P<0.001), and post-treatment QMD was 0.4 inches larger than the maximum QMD in 1860 (Battaglia et al., 2018). This comparison suggests that additional larger overstory trees could have been removed, and more pockets of younger age classes retained while remaining within historical forest structure parameters. This could promote higher age diversity and increase variability in the canopy and forest structure.

Treatments shifted overstory tree composition to favor ponderosa pine, from 49% of BA before treatment, to an average of 59% of remaining BA after treatment (P=0.066; Table 3). While this change was not statistically significant due to high variability between plots, on average forest thinning still created an overstory dominated by ponderosa pine. Future forest management should continue to promote ponderosa pine as historical conditions at Staunton State Park recorded ponderosa pine BA at a minimum of 66% (Battaglia et al., 2018). Seedling density at Newton Park decreased by 58% following forest thinning (P=0.046), a response within the range of variation following treatments at other USPP sites and Colorado Front Range ponderosa pine forests (Table 3; Slack et al., 2021; Briggs et al., 2017; Fialko et al., 2020; Ertl, 2015). The ratio of ponderosa pine seedlings to other conifer seedlings increased from 10% to 39%, larger spruce seedlings were retained, and aspen seedlings decreased slightly but still comprise 9% of post-treatment seedlings.

Thinning fulfilled the goals of increasing the ratio of ponderosa pine to other conifers while retaining spruce. Although many aspens were removed, this species sprouts following disturbance and will likely increase in the next few years (Kurzel et al., 2007), though we have not seen this pulse yet. Additional monitoring is needed to evaluate whether the goal of retaining aspen was achieved.

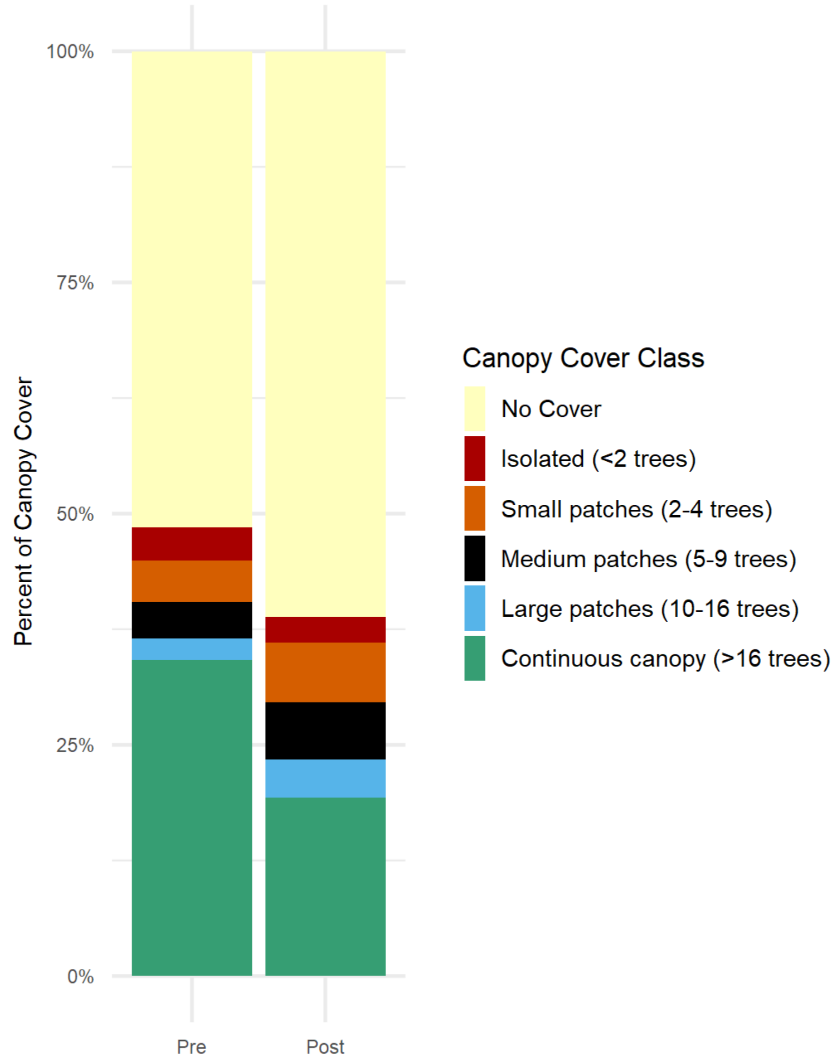


Figure 4. Canopy cover by tree group size class.

