NORTHERN ARIZONA UNIVERSITY

Center for Adaptable Western Landscapes

Final Report

4FRI Rapid Plot Monitoring: Implementation & Analysis

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Introduction

The Four Forest Restoration Initiative (4FRI) is a landscape-scale collaborative program working toward restoring healthy, fire-resilient ponderosa pine ecosystems across the Kaibab, Coconino, Apache-Sitgreaves, and Tonto National Forests in Arizona. In partnership with a broad group of stakeholders, the United States Forest Service (USFS) has set goals for forest structure and function which are expected to reduce negative effects of wildfire and improve conditions for watersheds, vegetation, wildlife, and human communities (US Forest Service 2015, US Forest Service & 4FRI Stakeholder Group 2017).

The 4FRI Multi-Party Monitoring Board (MPMB) was established to oversee implementation of the 4FRI monitoring plan, Appendix E of the Final Environmental Impact Statement (FEIS) for the first 4FRI National Environmental Policy Act (NEPA) analysis area (US Forest Service 2015, Appendix E). Working with partners to collect and analyze monitoring data, the MPMB evaluates the effect of 4FRI management activities within an adaptive management framework and communicates recommendations to the full 4FRI Stakeholder Group. The monitoring plan (USFS 2015, Appendix E) highlights effectiveness monitoring (evaluating treatment effectiveness in achieving desired conditions) as a priority for informing adaptive management decisions and suggests a broad suite of biophysical indicators for monitoring at multiple scales.

To meet the need for monitoring treatment outcomes at a broad scale, the MPMB selected a rapid plot monitoring approach to efficiently collect data on multiple biophysical indicators across 4FRI treatment areas. A rapid plot approach seeks to balance inherent tradeoffs between extent of sampling (number of sites, spatial scale) and intensity of sampling (number of variables, number of measurements, level of detail), assuming finite time and financial resources (Davis et al. 2015). Thus, to prioritize high site replication at a large spatial scale while still addressing a broad range of indicators, individual measurements were taken at the coarsest possible level to maximize efficiency. With this approach, the MPMB has been able to gather monitoring data on many key variables simultaneously, at the scale of restoration treatment implementation.

In 2016, the USFS (Coconino and Kaibab National Forests) established an agreement with Northern Arizona University's (NAU) Landscape Conservation Initiative (LCI, now the Center for Adaptable Western Landscapes, CAWL)[1] to refine protocols and coordinate field data collection, conduct data analysis, and report results to the MPMB. The agreement and subsequent modifications center around the goal of providing information about the effects of 4FRI restoration treatments on forest vegetation (trees and understory), wildlife habitat, and watershed health. Specific objectives have been adapted over the course of the agreement to reflect the priorities of the MPMB and the real-time dynamics of 4FRI treatment implementation. This report leverages the rapid plot monitoring field data collected over the past five years toward two objectives: 1) describe the pre-treatment condition of ponderosa pine forest overstory in the first 4FRI NEPA analysis area, and 2) quantify the effects of restoration treatment by comparing pre-treatment and post-treatment data in a case study.

[1] In 2020, the Landscape Conservation Initiative (LCI) merged with another research center at NAU to become the Center for Adaptable Western Landscapes (CAWL). We will refer to our group as CAWL throughout this report for clarity.

Methods

Study area & sampling design

The study area for this project was defined by ponderosa pine-dominated vegetation types within the first 4FRI NEPA analysis area (Coconino and Kaibab National Forests) (Figure 1).

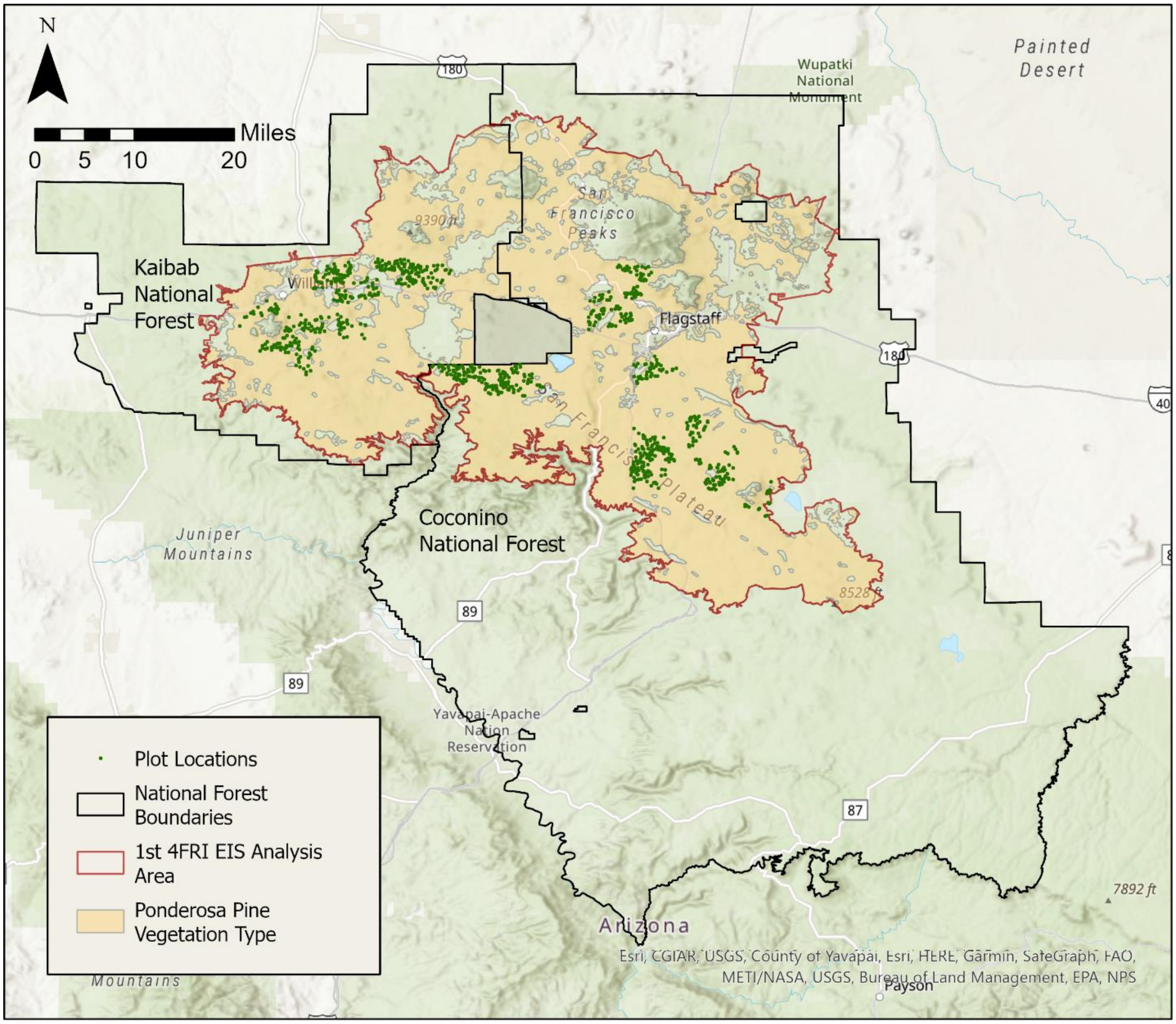

Figure 1. The study area for 4FRI rapid plot monitoring addressed in this report is the orange shaded polygon representing ponderosa pine-dominated vegetation within the boundary of the first 4FRI EIS analysis area (red outline). Boundaries of the Coconino and Kaibab National Forests are shown in black, and locations of plots are shown in dark green.

During the first phase of this agreement, we created a sampling design for collecting rapid plot data within the designated study area and conducted power analyses to determine appropriate sample size (Gray 2017, Gray & Zachmann 2017)[2]. Using the Reversed Randomized Quadrant-Recursive Raster (RRQRR) algorithm (Theobald et al. 2007), we created an 'oversample' of all possible plot locations within the sampling area. By selecting points in sequential order from the oversample, a spatially

[2] Plots sampled by The Nature Conservancy in 2015 were selected using a different sampling design, see Woolley 2016.

balanced randomized set of plot locations can be generated within any given treatment unit (subsample) (Gray 2017). We conducted power analyses after both the 2016 and 2017 field seasons and in consultation with the MPMB determined that a sample density of one plot per 50 acres would both meet requirements for detecting significant effects of treatment, and needs for sampling efficiency (Gray 2017, Gray & Zachmann 2017).

Data collection protocol

The 4FRI MPMB selected a rapid plot monitoring field protocol based heavily on a protocol used for rapid plot monitoring across the Kaibab National Forest in 2014 (Ray et al. 2013, Davis et al. 2015), with adjustments made to ensure compatibility with biophysical indicators listed in the 4FRI monitoring plan. The first iteration of the 4FRI rapid plot protocol was used by The Nature Conservancy (TNC) to collect data in 2015 (Woolley 2016). Between the 2015 and 2016 field seasons, the protocol was significantly changed, as described in detail by Esch and Waltz (2019). Since the beginning of CAWL involvement in 2016, only minor adjustments have been made. The complete narrative protocol document, as well as field data sheets are presented in Appendix A. Here, we provide brief descriptions of each of the seven components of the protocol used for data collection from 2016 through 2021[3].

Plot establishment

At each sampling point, we set up a 0.2-acre circular plot (52’ 8” radius). After monumenting the plot center with a metal stake and tag, we used transect tapes to establish four transects (52’ 8”) in each of the cardinal directions (north, east, south, west), radiating from the plot center like wheel spokes. To enable future plot relocation, we took two standardized photos and marked and measured two reference trees.

Trees

Within the full 0.2-acre plot, we measured the diameter at breast height (DBH) of each tree and recorded its species and live/dead status. We also measured the height of three codominant trees, and the three lowest crown base heights (CBH).

Saplings and seedlings

We set up four 45’ by 6’ belt transects (0.025 acres total area) along each of the four plot transects, within which we recorded species and count for all saplings and seedlings. Saplings were defined as trees with a DBH of less than 4”, and taller than 4’ 6” (breast height). Seedlings were defined as shorter than 4’ 6”.

Understory cover

To collect information on understory vegetation canopy cover and ground cover (substrate) type, we used a simplified line-point intercept method (Herrick et al. 2017). Vegetation was categorized by plant functional group: graminoid, forb, shrub, or tree. Ground cover types were bare soil, rock, moss/lichen, herbaceous litter, woody debris, basal graminoid, basal forb, basal shrub, and basal tree. We recorded cover at 23 individual points along both the north and east plot transects (46 points total). Ground cover was recorded at each point, and vegetation was recorded where present between zero and four feet high.

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[3] For a detailed description of the field protocol used by TNC in 2015, see Woolley 2016.

Disturbance indicators

In each 0.2-acre plot, we searched for physical evidence of soil erosion, soil compaction, cattle grazing, recent fire, and invasive plants (specifically targeting invasive thistles, knapweeds, dalmatian toadflax, and cheatgrass). For each of these disturbance types and invasive species, we recorded the number of plot 'quadrants' (total of 0 – 4) where evidence was present.

Wildlife indicators

We recorded the presence or absence of squirrel sign and Mogollon vole sign individually at the plot level (yes or no for each type of animal). As an additional metric of wildlife habitat, we also counted the total number of downed logs (at least 12" diameter and 8' length) within the entire 0.2-acre plot.

Woody fuels

We used the photoload sampling technique (Keane and Dickson 2007) to estimate fine woody fuels within four 1 m^2 (10.76 ft^2) quadrats placed in a standardized location on each of the four plot transects. In each quadrat, we estimated fuel loading in 1-hour, 10-hour, and 100-hour classes. We also recorded one stand estimate for woody fuel loading at each plot, based on reference photos from both the photoload technique (1000-hour fuel class) and standard fire behavior fuel models (Scott and Burgan 2005).

Field implementation

From 2016 through 2021, pre-treatment data were collected in 21 4FRI treatment units (task orders) selected by the USFS 4FRI Monitoring Coordinator and the MPMB. These units were located in the Coconino and Kaibab National Forests and selected based on areas where mechanical thinning treatment was scheduled or expected to occur. In 2016 and 2017, field crews from TNC and the Ecological Restoration Institute (ERI) also collected rapid plot data using the same sampling design and protocol in five treatment units- three unique areas (Cougar, Ham, and Moonset) and two where CAWL collected additional data (Chimney Springs and Coyote). CAWL collected all pre-treatment data from the remaining 16 treatment units between 2016 and 2021 (Table 1, Figure 2).[4]

[4] Prior to this agreement, in 2015, TNC collected pre-treatment data in four treatment units on the Coconino National Forest: Wing Mountain East, Hart Prairie, Hochderffer, and Clints Well (Woolley 2016). The data from 2015 were collected using a different version of the rapid plot monitoring protocol and have not been thoroughly error-checked, therefore they are not included in the main summary and analysis in this report. However, we have included a broad overview of the TNC plots in Appendix B.

*Table 1. Pre-treatment plots completed per treatment unit (task order), and year(s) when pre-treatment data were collected. Treatment units/years where field data were collected by ERI are noted with a *. Treatment unit/year where field data were collected by TNC is noted with **. Data from all other treatment units/years were collected by CAWL.*

Treatment Unit	Year(s) Collected	Pre-treatment Plots
Chimney Springs**	2016**, 2017	58
Johnny's	2016, 2018	28
Willard	2016, 2021	51
Cloverdog	2017	69
Cougar*	2017	10
Coyote*	2017*, 2019	35
Ham*	2017	16
Moonset*	2017	30
A1 North	2018	14
A1 South	2018	47
Dude	2018	22
Parks West	2018	78
Zorro	2018	41
Beacon	2019	36
Bootleg	2019	29
Clark	2019	34
Dutton	2019	86
LOP Mooney	2019	60
Newman	2019	67
Double Springs	2021	15
Southside Airport	2021	41
Total		**867**

By the 2020 field season, thinning treatment was complete or in-progress at several of the treatment units where we had established plots and collected pre-treatment data. In 2020 we partnered with a USFS timber crew to conduct post-treatment data collection at Chimney Springs treatment unit. In 2021, CAWL crews completed the remaining Chimney Springs post-treatment data collection and collected additional post-treatment data in the portions of Clark, A1 South, Parks West, and Cloverdog that had been thinned to date (Table 2, Figure 2).

*Table 2. Post-treatment plots completed per treatment unit, and year(s) when post-treatment data were collected. Also shown are the number of pre-treatment plots (from Table 1), and the percentage of pre-treatment plots where post-treatment data have been collected to date. Treatment unit/year where field data were collected by USFS is noted with a *.*

Treatment Unit	Year(s) Collected	Post-treatment Plots	Pre-treatment Plots	% Plots Treated
Chimney Springs*	2020*, 2021	58	58	100.00%
Cloverdog	2021	15	69	21.74%
A1 South	2021	8	47	17.02%
Parks West	2021	46	78	58.97%
Clark	2021	12	34	35.29%
Total		**139**	**286**	**48.60%**

Throughout each season of data collection, quality assurance/quality control checks were conducted in the field by crew leaders at 2 – 4 out of every 20 plots completed by the crews to ensure accuracy and provide an opportunity to address any errors.