Spatial Heterogeneity

Table 4. Changes in tree groups pre- and post-treatment. Cover for isolated and continuous canopy tree groups is the percent of total canopy cover.

Phase	Total Canopy Cover (%)	Isolated Tree Cover (% of canopy cover)	Continuous Canopy Cover (% of canopy cover)
Pre	48.5	7.4	70.4
Post	38.9	7.3	49.7

Analysis of canopy cover helps us to understand whether treatments successfully increased heterogeneity in spatial distribution of trees across the site. The USPP has set canopy cover goals that include an average canopy cover of 30%, with 25% of this composed of individual trees rather than groups. After treatment at Newton Park, average canopy cover decreased by about 10% (Table 4), but remaining canopy cover was still about 40%. Larger continuous canopy tree groups (>16 trees) occupied 20% less of the canopy following treatment, but nearly 50% of the canopy is still continuous (Figure 4). Forest thinning did not increase the presence of isolated tree cover, which continue to occupy slightly above 7% of the canopy cover at Newton Park (Table 4). Newton Park's treatments brought canopy cover closer to desired conditions by creating new small-to-large tree groups and reducing canopy continuity. However, other USPP post-treatment sites and historical reconstruction at Staunton State Park have substantially more tree groups with fewer trees (Slack et al., 2021; Battaglia et al., 2018). Thinning more aggressively in the overstory could further reduce canopy cover, break

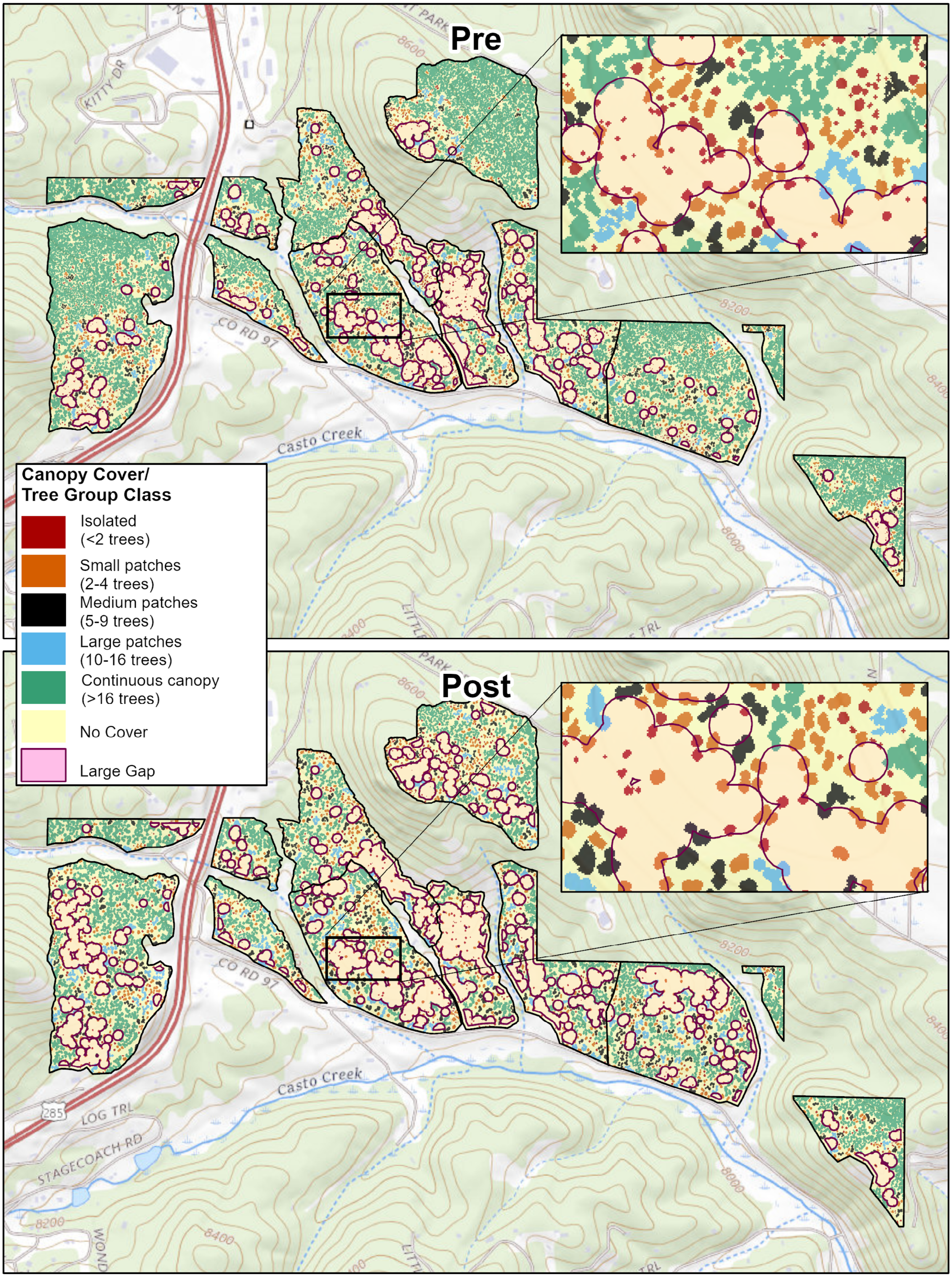


Figure 5. Map of Newton Park's forest canopy pre- and post-treatment.

up remaining large continuous canopy tree groups, and create additional isolated trees and small tree groups.

Forest thinning met the goal of leaving denser areas on north-facing slopes and drainages and creating more openings on south-facing slopes and ridgetops (Figure 5). Following thinning, Newton Park's gap cover increased by 12% to nearly 28% (Table 5). For comparison, reference conditions from the 1860 reconstruction at Staunton State Park estimated forest gaps to cover 67% of the area (Battaglia et al., 2018). The average gap size at Newton Park slightly increased to 0.66 acres and there was more variability in gap size following treatment. The increase in variability is due to thinning creating more large gaps, while maintaining small gaps. The complexity of gap shapes (median shape index) was unchanged following thinning (Table 5). When compared to other treatments within the USPP area of concern (Slack et al. 2021), the increased gap cover, size, and size variability were relatively modest.

Table 5. Changes in forest gaps pre- and post-treatment. Median shape index describes gap shape complexity.

Phase	Gap Cover (%)	Mean Gap Size (acres)	Gap Size Variability (CV)	Gap Size Range (acres)	Median Shape Index
Pre	15.5	0.47	1.54	0.04 - 5.81	0.97
Post	27.7	0.66	2.20	0.04 - 12.99	0.96

It is difficult to determine desired conditions on north facing slopes in the upper montane zone around Newton Park because these forests likely supported highly variable fire regimes and high severity fire was believed to be common when a fire did occur (Schoennagel et al., 2011). While it may be ecologically appropriate to leave denser stands on north facing slopes that support high severity fire behavior, factors such as climate change which may make drought a larger factor in these areas and values at risk such as homes and infrastructure can make these forest conditions and subsequent fire behavior less desirable. Furthermore, there is growing evidence that north facing slopes did contain forest patches that supported low severity surface fire (Battaglia et al., 2018; Brown et al., 2015). Patches of high severity fire would have also created transient openings on north facing slopes across the landscape, and it is believed that these openings were more common historically (Kaufmann et al., 2003). These factors should be considered when developing site specific desired conditions and prescriptions on north facing slopes going forward.

Fuels and Fire Behavior

Table 6. Surface fuel conditions (mean ± standard deviation) pre- and post-forest thinning. Asterisks (*) denote a statistically significant difference at an α=0.05 level.