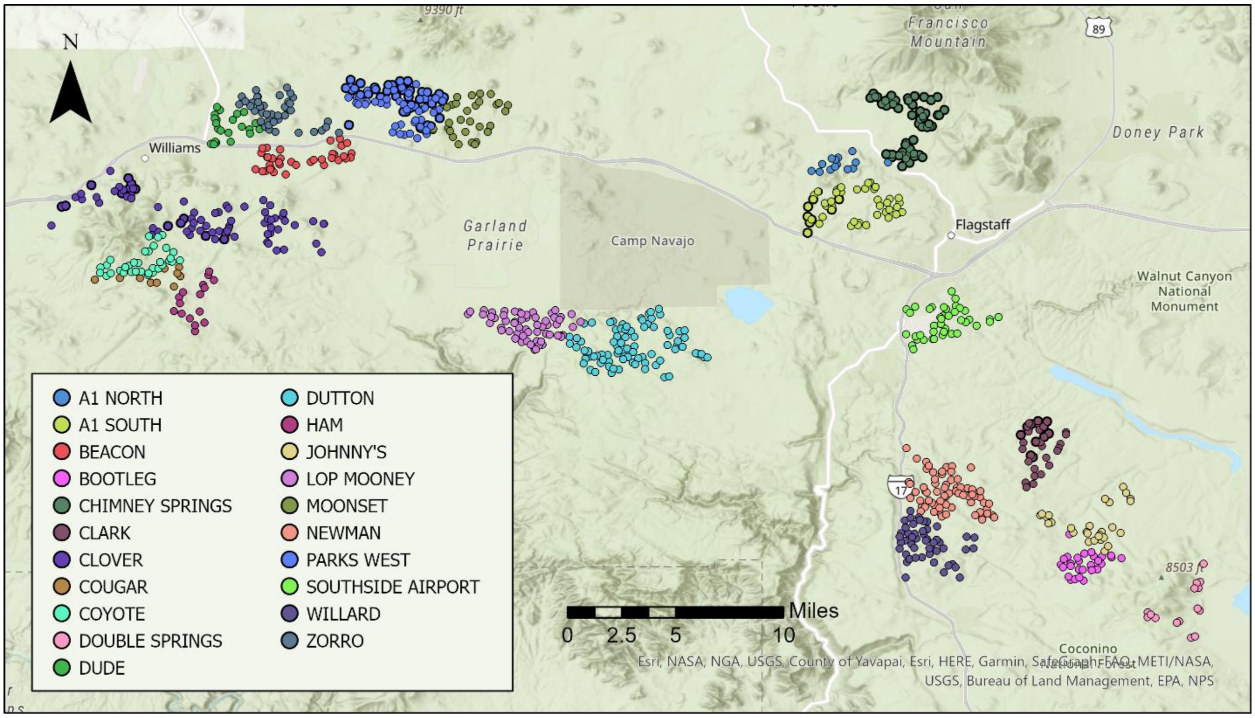

Figure 2. Rapid plot locations symbolized by treatment unit. Pre-treatment data have been collected at all plots shown. Post-treatment data have been collected at plots with a thick black outline.

Data management

Data management systems and data entry procedures have varied throughout the course of this project. The evolution of 4FRI rapid plot monitoring data management in the period between 2015 and 2019 is comprehensively described by Esch and Waltz (2019). Since 2019, we have worked to ensure that all data collected to date are present and accurate in the current Microsoft Access database. Migration of data of all data collected prior to 2018 from previous storage locations into the current Access database resulted in corruption of many records, necessitating thorough error-checking of all data from those plots. Our data cleaning process prioritized all data from Chimney Springs plots, to facilitate analysis of the pre- and post-treatment data in the one unit where treatment has been completed. We have further prioritized error-checking tree data from all pre-treatment plots, based on the MPMB's interest in summarizing those data.

Pre-treatment tree data summaries

The first objective of this report is to describe the pre-treatment condition of ponderosa pine forest overstory in the first 4FRI NEPA analysis area. To this end we have compiled the pre-treatment tree data collected from the 21 treatment units where pre-treatment data collection was completed. We exported all pre-treatment tree data from the Access database, and then used R statistical computing software (R Core Team 2021) to generate summary statistics, tables, and figures.

We use all records of all trees across all treatment units to calculate mean and standard error for diameter at breast height (DBH) (live trees and dead trees summarized separately), codominant tree height (only three trees per plot), and canopy base height (CBH) (only three trees per plot) for each treatment unit. We summarized the number of both live and dead trees per acre in each 4-inch diameter class at the plot level, before generating a means and standard errors for each treatment unit. Trees per acre (TPA), basal area per acre (BAPA), and quadratic mean diameter (QMD) were calculated using individual tree records at the plot level before we calculated means and standard errors for each treatment unit. We summarized TPA for live trees and dead trees separately, and only considered live trees in our summaries of BAPA and QMD. Additionally, we calculated live TPA for each tree species observed across treatment units.

Analysis of treatment effects: Chimney Springs treatment unit

The second objective of this report is to determine the effects of mechanical thinning treatment on all measured variables in the Chimney Springs treatment unit. Out of the 58 plots where we collected data at Chimney Springs, 49 were mechanically thinned and nine were not treated. For our summaries and analyses of treatment effect, we only used data from the 49 treated plots. Each of these plots was visited both pre-treatment and post-treatment.

Data summary & description

At the plot level, we calculated total TPA as well as TPA in each 4-inch diameter class for live and dead trees separately, then generated means and standard errors for the pre-treatment measurements and the post-treatment measurements. Species composition was summarized as live TPA for each species present. Additionally, we separated records of live and dead tree DBH to calculate means and standard errors for pre- and post- treatment groups. Only live trees were used to calculate codominant tree height, CBH, BAPA, and QMD values at the plot level, which were then used to generate means and standard errors for pre- and post- treatment groups. Number of seedlings and saplings per acre (only *Pinus ponderosa* observed in this treatment unit), as well as percent cover of understory vegetation, percent cover of substrate classes, and logs per acre were calculated at the plot level and summarized for each treatment group.

All disturbance data (soil erosion, soil compaction, recent fire, grazing, invasive species) were converted to presence/absence at the plot level, then summarized as percent plots with presence of the indicator out of the total number of plots. Animal sign data (squirrel and vole) were also summarized by percent presence for both pre- and post- treatment groups. Woody fuels (1-hour, 10-hour, and 100-hour fuel load estimates) were summarized as percent of total quadrats (four in each plot) in each possible load category. Similarly, stand estimate for 1000-hour fuels was summarized as percent of total plots (one measurement per plot) in each load category.

Statistical Analysis

We used generalized linear mixed models to test for significant differences between pre-treatment and post-treatment observations in all continuous, count, and presence/absence response variables. In these models, plot was included as a random effect, and error distribution was parameterized based on response variable in each model. Analyses were performed in R (R Core Team 2021) using the package lmerTest (Kuznetsova et al. 2017).

Results & Discussion

Summary of pre-treatment overstory data

Between 2016 and 2021, we collected pre-treatment data at 867 individual plots across 21 different treatment units. The number of trees measured in all treatment units totaled 29,595. Of those, 94.4% (27,937) were living and 5.6% (1,658) were dead.

Trees per acre

The mean number of live trees per acre ranged from 107.36 (±10.32) in the Beacon treatment unit to 219.66 (±15.04) at Bootleg (Table 3, Figure 3). Six out of the seven treatment units with the highest density of live trees (Bootleg, Newman, Double Springs, Willard, Clark, and Johnny's) are clustered in the same geographic area southwest of Lake Mary and east of I-17 in the Coconino National Forest. Five out of the seven treatment units with the lowest density of live trees (Beacon, Cougar, Zorro, Dude, and Parks West) are located south and east of Williams in the Kaibab National Forest.

The mean number of dead trees per acre was lowest at Dude with a value of 0.23 (±0.23) and highest in the A1 North treatment unit at 25.71 (±24.19). Generally, due to the far lower number of dead trees compared to living trees in every treatment unit, dead tree density is much lower than live tree density across units.

***Table 3**. Trees per Acre (TPA)- mean and standard error (SE) for the number of live TPA and dead TPA in each treatment unit.*

Treatment Unit (# plots)	**Live TPA** mean (SE)	**Dead TPA** mean (SE)
A1 North (14)	119.64 (25.65)	25.71 (24.19)
A1 South (47)	143.09 (17.46)	2.02 (0.67)
Beacon (36)	107.36 (10.32)	4.58 (1.76)
Bootleg (29)	219.66 (15.04)	23.79 (3.67)
Chimney Springs (58)	138.10 (12.01)	3.53 (0.86)
Clark (34)	192.94 (16.68)	6.62 (2.02)
Cloverdog (69)	162.17 (10.33)	3.99 (1.02)
Cougar (10)	121.00 (35.42)	21.00 (5.04)
Coyote (35)	151.00 (11.52)	21.57 (4.43)
Double Springs (15)	215.00 (15.63)	11.00 (2.54)
Dude (22)	123.86 (11.84)	0.23 (0.23)
Dutton (86)	210.47 (11.54)	9.83 (1.52)
Ham (16)	148.75 (19.00)	25.62 (6.00)
Johnny's (28)	169.11 (16.61)	2.86 (0.98)
LOP Mooney (60)	143.75 (11.36)	3.75 (0.71)
Moonset (30)	143.83 (14.38)	17.33 (2.35)
Newman (67)	216.27 (14.11)	20.52 (5.11)
Parks West (78)	133.14 (7.46)	4.10 (1.05)
Southside Airport (41)	113.17 (9.57)	1.10 (0.51)
Willard (51)	199.02 (13.06)	17.94 (3.40)
Zorro (41)	122.56 (9.78)	9.88 (3.48)

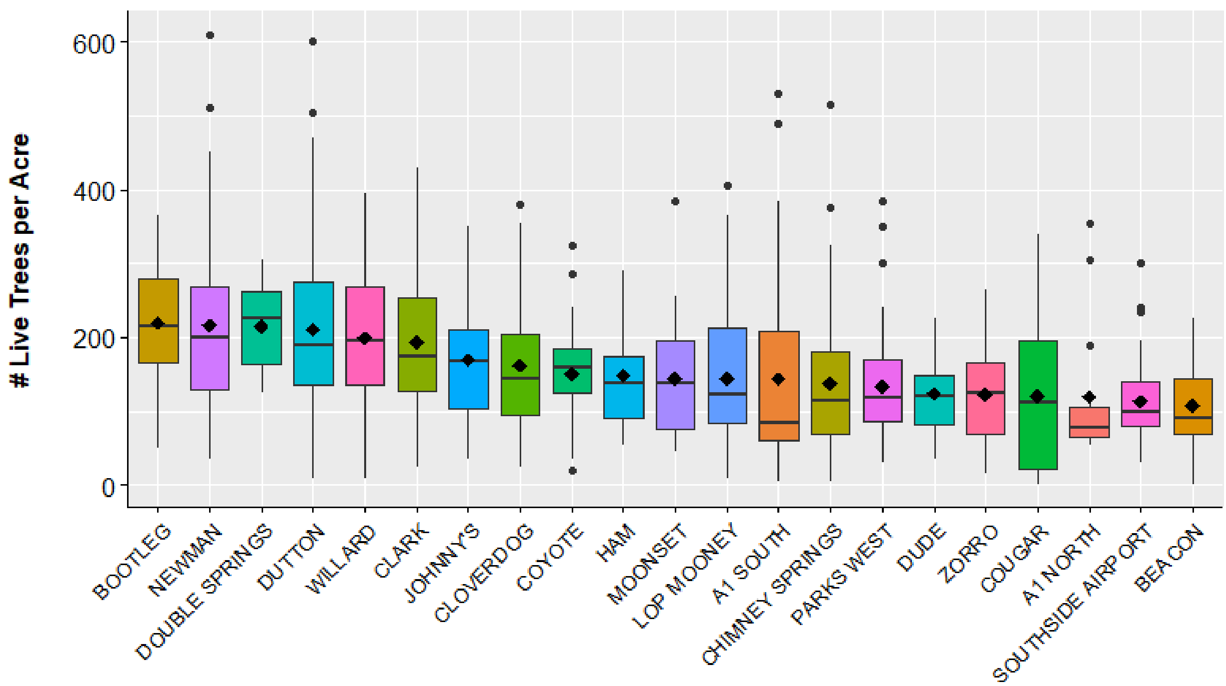

Figure 3. *Live Trees per Acre (TPA)- box plot where the horizontal center line is the median value, the colored box contains all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds. Note difference in y-axis scale between Figure 3 and Figure 4.*

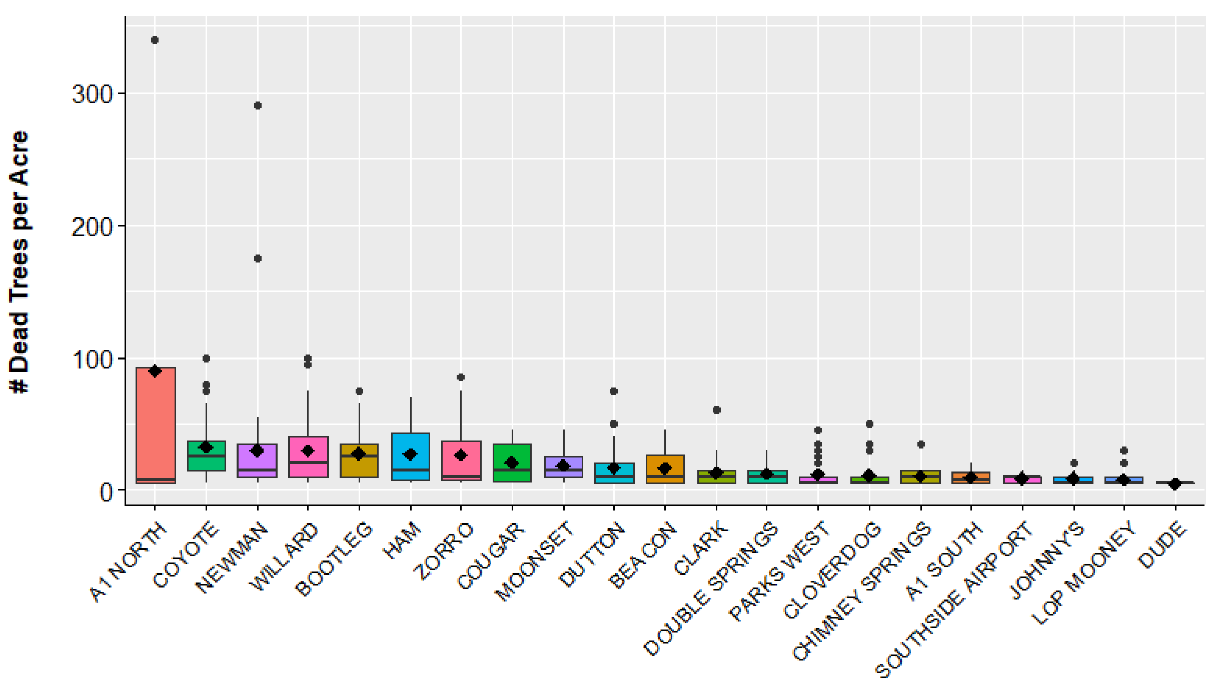

Figure 4. *Dead Trees per Acre (TPA)- box plot where the horizontal center line is the median value, the colored box contains all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds. Note difference in y-axis scale between Figure 4 and Figure 3.*

Species distribution

Across all 21 treatment units that were sampled, we recorded nine tree species: ponderosa pine (*Pinus ponderosa,* PIPO), Gambel oak (*Quercus gambelii,* QUGA), alligator juniper (*Juniperus deppeana,* JUDE), white fir (*Abies concolor,* ABCO), pinyon pine (*Pinus edulis,* PIED), Douglas fir (*Pseudotsuga menziesii,* PSME), southwestern white pine (*Pinus strobiformis,* PIST), oneseed juniper (*Juniperus monosperma,* JUMO), and aspen (*Populus tremuloides,* POTR) (Figure 5, table in Appendix C). Ponderosa pine were by far the most abundant and dense, and present in all treatment units. Density of ponderosa pine ranged from a high of 191.34 (±10.97) TPA at Dutton to 86.94 (±8.68) TPA at Beacon. This lowest density of ponderosa was still larger than the highest density of any other species in any other treatment unit.