Visit	Fine Woody Fuel Loading (tons/acre)	Coarse Woody Fuel Loading (tons/acre)	Litter/Duff Depth (in)	Shrub Cover (%)
Pre	1.83 ± 2.59	*2.60 ± 3.02	1.54 ± 0.55	*22.04 ± 17.32
Post	2.24 ± 1.66	*1.52 ± 1.23	1.57 ± 0.86	*10.18 ± 12.27

Forest management had various impacts on Newton Park's surface fuels. Fine woody fuel loading did not change significantly, but did increase by about 0.4 tons/acre following treatments (P>0.05; Table 6). This increase is similar to other USPP and Collaborative Forest Landscape Restoration Program treatments (Slack et al., 2021; Briggs et al., 2017). Overall surface fuel loading at Newton Park remains relatively low—for comparison, in masticated treatment areas where there was no product removal, average post-treatment fine woody fuel loading was 15 tons/acre (Battaglia et al., 2010). Coarse woody fuel loading significantly decreased by more than 1 ton/acre (P=0.006; Table 5), similar to other treatments in the area (Slack et al., 2021; Briggs et al., 2017; Battaglia et al., 2010). Newton Park's treatment resulted in desirable conditions for surface fuels because slash management following thinning successfully limited large increases in fine woody fuel loading, and decreased coarse woody fuel loading. The cover of shrubs decreased significantly by about 50% (P<0.001; Table 5), the same change seen following other USPP and CLFRP treatments (Slack et al., 2021; Briggs et al., 2017). Shrubs typically require 2-4 years to return to pre-treatment levels following thinning, so a temporary, significant decrease one-year post-treatment is expected (Fornwalt et al., 2017).

Table 7. Modeled fire behavior results from field monitoring data using FFE-FVS.

Visit	Pre		Post	
Fire Weather Conditions	Moderate	Severe	Moderate	Severe
Total Flame Length (feet)	3.8	23.6	3.7	13.7
Surviving Tree Basal Area (%)	33	2	42	7

Modeled fire behavior was less intense after treatment under both moderate and severe fire weather conditions. Also in both cases, plots with the tallest flames before treatment had the largest decreases in flame lengths and largest increases in surviving tree BA. Modeling at other

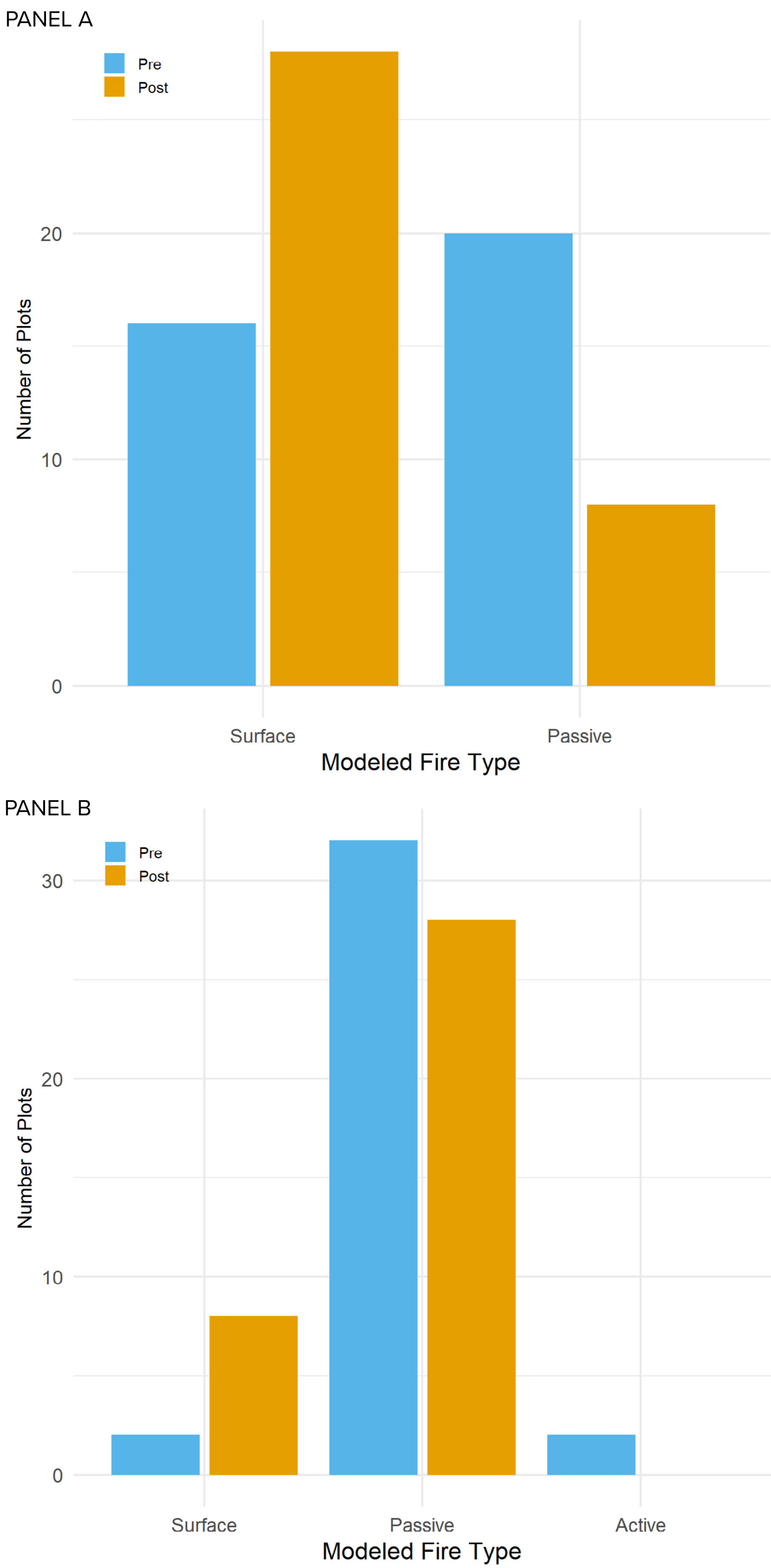


Figure 6. Number of pre- and post-treatment plots within each modeled fire type under moderate (Panel A) and severe (Panel B) fire weather conditions.

USPP sites has shown this to be a typical impact of thinning treatments (Slack et al., 2021). Under moderate fire weather, average flame length was relatively unchanged; however, the average surviving tree BA increased by nearly 10% following treatments (Table 7). Initially, 20/36 plots were predicted to support passive crown fire under moderate conditions, but after thinning only 8/36 plots were predicted to accommodate passive crown fires (Figure 6A).

Under severe conditions, there was a 10-foot reduction in average flame length following treatment; average surviving BA increased by 5% (Table 7). Compared to other USPP sites modeled with the same parameters, the decrease in flame length is better than average (Slack et al., 2021). Passive crown fire was the most frequently predicted modeled fire type before and after treatment, though treatment reduced the modeled probability of active crown fire, and also dropped some plots into surface fire (Figure 6B).

Newton Park's thinning treatments increased both the modeled wind speed needed to initiate passive crown fire (torching index) and carry active crown fire activity (crowning index). Torching indices across all plots typically increased by 10 mph (Figure 7). However, at most plots the torching index was still below 25 mph, a wind speed regularly exceeded at Newton Park. This means that even under moderate fire weather conditions post-thinning, passive crown fire was predicted at about one third of plots. However, the average post-treatment crowning index increased to about 75 mph, so higher windspeeds will be needed to carry active crown fire (Figure 7). These results suggest that forest thinning was successful in reducing but not eliminating the risk of high intensity fire behavior.