Gambel oak was the second most commonly observed species, present in 15 out of 21 treatment units. The highest density of Gambel oak was recorded in the Bootleg treatment unit where TPA was 71.72 (±13.04). The units where oaks were most common are clustered between Lake Mary and I-17 (Bootleg, Newman, and Double Springs) and south of Williams (Ham, Coyote, Cloverdog, and Cougar). Alligator juniper was recorded in 16 treatment units, though generally at lower densities than Gambel oak. The units with the highest juniper TPA were clustered on the Kaibab National Forest south and east of Williams (Zorro, Dude, Coyote, Cougar, Beacon, Moonset) (Figure 5, table in Appendix C).

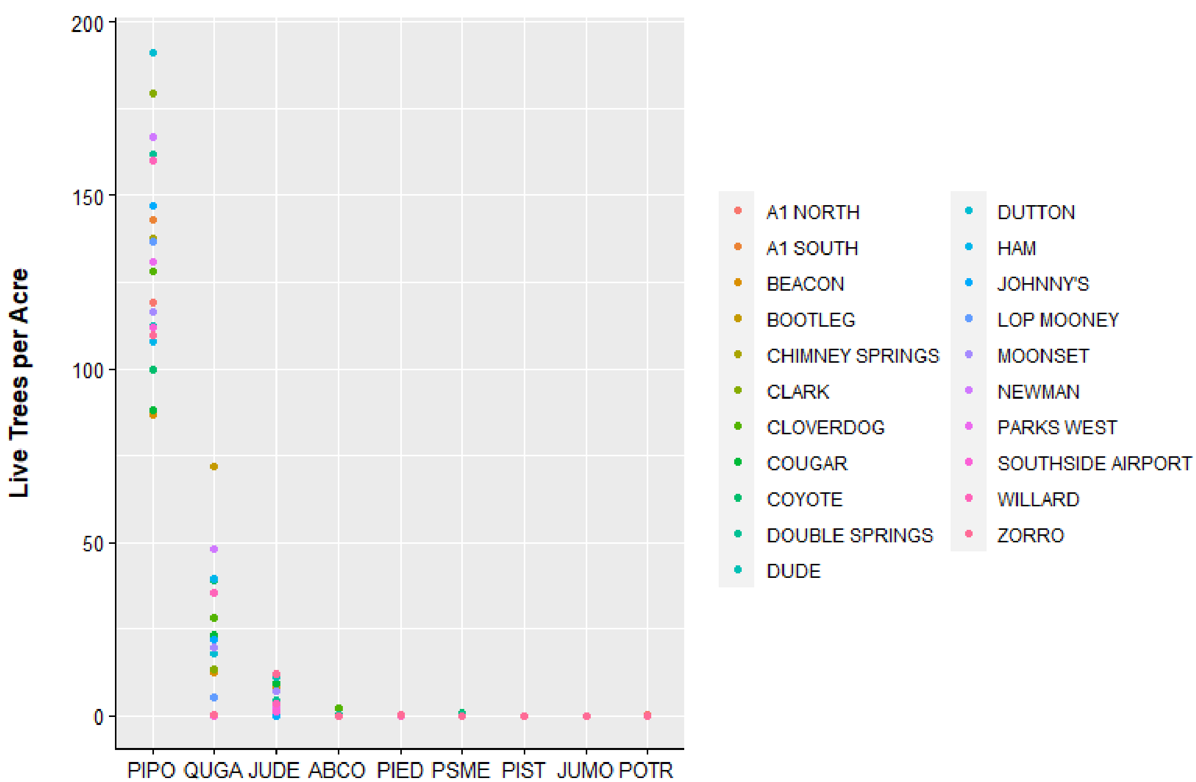

Figure 5. *Live Tree Species Distribution- Points correspond to the mean number of live trees per acre of each species listed from each treatment unit. Species abbreviations are as follows: PIPO = ponderosa pine, QUGA = Gambel oak, JUDE = alligator juniper, ABCO = white fir, PIED = pinyon pine, PSME = Douglas fir, PIST = southwestern white pine, JUMO = oneseed juniper, POTR = aspen. A full table of mean and standard error values for all treatment units is presented in Appendix C.*

Diameter classes & mean DBH

We categorized each tree measured according to 4-inch diameter classes beginning with 4 – 8 inches as 4 inches was the minimum DBH for trees measured and recorded as adult individuals. We found that there was a large range of mean TPA values in the smaller diameter classes (specifically 4 – 8 inches, 8 – 12 inches, and 12 – 16 inches) between treatment units, and that densities were also generally higher in those small classes. For example, TPA in the 4 – 8 inch diameter class ranged from 27.07 (±4.92) at Southside Airport to 96.72 (±12.78) at Bootleg (Figure 6, table in Appendix C). Conversely, lower densities of trees in larger diameter classes were observed across treatment units, but mean values were more similar. For example, in the 28 – 32 inch diameter class, two treatment units had no trees (A1 North and Ham), and the highest density (Double Springs) was only 1.67 (±0.63) TPA. Live trees in the two largest diameter classes (32 – 36 inches and 36 – 40 inches) were only observed in 12 out of 21 treatment units (Figure 6, table in Appendix C). We also placed measured trees into 2-inch diameter classes to show distribution at a finer scale (Figure D1 and table in Appendix D).

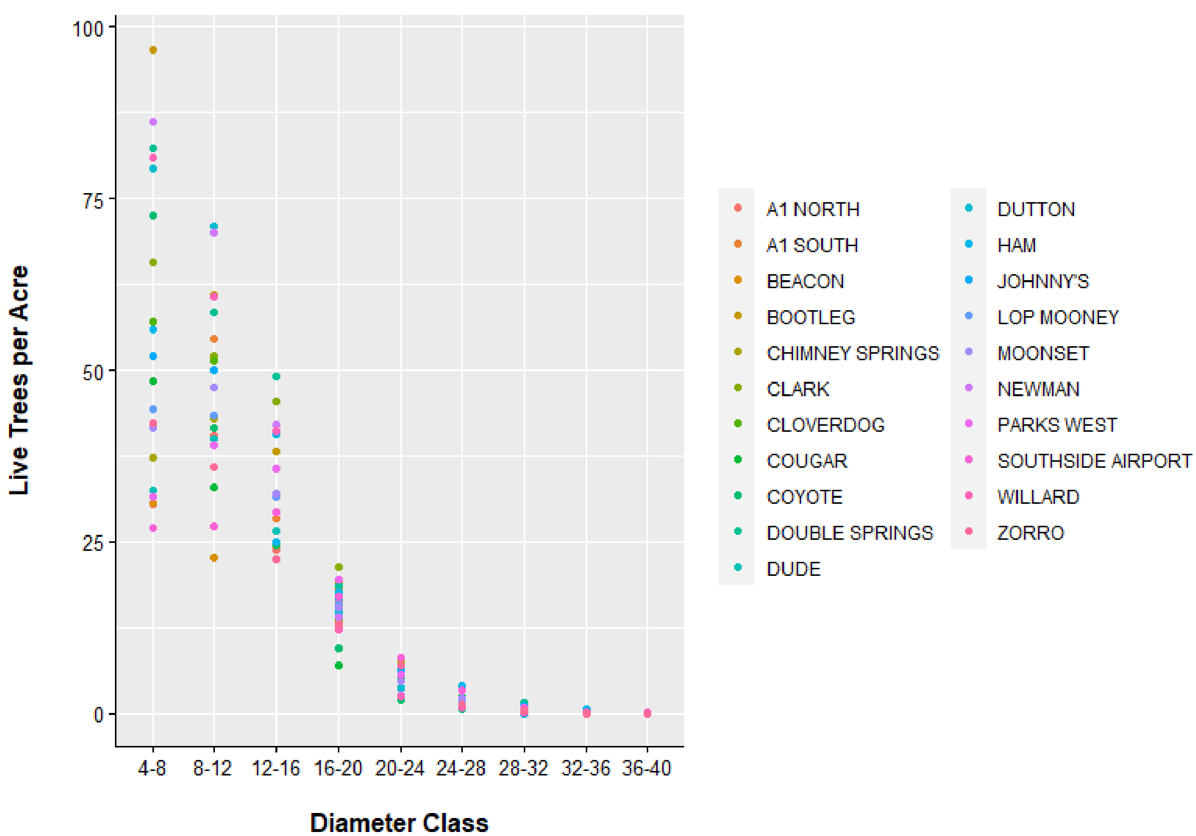

Figure 6. *Live Tree Diameter Class Distribution- Points correspond to the mean number of live trees per acre from each treatment unit in each 4-inch diameter class. A full table of mean and standard error values for all treatment units and diameter classes is presented in Appendix C. Note difference in y-axis scale between Figure 6 and Figure 7.*

We also categorized all dead trees using the same diameter classes (Figure 7, table in Appendix C). The highest densities were observed in the smallest diameter class (4 – 8 inches), though even the highest number of mean dead TPA in this class (A1 North, 22.14 +21.00) was less than the lowest number of mean live TPA in the same class (Figures 6 and 7). Mean dead TPA for all other diameter classes was less than 5.00 in every treatment unit. Large snags (above 24” diameter) were present in 12 out of 21 units, though densities remained very low.

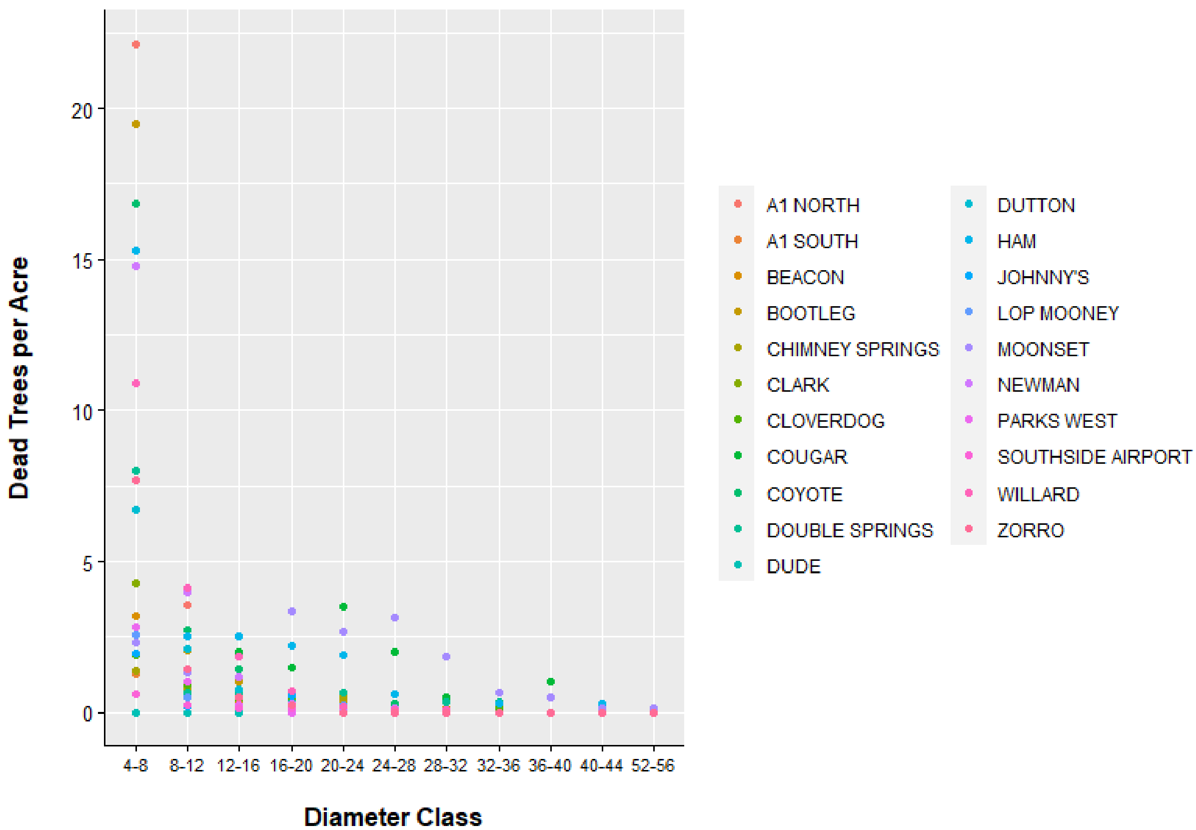

Figure 7. Dead Tree Diameter Class Distribution- Points correspond to the mean number of dead trees per acre from each treatment unit in each 4-inch diameter class. A full table of mean and standard error values for all treatment units and diameter classes is presented in Appendix C. Note difference in y-axis scale between Figure 7 and Figure 6.

We also characterized diameter for both live and dead trees by calculating the mean DBH for each treatment unit (Table 4, Figures 8 and 9). Mean live DBH ranged only between 9.38 (+0.14) (Coyote) and 12.86 (+0.19) (Southside Airport) across all units. Dead DBH ranged more widely from 6.25 (+0.20) (A1 North) to 21.05 (+0.93) (Moonset) due to three treatment units (Moonset, Dude, Cougar) with higher means.

Table 4. *Diameter at Breast Height (DBH)- mean and standard error (SE) for live tree DBH dead tree DBH.*

Treatment Unit (# plots)	**Live DBH** (inches) mean (SE)	**Dead DBH** (inches) mean (SE)
A1 North (14)	11.94 (0.28)	6.25 (0.20)
A1 South (47)	10.88 (0.12)	7.44 (0.49)
Beacon (36)	12.47 (0.22)	8.02 (1.05)
Bootleg (29)	9.70 (0.13)	6.80 (0.34)
Chimney Springs (58)	11.73 (0.13)	11.79 (1.00)
Clark (34)	10.99 (0.14)	8.00 (0.70)
Cloverdog (69)	10.68 (0.10)	10.58 (0.91)
Cougar (10)	10.42 (0.33)	15.09 (1.53)
Coyote (35)	9.38 (0.14)	6.89 (0.31)
Double Springs (15)	10.31 (0.19)	9.40 (1.27)
Dude (22)	11.61 (0.21)	16.60 (NA)
Dutton (86)	10.06 (0.07)	7.42 (0.26)
Ham (16)	11.06 (0.26)	10.67 (0.87)
Johnny's (28)	11.22 (0.16)	8.93 (1.18)
LOP Mooney (60)	11.23 (0.12)	8.42 (0.78)
Moonset (30)	11.16 (0.17)	21.05 (0.93)
Newman (67)	9.90 (0.08)	7.36 (0.22)
Parks West (78)	11.97 (0.11)	7.26 (0.34)
Southside Airport (41)	12.86 (0.19)	8.91 (1.61)
Willard (51)	9.92 (0.10)	8.54 (0.31)
Zorro (41)	11.02 (0.17)	7.02 (0.35)

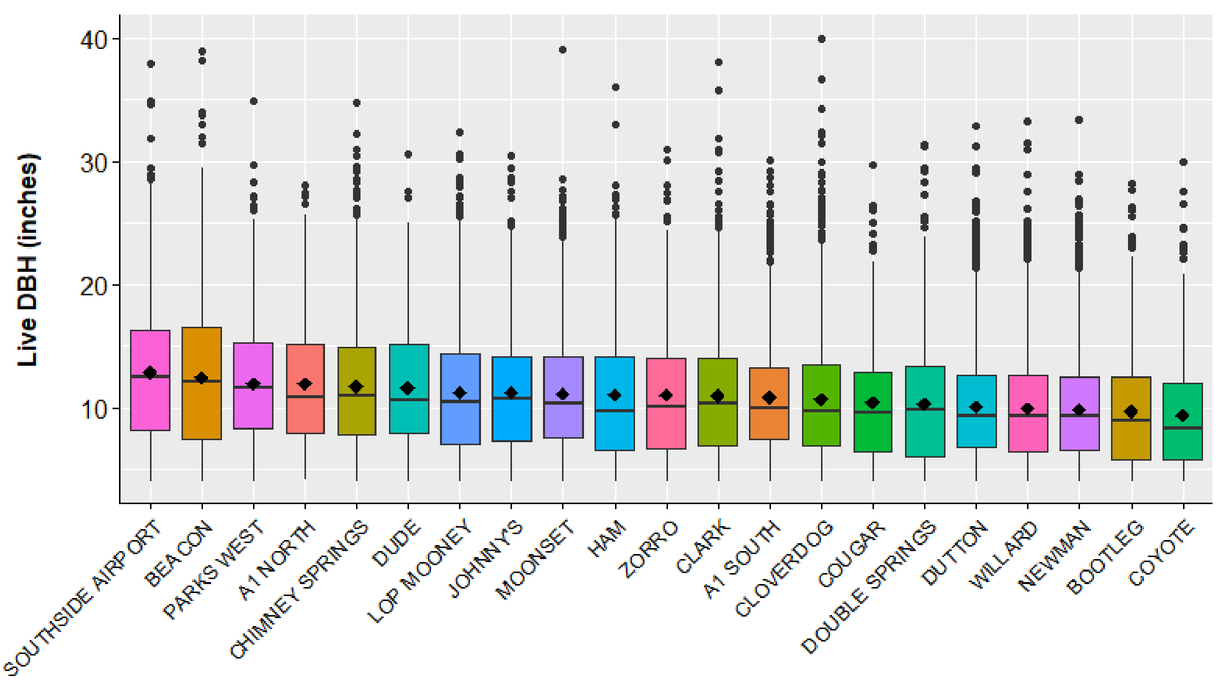

Figure 8. *Live Tree Diameter at Breast Height (DBH)- box plot where the horizontal center line is the median value, the colored box contains all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds. Note difference in y-axis scale between Figure 8 and Figure 9.*

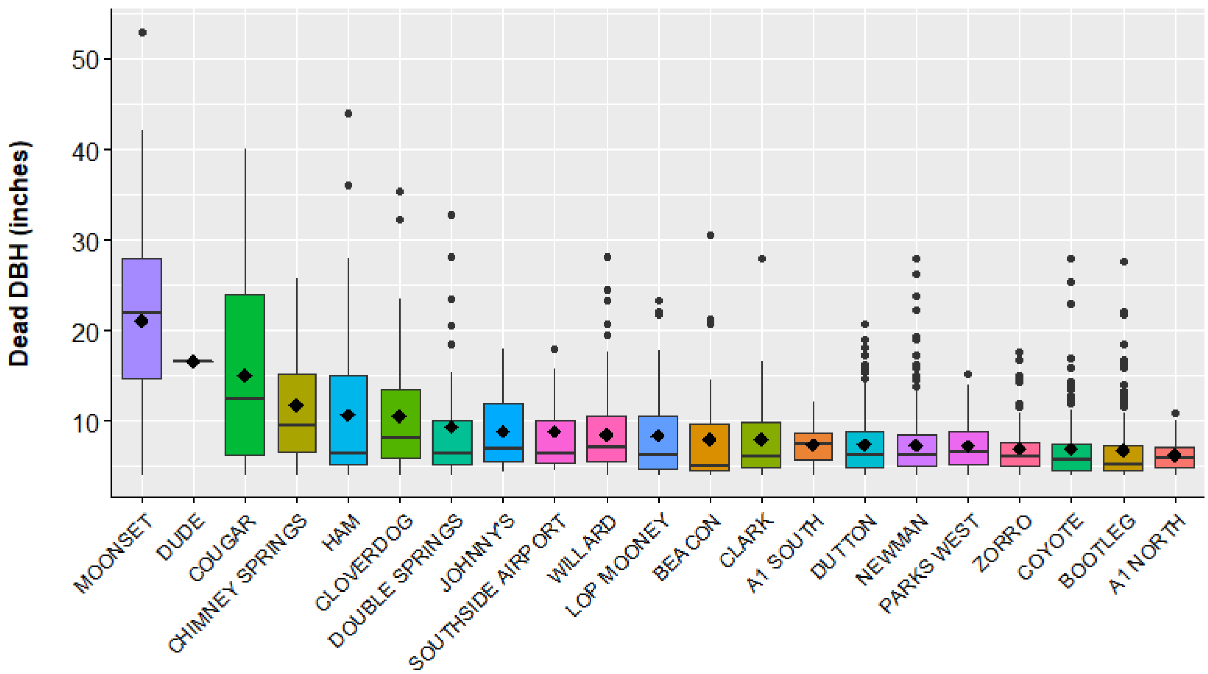

Figure 9. *Dead Tree Diameter at Breast Height (DBH)- box plot where the horizontal center line is the median value, the colored box contains all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds. Note difference in y-axis scale between Figure 9 and Figure 8.*

Basal area

Among treatment areas, basal area per acre ranged modestly from 88.29 (±8.09) ft^2/acre (Coyote) to 154.20 (±8.78) ft^2/acre (Clark) (Table 5, Figure 10). Only living trees are included in this summary.

Table 5. *Basal Area per Acre (BAPA)- mean and standard error (SE) for live trees in each treatment unit.*

Treatment Unit (# plots)	**BAPA** (ft^2/acre) mean (SE)
A1 North (14)	109.60 (13.79)
A1 South (47)	107.92 (7.63)
Beacon (36)	112.04 (7.57)
Bootleg (29)	137.43 (7.32)
Chimney Springs (58)	123.92 (5.27)
Clark (34)	154.20 (8.78)
Cloverdog (69)	122.28 (5.58)
Cougar (10)	88.50 (17.92)
Coyote (35)	88.29 (8.09)
Double Springs (15)	152.84 (13.39)
Dude (22)	107.75 (8.71)
Dutton (86)	136.61 (5.71)
Ham (16)	124.65 (9.85)
Johnny's (28)	138.58 (9.33)
LOP Mooney (60)	119.17 (6.04)
Moonset (30)	116.74 (6.77)
Newman (67)	136.33 (6.50)
Parks West (78)	120.67 (5.06)
Southside Airport (41)	122.19 (7.09)
Willard (51)	126.83 (6.07)
Zorro (41)	99.51 (6.45)

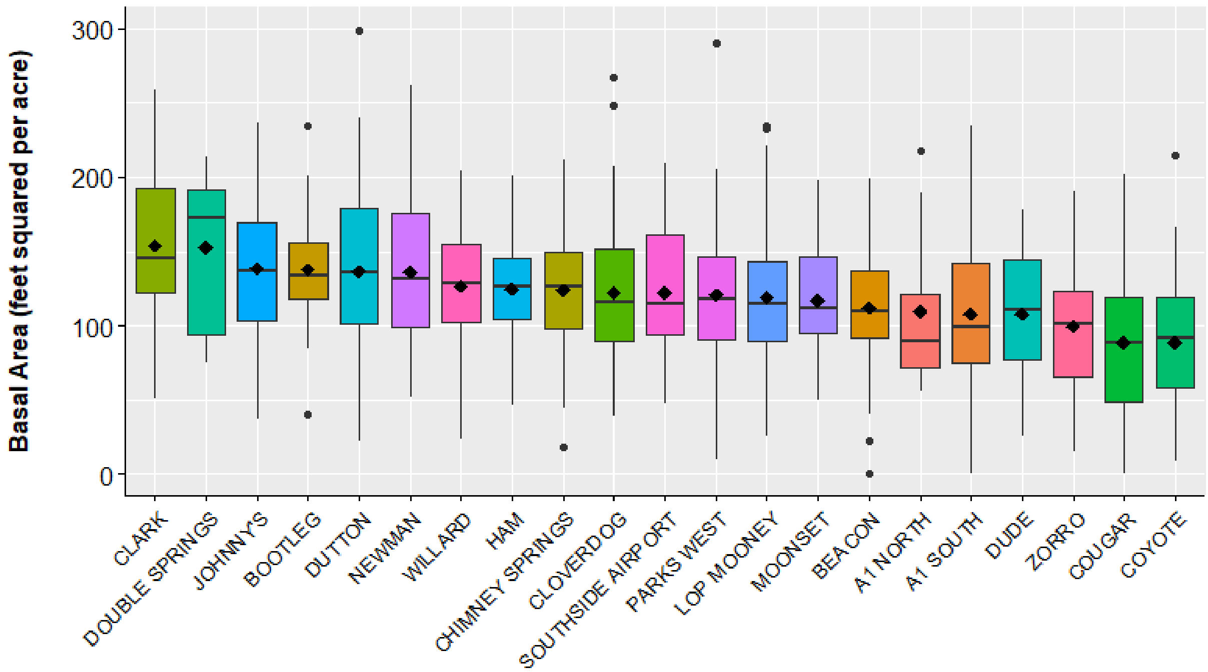

Figure 10. *Basal Area per Acre (BAPA)- box plot where the horizontal center line is the median value, the colored box contains all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds. Only live trees included in this summary.*

Quadratic mean diameter

Quadratic mean diameter ranged minimally from 10.21 (±0.39) inches (Coyote) to 14.79 (±0.39) (Southside Airport) (Table 6, Figure 11). Only living trees are included in this summary.

Table 6. Quadratic Mean Diameter (QMD)- mean and standard error (SE) for live trees in each treatment unit.

Treatment Unit (# plots)	**QMD** (inches) mean (SE)
A1 North (14)	13.94 (0.64)
A1 South (47)	13.08 (0.49)
Beacon (36)	14.31 (0.66)
Bootleg (29)	11.01 (0.33)
Chimney Springs (58)	14.21 (0.46)
Clark (34)	12.88 (0.41)
Cloverdog (69)	12.50 (0.37)
Cougar (10)	13.15 (2.23)
Coyote (35)	10.21 (0.39)
Double Springs (15)	11.35 (0.35)
Dude (22)	12.82 (0.33)
Dutton (86)	11.52 (0.29)
Ham (16)	13.22 (0.83)
Johnny's (28)	13.04 (0.48)
LOP Mooney (60)	13.50 (0.40)
Moonset (30)	13.02 (0.49)
Newman (67)	11.19 (0.22)
Parks West (78)	13.28 (0.25)
Southside Airport (41)	14.79 (0.39)
Willard (51)	11.56 (0.39)
Zorro (41)	12.81 (0.38)

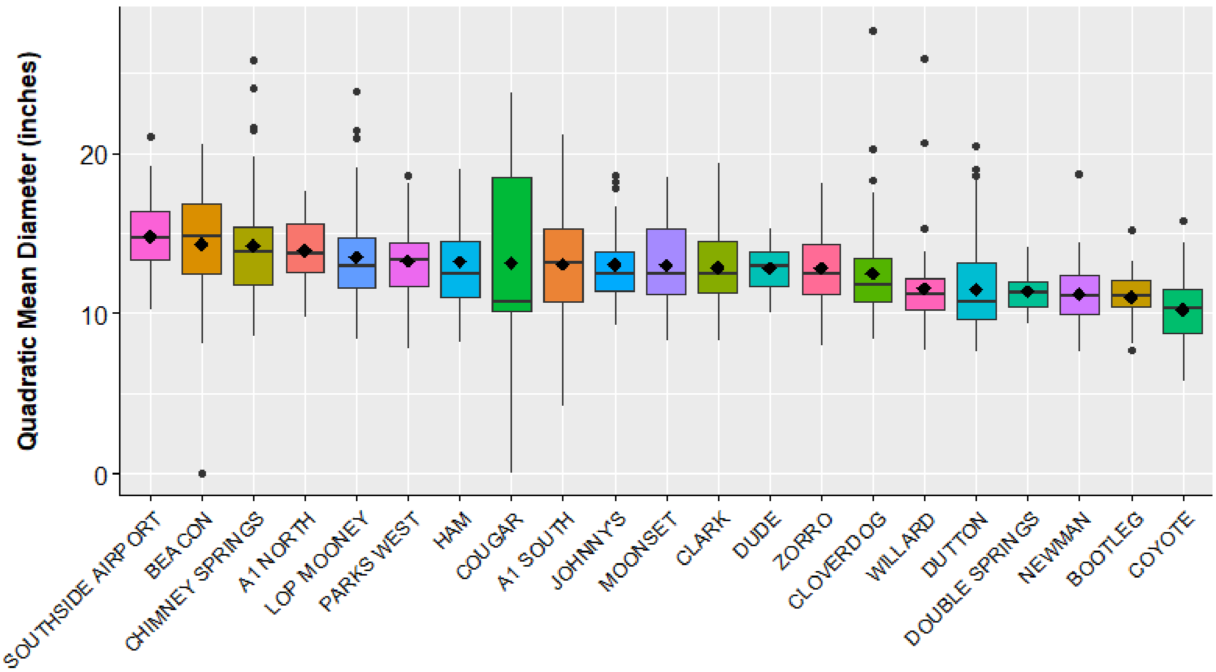

Figure 11. *Quadratic Mean Diameter (QMD)- box plot where the horizontal center line is the median value, the colored box contains all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds. Only live trees included in this summary.*

Codominant tree height

Height of codominant trees ranged from 46.87 (±1.45) feet (Coyote) to 63.58 (±1.19) (Clark) (Table 7, Figure 12).

Table 7. *Codominant Tree Height- mean and standard error (SE) for each treatment unit.*

Treatment Unit (# plots)	**Height** (feet) mean (SE)
A1 North (14)	54.62 (1.69)
A1 South (47)	55.49 (0.84)
Beacon (36)	57.50 (1.25)
Bootleg (29)	54.73 (1.26)
Chimney Springs (58)	61.55 (0.84)
Clark (34)	63.58 (1.19)
Cloverdog (69)	53.46 (0.98)
Cougar (10)	53.85 (3.10)
Coyote (35)	46.87 (1.45)
Double Springs (15)	52.77 (1.64)
Dude (22)	48.56 (1.24)
Dutton (86)	55.11 (0.76)
Ham (16)	54.40 (1.97)
Johnny's (28)	57.12 (0.97)
LOP Mooney (60)	58.38 (0.85)
Moonset (30)	55.39 (1.49)
Newman (67)	51.91 (0.77)
Parks West (78)	53.91 (0.78)
Southside Airport (41)	53.93 (1.10)
Willard (51)	55.57 (0.78)
Zorro (41)	49.69 (1.03)

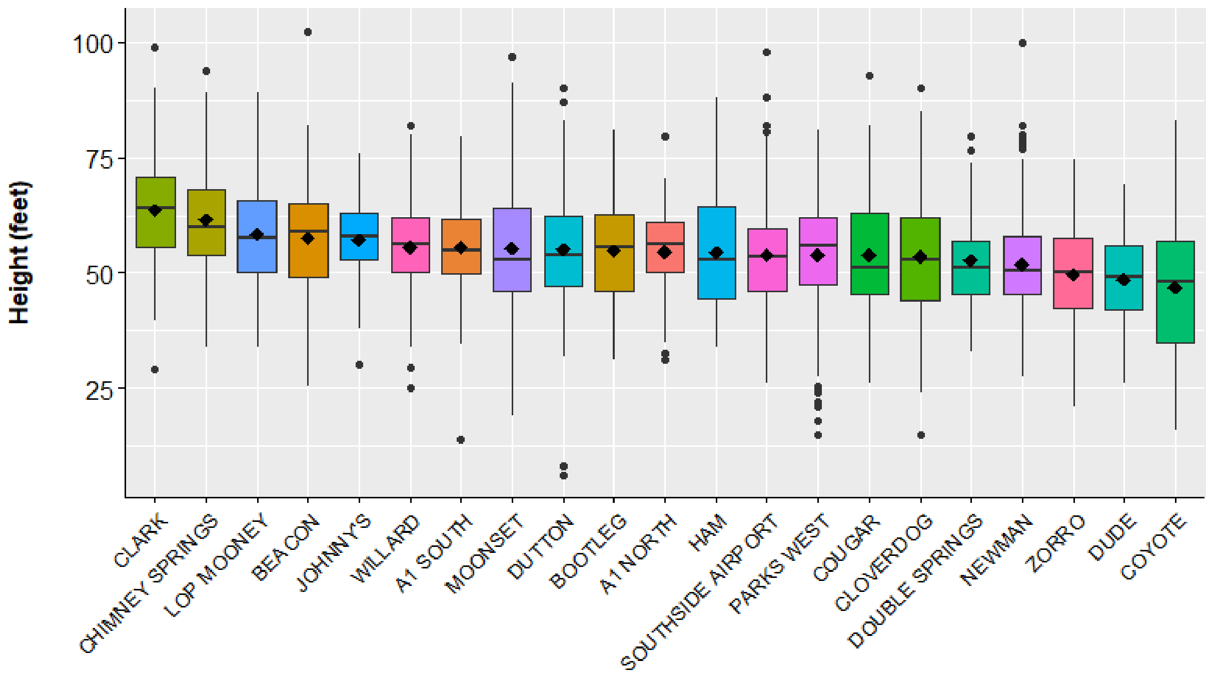

Figure 12. *Codominant Tree Height- box plot where the horizontal center line is the median value, the colored box contains all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds. Only live trees included in this summary.*

Crown base height

Crown base height ranged from 3.30 (±0.31) feet (Dude) to 10.36 (±0.62) (A1 South) (Table 8, Figure 13). Figure 13 shows that the data in each treatment unit have a larger spread in the third and fourth quartiles, with a high number of outlying plot values above the upper whisker.