The increases in both torching and crowning indices following thinning at Newton Park followed trends at other USPP treatments and numerous thinnings in mixed conifer and ponderosa

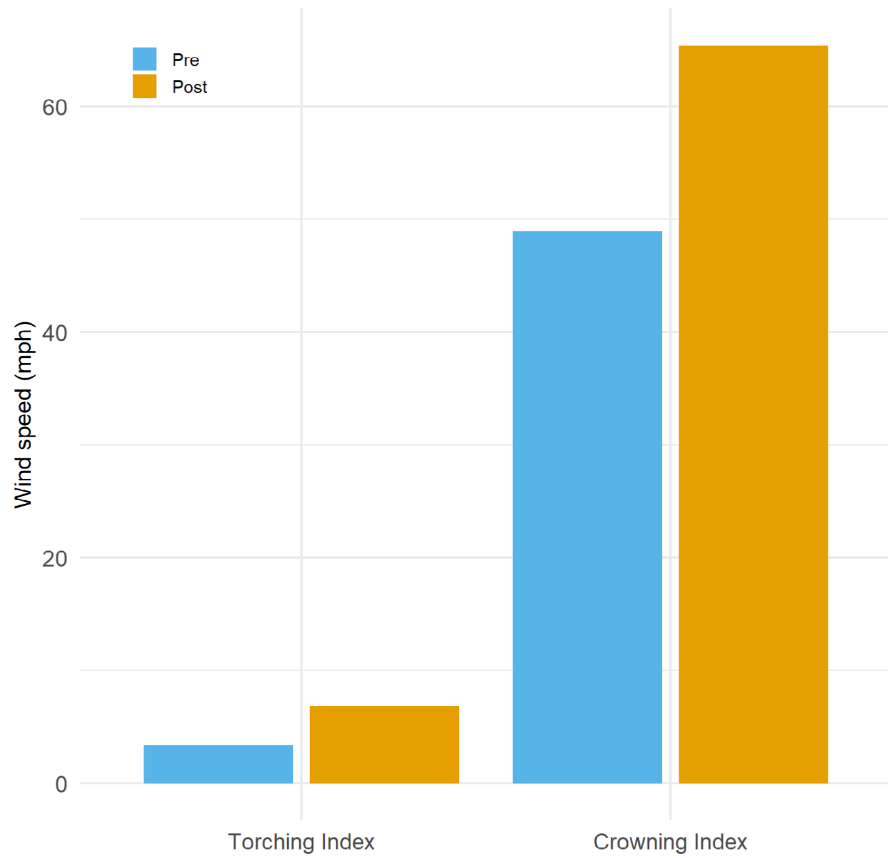


Figure 7. Bar chart showing the average windspeeds predicted to support torching (Torching Index) and active crown fire (Crowning Index) of pre- and post-treatment plots.