Table 8. Crown Base Height- mean and standard error (SE) for each treatment unit.

Treatment Unit (# plots)	**CBH** (feet) mean (SE)
A1 North (14)	9.52 (0.91)
A1 South (47)	10.36 (0.62)
Beacon (36)	6.55 (0.57)
Bootleg (29)	4.93 (0.27)
Chimney Springs (58)	8.94 (0.59)
Clark (34)	9.45 (0.65)
Cloverdog (69)	4.25 (0.31)
Cougar (10)	6.56 (1.03)
Coyote (35)	5.15 (0.46)
Double Springs (15)	4.82 (0.29)
Dude (22)	3.30 (0.31)
Dutton (86)	7.79 (0.29)
Ham (16)	4.69 (0.60)
Johnny's (28)	4.85 (0.36)
LOP Mooney (60)	6.30 (0.26)
Moonset (30)	4.94 (0.40)
Newman (67)	6.30 (0.24)
Parks West (78)	8.63 (0.38)
Southside Airport (41)	6.93 (0.36)
Willard (51)	5.51 (0.29)
Zorro (41)	6.76 (0.73)

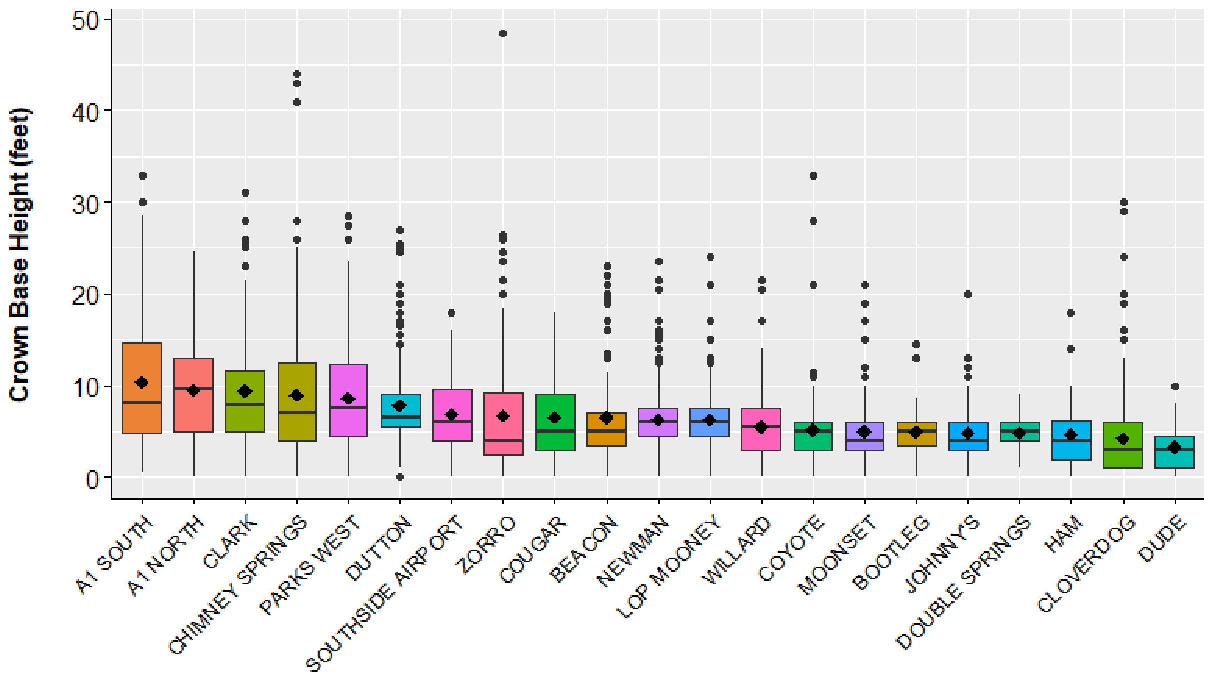

Figure 13. *Crown Base Height- box plot where the horizontal center line is the median value, the colored box contains all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds. Only live trees included in this summary.*

Analysis of treatment effects: Chimney Springs treatment unit

Pre-treatment data were collected in the Chimney Springs treatment unit during the summer field seasons of 2016 and 2017 (one pre-treatment visit per plot). Mechanical thinning treatment was implemented in 2018 and 2019. Post-treatment data were collected at the same plots in 2020 and 2021 (one post-treatment visit per plot). Therefore, depending on the year of treatment and the year of post-treatment data collection, there is a maximum of three years and a minimum of one year between treatment implementation and post-treatment observations.

Trees

During pre-treatment data collection, we recorded a total of 1,250 trees across the 49 plots that are included in this assessment. Before treatment, 96.9% (1211) of those recorded trees were living, and 3.1% (39) were dead. After treatment, we observed 357 total trees across the same 49 plots. Still, 96.9% (346) were alive and 3.1% (11) were dead.

Trees per acre

The number of both live TPA and dead TPA were significantly reduced after treatment (Table 9, Figure 14). Prior to treatment, mean live TPA at Chimney Springs was 123.57 (±10.84). That beginning density was reduced by 71.43% to a post-treatment mean of 35.31 (±3.18) TPA. Dead tree density experienced a similar percent reduction from pre- to post- treatment, though both values were far lower. Pre-treatment mean dead TPA was 3.98 (±1.00), while post-treatment density of dead trees was 1.12 (±0.39) TPA (Table 9, Figure 14). These results align with general expectations of treatment outcomes since thinning is inherently the process of removing trees.

Table 9. *Trees per Acre (TPA)- mean and standard error (SE) for the number of live TPA and dead TPA pre- and post- treatment. Significant p-values are bold.*

Trees per Acre	**# Plots**	**Live TPA** mean (SE)	**Dead TPA** mean (SE)
Pre-treatment	49	123.57 (10.84)	3.98 (1.00)
Post-treatment	49	35.31 (3.18)	1.12 (0.39)
% Change	-	*-71.43*	*-71.86*
χ^2 statistic	-	*2118.1*	*68.72*
P value	-	***2.2E-16***	***2.2E-16***

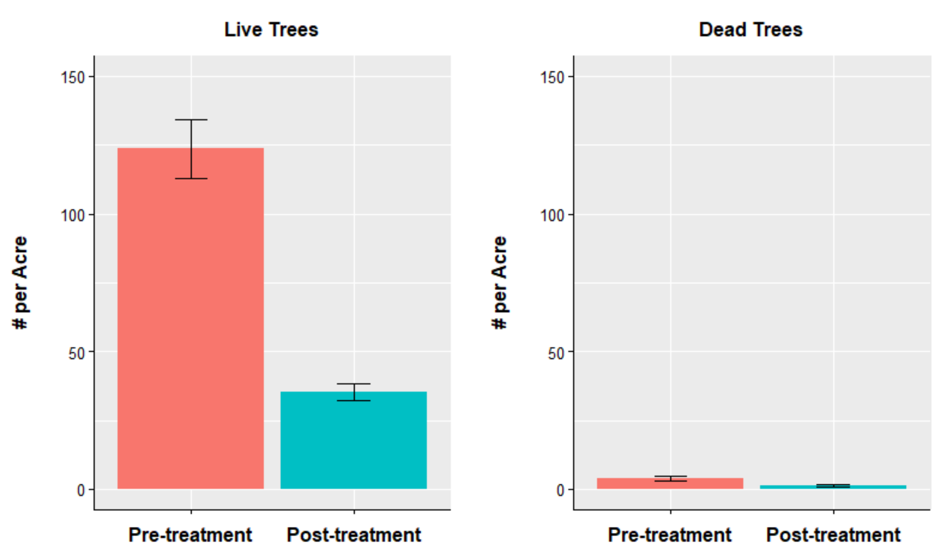

Figure 14. Trees per Acre (TPA)- bar chart where the top of each bar corresponds to the mean value, while the error bars show the standard error (SE) around the mean.

Species distribution

The large majority of all live trees recorded both before and after treatment were ponderosa pine (*Pinus ponderosa*) – 99.6% of pre-treatment trees and 99.4% of post-treatment trees. One to three individual trees of three other species (white fir – *Abies concolor*, pinyon pine – *Pinus edulis*, Douglas fir – *Pseudotsuga menziesii*) were observed in each of the treatment groups. Species distribution is presented as density of each species (TPA) in Table 10.

Table 10. *Live Tree Species Distribution- mean and standard error (SE) of TPA for each species observed at Chimney Springs.*

Trees per Acre	***Pinus ponderosa*** mean (SE)	***Abies concolor*** mean (SE)	***Pinus edulis*** mean (SE)	***Pseudotsuga menziesii*** mean (SE)
Pre-treatment	123.06 (10.83)	0.31 (0.17)	0.20 (0.14)	0 (0)
Post-treatment	35.10 (3.21)	0.10 (0.10)	0 (0)	0.10 (0.10)

Diameter classes & mean DBH

We categorized individual trees according to 4-inch diameter classes beginning with 4 – 8 inches (4 inches is the minimum DBH in our protocol) and summarized them as number of trees per acre (TPA) in pre- and post- treatment groups. Prior to thinning treatment, the classes with the three highest TPA values were also the three classes representing the smallest trees: 8 – 12 inches (mean 38.27 TPA), 12 – 16 inches (30.00 TPA), and 4 – 8 inches (28.47 TPA). In the pre-treatment group, density of larger trees drops much lower starting with the 16 – 20 inch class (15.82 TPA) and is only 0.2 TPA in the largest observed class (32 – 36 inches) (Table 11). After treatment, mean TPA sharply decreased in the three smallest diameter classes (4 – 8, 8 – 12, and 12 – 16 inches), was moderately lower in the two middle classes (16 – 20 and 20 – 24 inches), and was equal or higher in the three largest classes (24 – 28, 28 – 32, and 32 – 36 inches) (Figure 15). We also placed measured live trees into 2-inch diameter classes to show distribution at a finer scale (Figure D2 and table in Appendix D).

Table 11. *Live Tree Diameter Class Distribution- mean and standard error (SE) of TPA in each 4-inch diameter class.*

Live *Trees*	**4 - 8 in** mean (SE)	**8 - 12 in** mean (SE)	**12 - 16 in** mean (SE)	**16 - 20 in** mean (SE)	**20 - 24 in** mean (SE)	**24 - 28 in** mean (SE)	**28 - 32 in** mean (SE)	**32 - 36 in** mean (SE)
Pre-treatment	28.47 (6.04)	38.27 (5.39)	30.00 (3.00)	15.82 (1.84)	7.86 (1.30)	1.94 (0.46)	1.02 (0.36)	0.2 (0.14)
Post-treatment	1.43 (0.46)	5.71 (1.56)	10.41 (1.74)	8.78 (1.22)	5.61 (1.04)	2.04 (0.44)	1.12 (0.36)	0.2 (0.14)

Table 12. *Dead Tree Diameter Class Distribution- mean and standard error (SE) of TPA in each 4-inch diameter class.*

Dead *Trees*	**4 - 8 in** mean (SE)	**8 - 12 in** mean (SE)	**12 - 16 in** mean (SE)	**16 - 20 in** mean (SE)	**20 - 24 in** mean (SE)	**24 - 28 in** mean (SE)
Pre-treatment	1.63 (0.80)	0.82 (0.34)	0.61 (0.31)	0.31 (0.17)	0.51 (0.26)	0.10 (0.10)
Post-treatment	0.10 (0.10)	0.10 (0.10)	0.10 (0.10)	0.20 (0.14)	0.51 (0.26)	0.10 (0.10)

We assessed dead tree diameter class in the same way, assigning trees to 4-inch classes and summarizing TPA for the two treatment groups (Table 12). Notably, pre- and post- treatment TPA values in all diameter classes were generally much lower than live trees. Post-treatment, fewer dead trees were observed in the smallest four diameter classes (4 – 8, 8 – 12, 12 – 16, and 16 – 20 inches). Larger dead snags in the 20 – 24 and 24 – 28 inch classes remained at the exact same density pre- and post-treatment (Figure 16, Table 12).

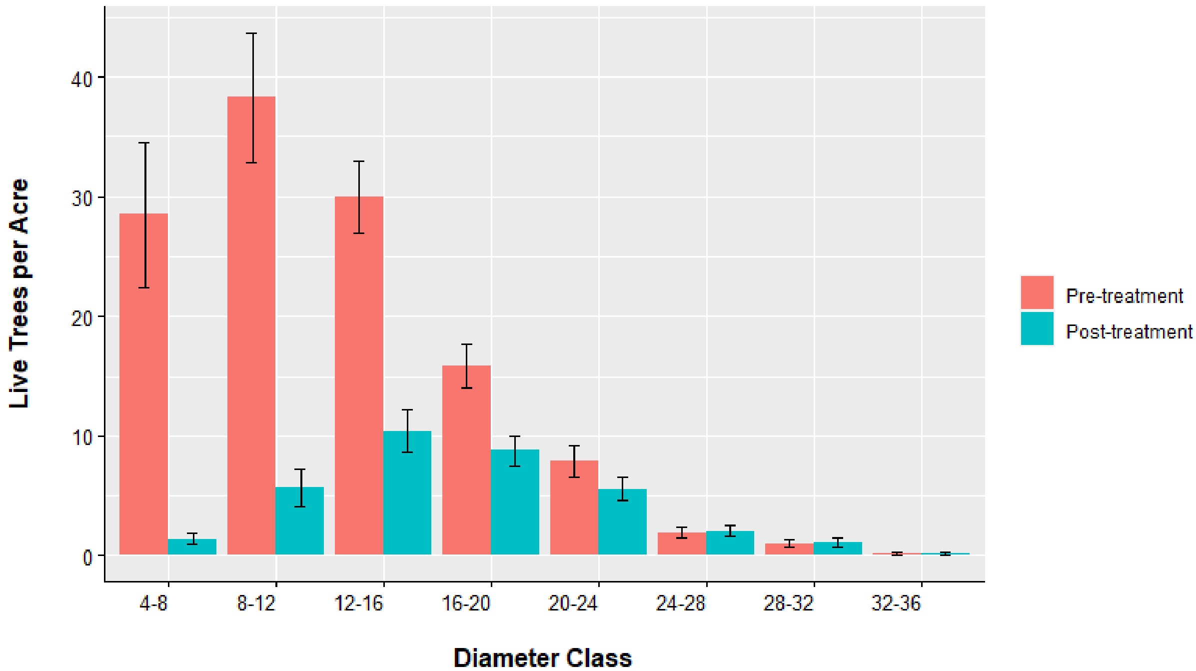

Figure 15. *Live Tree Diameter Class Distribution- bar chart where the top of each bar corresponds to the mean live TPA value, while the error bars show the standard error (SE) around the mean. Note difference in y-axis scale between Figures 15 and 16.*

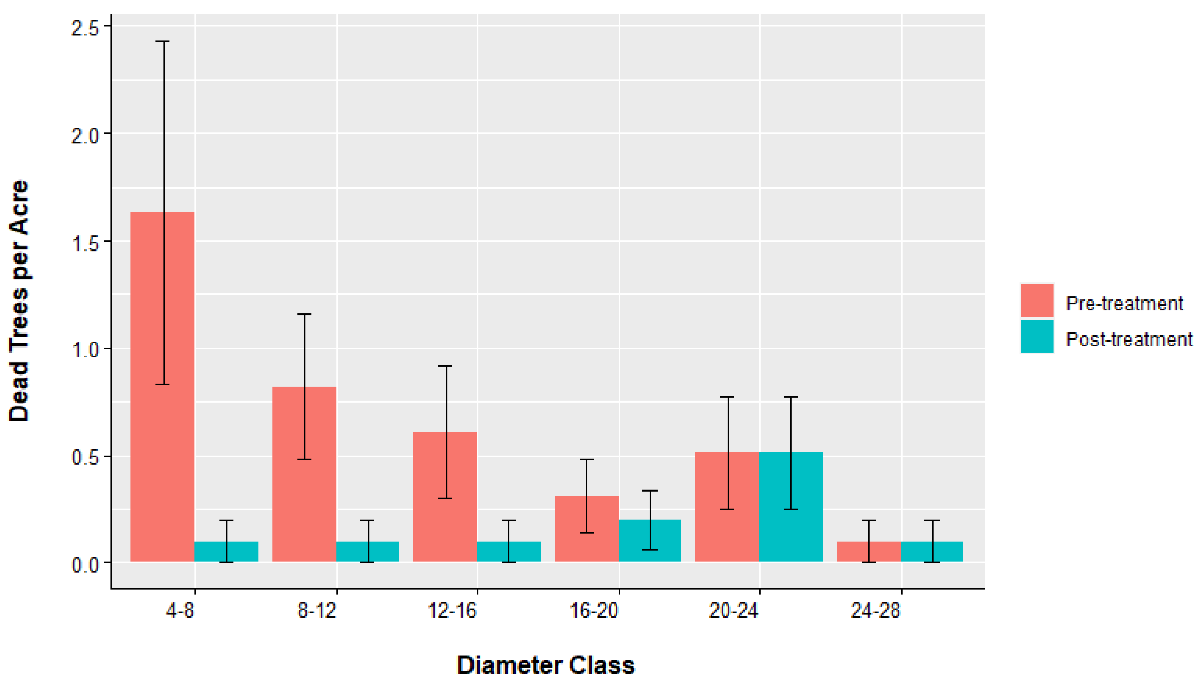

Figure 16. *Dead Tree Diameter Class Distribution- bar chart where the top of each bar corresponds to the mean dead TPA value, while the error bars show the standard error (SE) around the mean. Note difference in y-axis scale between Figures 15 and 16.*

We analyzed statistical significance between the mean pre-treatment and post-treatment diameter at breast height (DBH) for both live and dead trees. We found that the mean DBH of live trees was significantly larger by 36.39% in the post-treatment group compared to the pre-treatment group (Table 13, Figure 17). There was not a significant difference between the mean DBH of dead trees in the two groups, likely due to the fact that the sample size was considerably smaller for dead trees than for live (Table 13, Figure 17). These results follow expectations of treatment effect, since small diameter trees are the target of mechanical thinning operations.

Table 13. *Diameter at Breast Height (DBH)- mean and standard error (SE) for live tree DBH dead tree DBH, including sample size. Significant p-values are bold.*

Diameter at Breast Height	**# Live Trees**	**Live DBH (inches)** mean (SE)	**# Dead Trees**	**Dead DBH (inches)** mean (SE)
Pre-treatment	1211	12.23 (0.15)	39	11.65 (1.02)
Post-treatment	346	16.68 (0.30)	11	18.41 (1.95)
% Change	-	*+36.39*	-	-
F statistic	-	*38.07*	-	*2.2*
P value	-	***1.38E-07***	-	*0.1449*

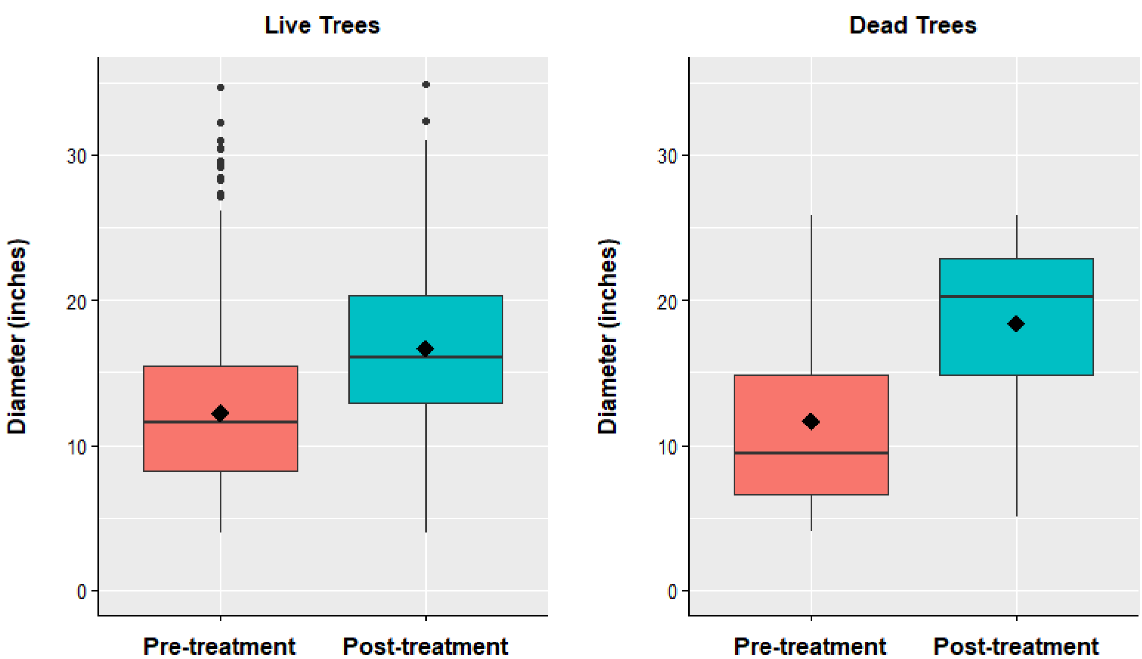

Figure 17. *Diameter at Breast Height (DBH) of Live and Dead Trees- box plots where the horizontal center line is the median value, the colored boxes contain all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds.*

Basal area

Prior to treatment, mean basal area per acre was 119.53 ($\pm$5.65) ft^2/acre at Chimney Springs. Post-treatment, our results show that basal area was 59.36 ($\pm$4.02) ft^2/acre, a statistically significant reduction of 50.34% (Table 14, Figure 18). This outcome is consistent with a thinning treatment that removes trees and therefore reduces basal area.

Table 14*. Basal Area per Acre (BAPA)- mean and standard error (SE) for pre- and post- treatment groups. Significant p-values are bold.*

Basal Area per Acre	**# Plots**	**BAPA (ft2/acre)** mean (SE)
Pre-treatment	49	119.53 (5.65)
Post-treatment	49	59.36 (4.02)
% Change	-	*-50.34*
F statistic	-	*115.29*
P value	-	***2.34E-14***

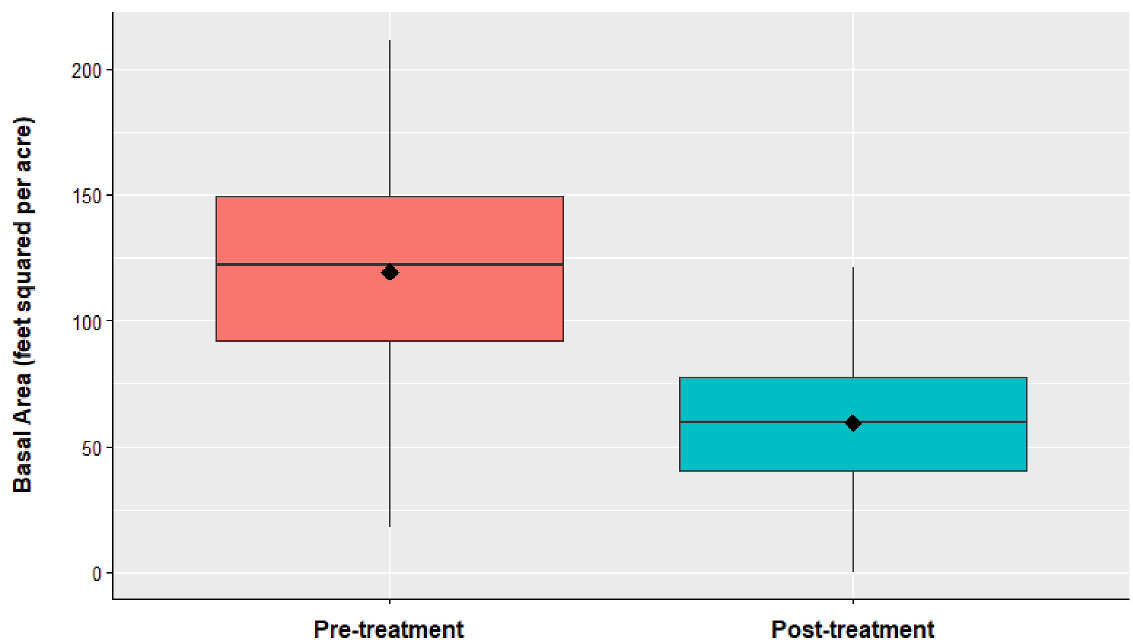

Figure 18. *Basal Area per Acre (BAPA)- box plot where the horizontal center line is the median value, the colored boxes contain all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box $\pm$ 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond $\pm$ 1.5*IQR. Mean values are represented by black diamonds.*

Quadratic mean diameter

We found that average quadratic mean diameter (QMD) had increased significantly from 14.64 (±0.51) inches to 18.11 (±0.70) inches after treatment. This change represents a 23.70% increase between pre- and post- treatment, a logical outcome considering that QMD is a function of TPA and BAPA, both of which also had significant differences between the treatment groups. This result is also consistent with expectations for a thinning treatment which targets small trees for removal.

Table 15. *Quadratic Mean Diameter (QMD)- mean and standard error (SE) for pre- and post- treatment groups. Significant p-values are bold.*

Quadratic Mean Diameter	**# Plots**	**QMD (inches)** mean (SE)
Pre-treatment	49	14.64 (0.51)
Post-treatment	49	18.11 (0.70)
% Change	-	*+23.7*
F statistic	-	*36.42*
P value	-	***2.216E-07***

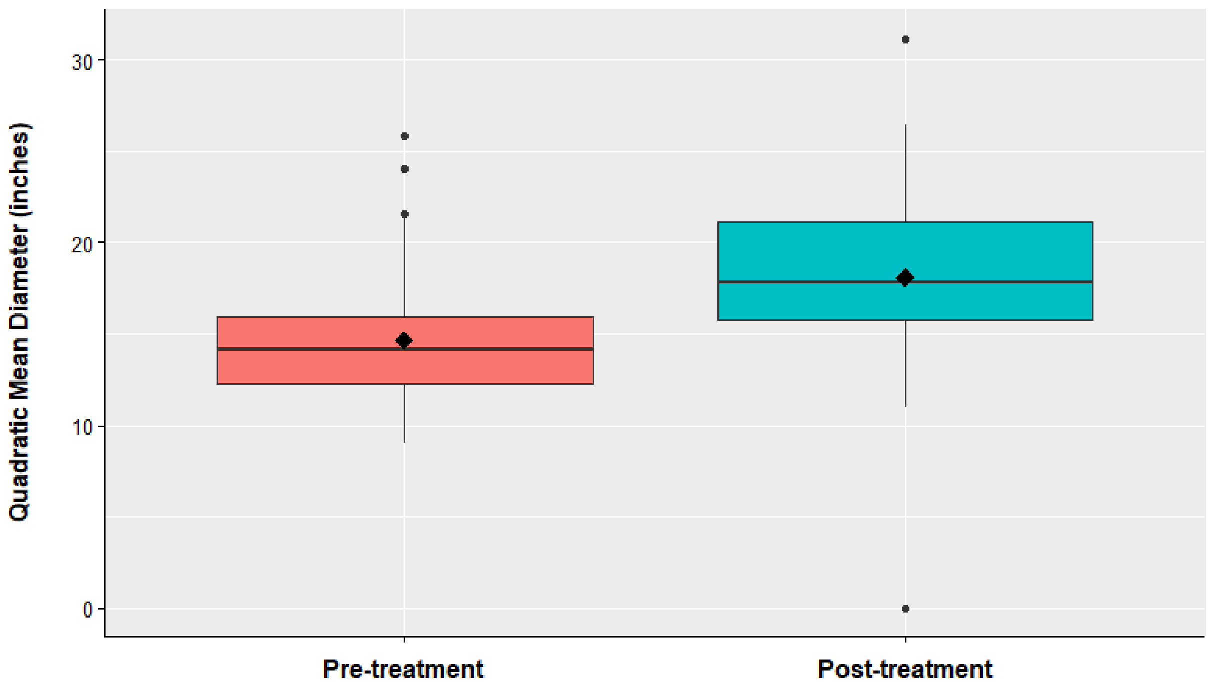

Figure 19. *Quadratic Mean Diameter (QMD)- box plot where the horizontal center line is the median value, the colored boxes contain all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds.*

Codominant tree height

The difference in mean codominant tree height was small (and not statistically significant) between pre- (61.96 ±0.90 ft) and post- treatment (64.73 ±1.15 ft) groups (Table 16, Figure 20). Change in codominant tree height is not a goal of thinning treatment, especially considering that codominant trees are likely in larger diameter classes and would be preferentially left. It is therefore consistent that there would not be a significant difference between the codominant height means of the two treatment groups.