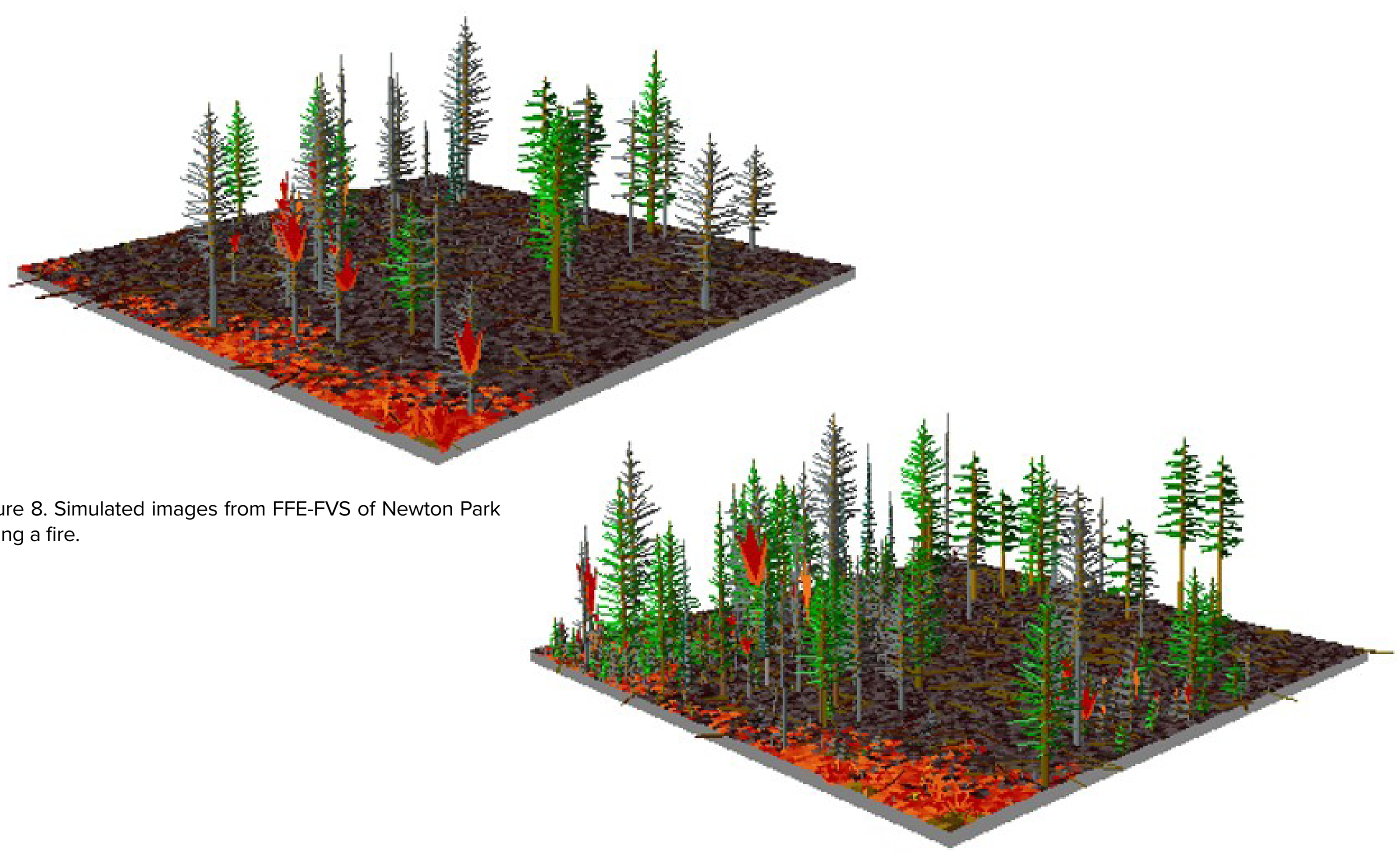


Figure 8. Simulated images from FFE-FVS of Newton Park during a fire.

pine forests (Slack et al., 2021; Fulé et al., 2012). While in general the fire hazard at Newton Park has been reduced following treatment, high intensity fire behavior, including passive crown fire and torching, remains a possibility during both moderate and severe fire weather conditions. Some smaller areas within the park could feasibly support broadcast burning in the future; however, widespread use of prescribed fire across the park could be challenging under post-treatment conditions. Additional mechanical fuels treatments will likely be needed to support future use of prescribed fire at Newton Park.

Conclusion

Monitoring at Newton Park revealed that thinning treatments were beneficial, and met many goals and objectives for the project, but fell short of desired conditions for spatial heterogeneity and potential fire behavior. Thinning only marginally increased the ratio of ponderosa pine to Douglas-fir and lodgepole pine, but successfully retained spruce when present.. Future monitoring is needed to ascertain treatment success for long-term aspen retention. Thinning partially met the goal of maintaining a complex forest mosaic at Newton Park. Although the canopy cover of small, medium, and large tree groups doubled, thinning did not increase the percent of individual tree groups, and the presence of individual or small tree groups remains low when compared to historical reference conditions at Staunton State Park. Thinning and slash management did decrease ladder fuels, as thinning preferentially removed small trees, but more fuels treatments are likely needed to support future prescribed fire implementation. Adding a more aggressive overstory thinning component to this treatment would meet more spatial heterogeneity and potential fire behavior goals. Although this thinning did not meet desired conditions for all metrics, it altered forest conditions in a positive direction. All aspects of Newton Park's treatments, regardless of whether they achieved goals or not, provide valuable lessons to rely on when planning future forest thinning in the Upper South Platte watershed.

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