Table 16. *Codominant Tree Height- mean and standard error (SE) for pre- and post- treatment groups. Sample size included. Significant p-values are bold.*

Codominant Tree Height	**# Trees Measured**	**Height (feet)** mean (SE)
Pre-treatment	**144**	61.96 (0.90)
Post-treatment	**140**	64.73 (1.15)
% Change	**-**	-
F statistic	-	*0.42*
P value	-	*0.52*

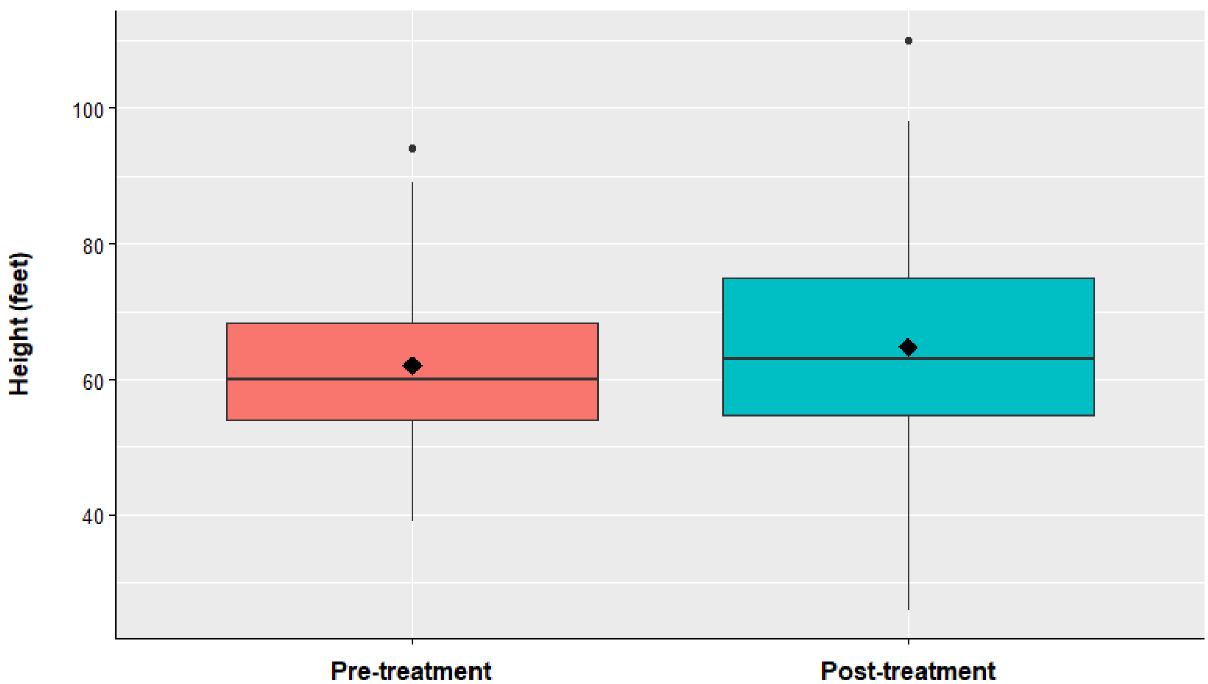

Figure 20. *Codominant Tree Height- box plot where the horizontal center line is the median value, the colored boxes contain all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box ± 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond ± 1.5*IQR. Mean values are represented by black diamonds.*

Crown base height

We found that there was a highly significant increase in crown base height (CBH) between pre- and post-treatment data. Before treatment, mean CBH was 10.03 (+0.66) feet and after treatment it was 88.83% higher at 18.94 (+0.80) feet (Table 17, Figure 21). It is useful to reiterate here that CBH was measured as the mean of the three trees in each plot with the *lowest* CBH. As a result, the pre- and post- treatment means that we report here are not the mean CBH of all trees in the plot or treatment group (values that would likely be much larger), but rather an indicator of the lowest extent of the canopy in a treatment unit. Increased CBH is an expected outcome of thinning treatment, which may confer increased fire resilience.

Table 17. *Crown Base Height (CBH) - mean and standard error (SE) for pre- and post- treatment groups. Sample size included. Significant p-values are bold.*

Crown Base Height	**# Trees Measured**	**CBH (feet)** mean (SE)
Pre-treatment	**144**	10.03 (0.66)
Post-treatment	**139**	18.94 (0.80)
% Change	**-**	*+88.83*
F statistic	-	*64.74*
P value	-	***1.88E-10***

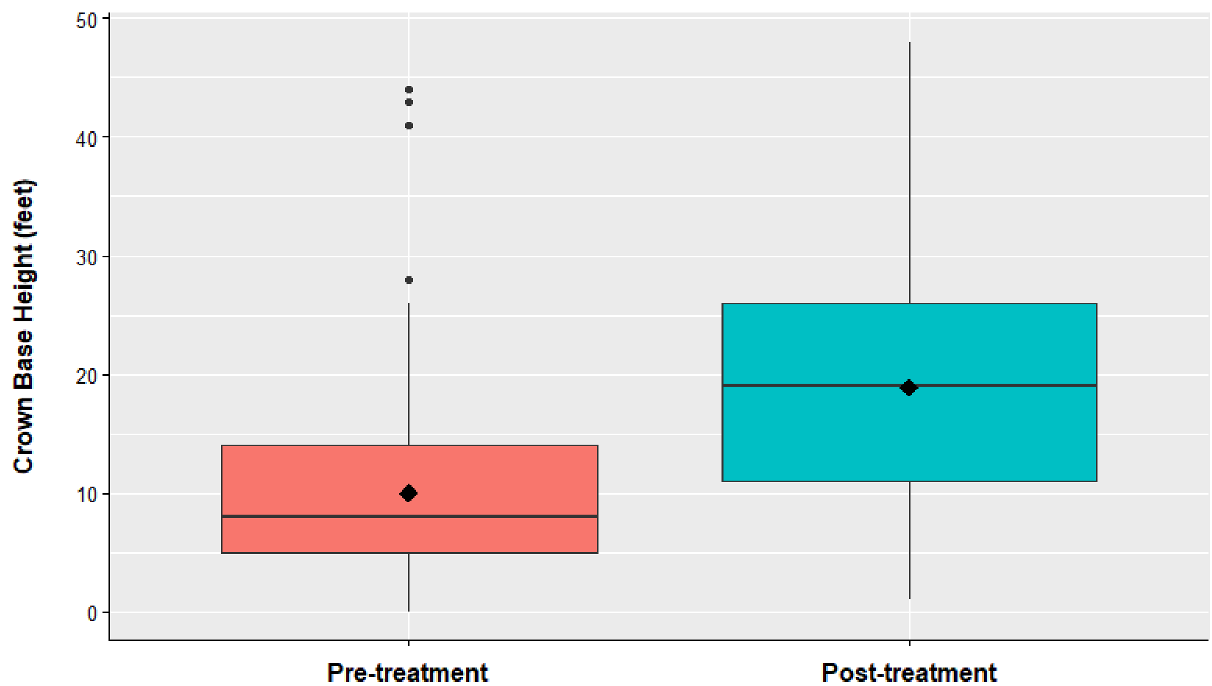

Figure 21. *Crown Base Height (CBH)- box plot where the horizontal center line is the median value, the colored boxes contain all values between the 25th and 75th percentiles (first to third quartiles), the vertical whiskers extend from the box + 1.5 times the inter-quartile range (IQR, difference between the first and third quartiles), and points are outlying values beyond + 1.5*IQR. Mean values are represented by black diamonds.*

Saplings and seedlings

Our results show highly significant decreases in both sapling and seedling density after thinning treatment. Sapling density was reduced by 94.85% from a pre-treatment mean of 348.57 (±138.38)/acre to a post-treatment mean of 17.96 (±9.41)/acre. Seedling density decreased by 60.75% after treatment, from 1674.29 (±424.92)/acre (pre-treatment) to 657.14 (±200.76)/acre (Table 18, Figure 22). Sapling results are in-line with expectations for the outcome of thinning which targets small diameter trees, as all saplings are under 4-inches DBH. Seedlings, especially those only a few years old, are not an intentional target of treatment. The significant decrease in their density may be tied to secondary effects of thinning operations such as soil compaction, or simply the amount of time between operations and post-treatment data collection.

Table 18. Sapling and Seedling Density- means and standard errors (SE) for seedlings per acre and saplings per acre. Significant p-values are bold.

	# Plots	Seedlings/Acre mean (SE)	Saplings/Acre mean (SE)
Pre-treatment	49	1674.29 (424.92)	348.57 (138.38)
Post-treatment	49	657.14 (200.76)	17.96 (9.41)
% Change	-	*-60.75*	*-94.85*
χ^2 statistic	-	*20230*	*7361.1*
P value	-	***2.20E-16***	***2.20E-16***

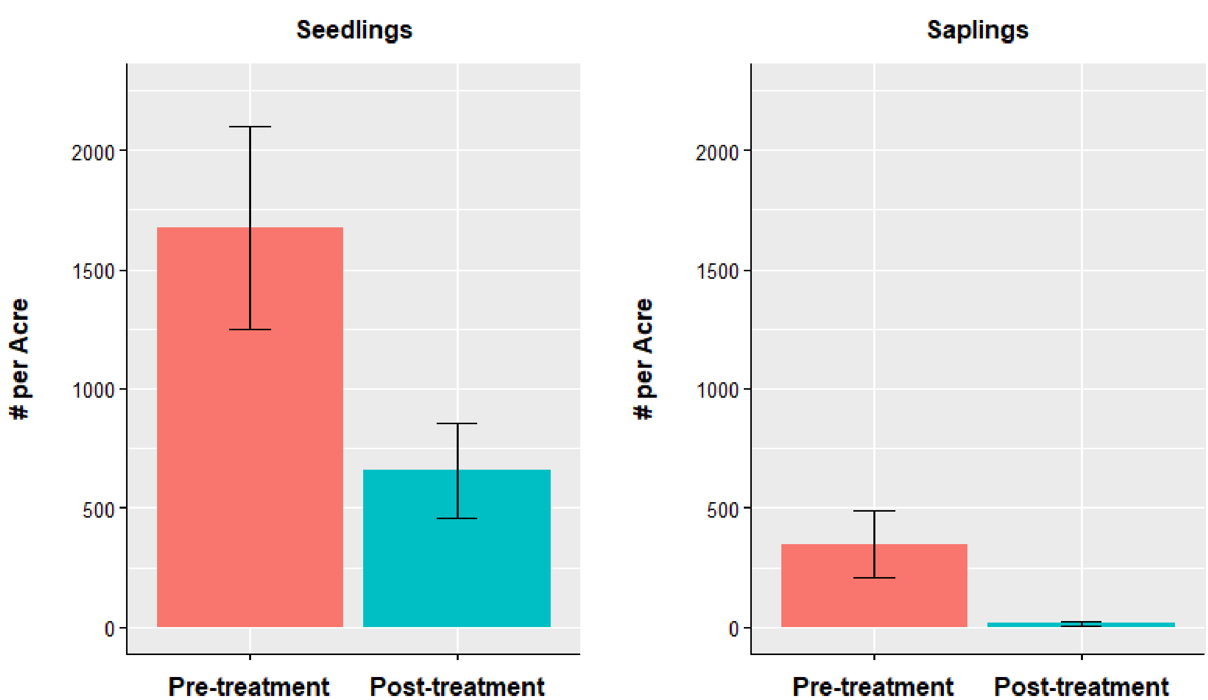

Figure 22. *Seedling and Sapling Density- bar chart where the top of each bar corresponds to the mean count (#) per acre, while the error bars show the standard error (SE) around the mean.*

Understory cover

Of the four vegetation canopy cover categories we analyzed in the understory (grass, forb, shrub, and tree), only two were significantly different between the pre- and post- treatment groups: grass and trees (Table 19). Mean grass cover before treatment was 20.85% (±2.50) and the post-treatment mean was 16.06% (±2.06), a reduction of 22.97%. Tree cover decreased from 2.71% (±1.14) (pre-treatment) to 1.02% (±0.61) (post-treatment), a 62.36% change, though both amounts are very small contributions to total cover. Total understory vegetation canopy cover was not significantly different between pre- (27.86% ±3.05) and post- treatment (24.00% ±2.57) groups. The p-values for the differences in the grass and tree cover analyses are closer to the significance threshold of 0.05 than many of the differences quantified in other analyses in this report, others are not significant. One factor that likely contributes to the 'noise' in this data set is the wide seasonal range of when these data were collected. The field season for rapid plot data collection extends from mid-May to October, which in our study sites comprises both the driest and wettest times of year. There also may be a stronger signal after an increased amount of recovery time (i.e., if post-treatment data is collected and analyzed again in another few years).

Table 19. *Understory Vegetation Canopy Cover- means and standard errors (SE) for percent cover of four categories of vegetation, and total vegetation (sum of all categories). Significant p-values are bold.*

Understory Vegetation Canopy	**% Grass Cover** mean (SE)	**% Forb Cover** mean (SE)	**% Shrub Cover** mean (SE)	**% Tree Cover** mean (SE)	**% Total Vegetation Cover** mean (SE)
Pre-treatment	20.85 (2.50)	4.26 (0.81)	0.04 (0.04)	2.71 (1.14)	27.86 (3.05)
Post-treatment	16.06 (2.06)	6.48 (1.02)	0.44 (0.23)	1.02 (0.61)	24.00 (2.57)
% Change	*-22.97*	*-*	*-*	*-62.36*	*-*
F statistic	*4.96*	*3.24*	*3.72*	*4.71*	*2.10*
P value	***0.03061***	*0.07798*	*0.05979*	***0.03503***	*0.1538*

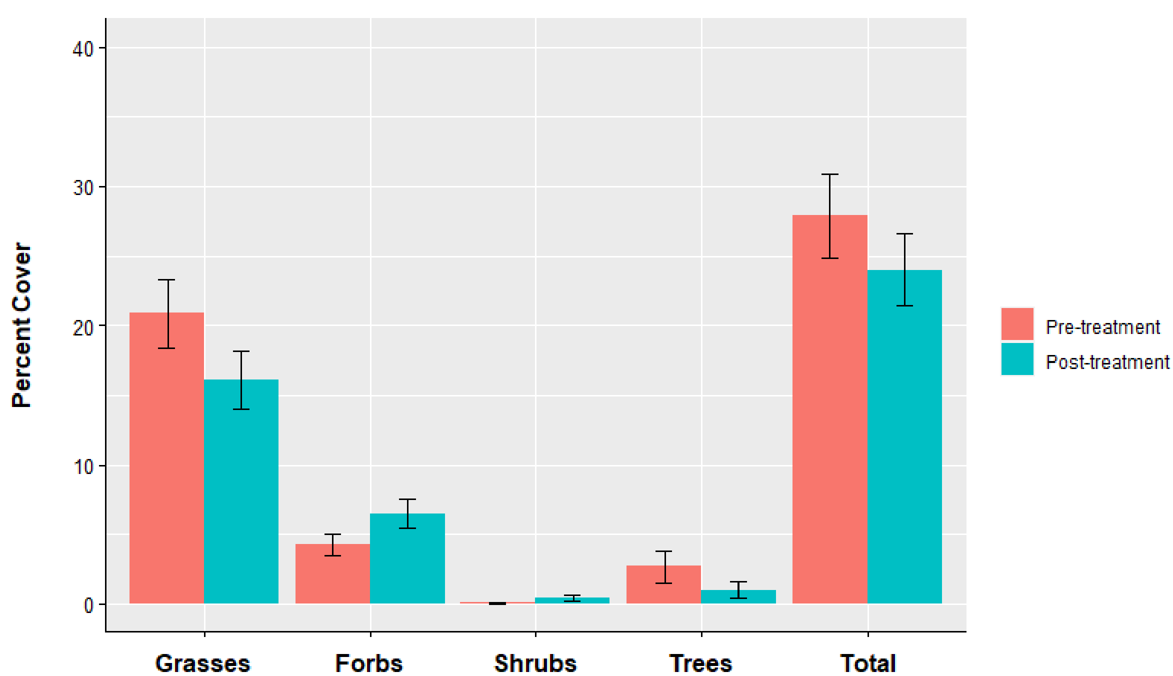

Figure 23. *Understory Vegetation Canopy Cover- bar chart where the top of each bar corresponds to the mean percent cover of each vegetation category, while the error bars show the standard error (SE) around the mean.*

We analyzed ground (substrate) cover in five different categories: bare soil, rock, herbaceous litter, woody debris, and basal vegetation. Between pre- and post- treatment groups, we found significant differences between means for bare soil, rock, and herbaceous litter cover. Bare soil cover increased from 3.82% (±0.92) (pre-treatment) to 13.62% (±2.48) (post-treatment). Rock cover decreased slightly, but significantly, from 7.76% (±0.99) before treatment to 5.46% (±0.80) after. Herbaceous litter cover was 77.77% (±1.57) in the pre-treatment group and was reduced to 68.90% (±2.31) post-treatment. An increase in bare soil cover and decrease in litter is logical following mechanical thinning treatment. Machinery operations, tree removal, and slash burning can all disturb ground cover, reducing or relocating litter and exposing more bare soil. As with vegetation cover, attention to seasonality of data collection and increased time since treatment may clarify these results.

Table 20. *Ground Cover- means and standard errors (SE) for percent cover of four non-vegetative categories of cover, and basal vegetation. Significant p-values are bold.*

Ground Cover	**% Bare Soil Cover** mean (SE)	**% Rock Cover** mean (SE)	**% Herbaceous Litter Cover** mean (SE)	**% Woody Debris Cover** mean (SE)	**% Basal Vegetation Cover** mean (SE)
Pre-treatment	3.82 (0.92)	7.76 (0.99)	77.77 (1.57)	7.23 (1.04)	3.42 (0.77)
Post-treatment	13.62 (2.48)	5.46 (0.80)	68.90 (2.31)	9.14 (1.17)	2.84 (0.55)
% Change	*+256.54*	*-29.64*	*-11.41*	-	-
F statistic	*13.8*	*7.6*	*10.11*	*2.4*	*0.45*
P value	***5.31E-04***	***8.25E-03***	***1.98E-03***	*0.128*	*0.5065*

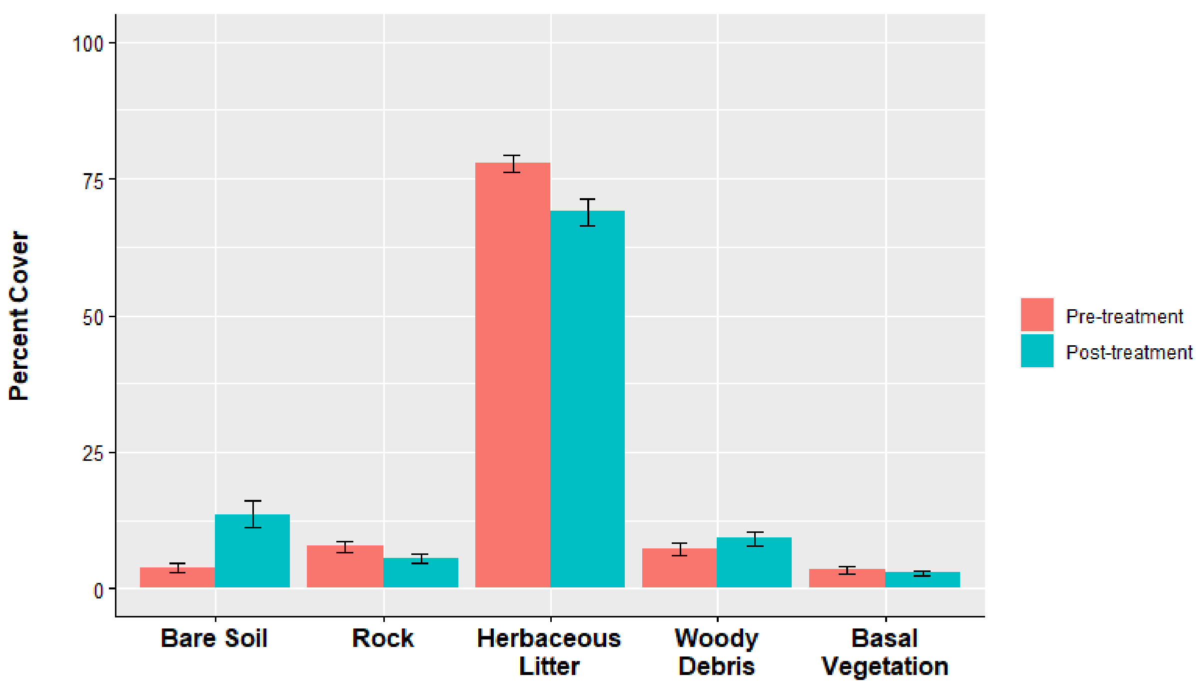

Figure 24. *Ground Cover- bar chart where the top of each bar corresponds to the mean percent cover of each cover category, while the error bars show the standard error (SE) around the mean.*

Disturbance indicators

Soil disturbance

We recorded presence or absence of evidence of soil compaction and soil erosion at each plot. Results show a significant difference between the amount of soil compaction present before and after thinning, and no significant difference in presence of erosion (Table 21, Figure 25). 14.29% of pre-treatment plots had evidence of soil compaction, while 46.94% displayed evidence of compaction after treatment. This increase in compaction is likely due to roads, skid trails, and other physical impacts of thinning operations, especially within 1 – 3 years post treatment.

Table 21. *Soil Erosion and Compaction- percent of plots where presence of each disturbance type was observed. Significant p-values are bold.*

Soil Disturbance	**# Plots**	% plots with **Compaction**	% plots with **Erosion**
Pre-treatment	49	14.29	4.08
Post-treatment	49	46.94	2.04
% Change	-	*228.48*	-
χ^2 statistic	-	*8.99*	*0.3308*
P value	-	***2.71E-03***	*0.5652*

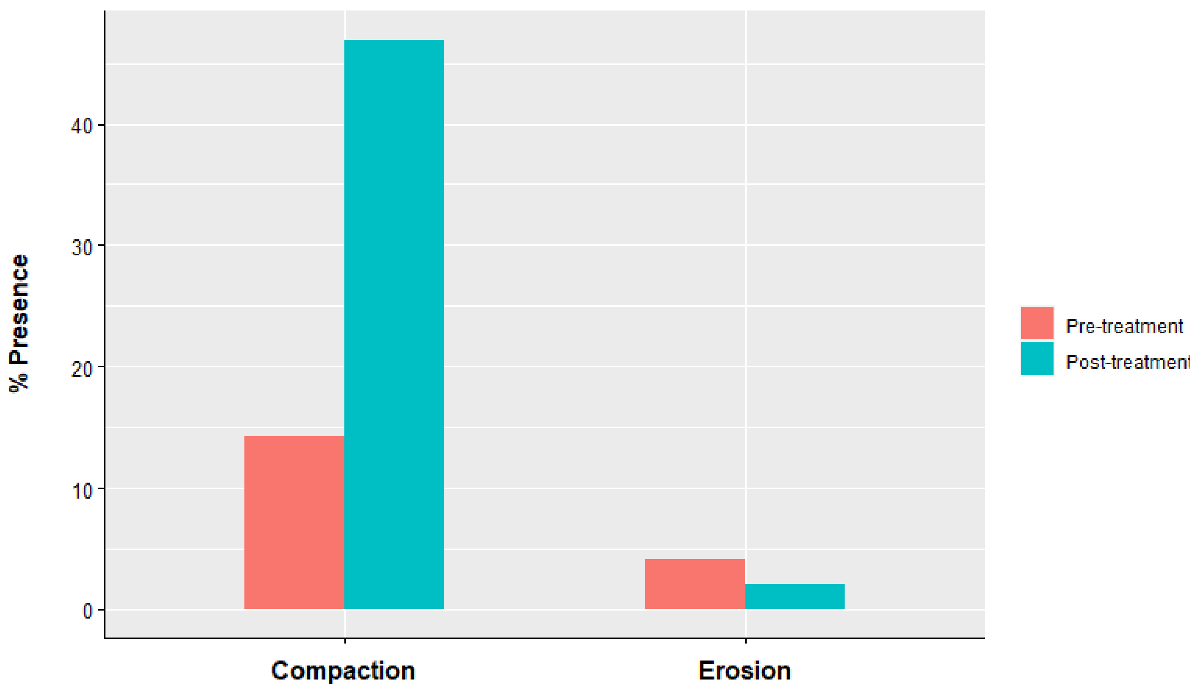

Figure 25. *Soil Erosion and Compaction- bar chart where the top of each bar corresponds to the percent of plots where the presence of each soil disturbance was observed.*

Invasive Species

Of the six types of invasive plant species that we recorded and analyzed, we found a significant increase in presence of three: cheatgrass (*Bromus tectorum*), dalmatian toadflax (*Linaria dalmatica*), and knapweeds (*Centaurea spp.*). Both cheatgrass and knapweeds were absent from the pre-treatment group, and both species increased to 6.12% presence post-treatment. Dalmatian toadflax was the most commonly present invasive species prior to treatment (46.94% presence), and it significantly increased to 67.35% presence after thinning. Russian thistle was not observed pre- or post- treatment. Other thistle species were present in fewer plots after treatment (a non-significant reduction of 32.65% to 18.37%). Observations of other invasive species (namely leafy spurge, *Euphorbia esula*) remained at the same level – 32.65% – before and after treatment (Table 22, Figure 26).

Table 22. *Invasive Species- percent of plots where presence of each invasive species was observed. Significant p-values are bold.*

Invasive Species	**# Plots**	% plots with **Cheatgrass**	% plots with **Dalmatian toadflax**	% plots with **Knapweed**	% plots with **Russian thistle**	% plots with **Other thistle**	% plots with **Other**
Pre-treatment	49	0	46.94	0	0	32.65	32.65
Post-treatment	49	6.12	67.35	6.12	0	18.37	32.65
% Change	**-**	*NA*	*+43.48*	*NA*	-	-	-
χ^2 statistic	-	*24.48*	*5.5391*	*72.3*	-	*2.87*	-
P value	-	***7.506E-07***	***0.0186***	***2.20E-16***	-	*0.09016*	-

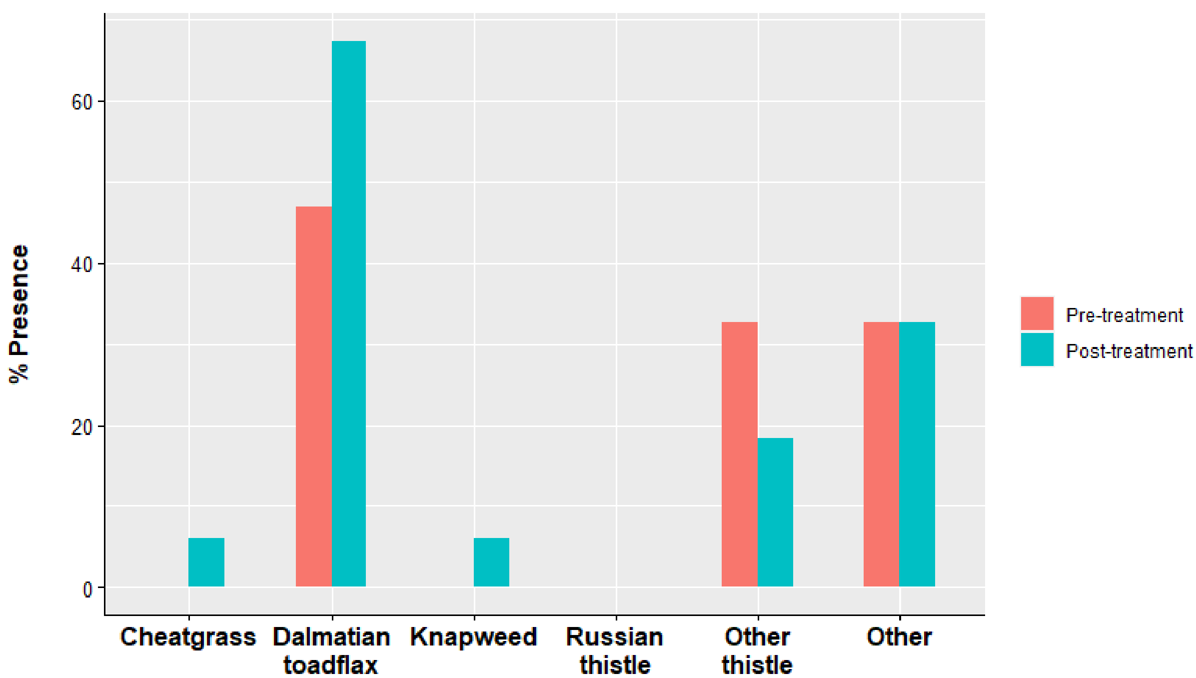

Figure 26. *Invasive Species- bar chart where the top of each bar corresponds to the percent of plots where the presence of each invasive species was observed.*

Recent fire & grazing

We summarized data for presence of two additional disturbance types: recent fire and grazing (Table 23). More evidence of recent fire was recorded in post-treatment plot visits. Presence of both recent fire and grazing were each recorded in one plot before treatment. We did not analyze these data because we know from fire history records maintained by the USFS that this treatment unit did not burn either in a prescribed or wildfire between 2016 and 2021. While charcoal and other evidence of fire is present in some plots, it can be difficult for field crews to accurately determine how 'recent' a fire was. Cattle grazing does not generally occur in the Chimney Springs unit, and so it also may be that scat was misidentified in the single record for grazing presence.

Table 23. *Recent Fire and Grazing- percent of plots where presence of each disturbance type was observed.*

Recent Fire & Grazing	**# Plots**	% plots with **Recent Fire**	% plots with **Grazing**
Pre-treatment	49	2.04	2.04
Post-treatment	49	22.44	0

Wildlife indicators

Squirrel & vole sign

Squirrel sign was present in 63.27% of plots before treatment and 28.57% of plots after treatment, a significant decrease of 54.84%. Squirrels are an indicator species for more dense forest structure, and so it is logical that presence of squirrel sign would decrease when density is reduced via thinning. No evidence of Mogollon voles was observed in any plot pre- or post- treatment.

Table 24. *Squirrel and Vole Sign- percent of plots where presence of each animal sign was observed.*

Squirrel & Vole Sign	**# Plots**	% plots with **Squirrel Sign**	% plots with **Vole Sign**
Pre-treatment	49	63.27	0
Post-treatment	49	28.57	0
% Change	**-**	*-54.84*	**-**
χ^2 statistic	-	*9.34*	-
P value	-	***0.002244***	-

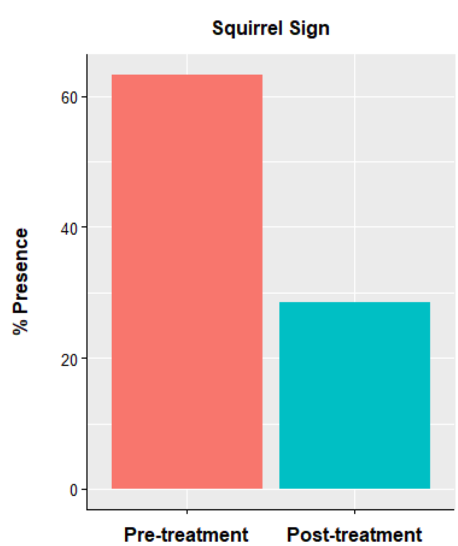

Figure 27. *Squirrel sign- bar chart where the top of each bar corresponds to the percent of plots where the presence of squirrels was observed.*

Logs per acre

The mean number of logs per acre decreased significantly by 33% from 5.82 (±1.19)/acre before thinning to 3.88 (±0.78)/acre after treatment (Table 25, Figure 28).

Table 25. *Logs per Acre- mean and standard error (SE) the number of logs per acre in pre- and post- treatment groups. Significant p-value is bold.*

Logs per Acre	**# Plots**	**Logs/Acre** mean (SE)
Pre-treatment	49	5.82 (1.19)
Post-treatment	49	3.88 (0.78)
% Change	-	*-33.33*
χ^2 ***statistic***	-	*18.74*
P value	-	***1.50E-05***

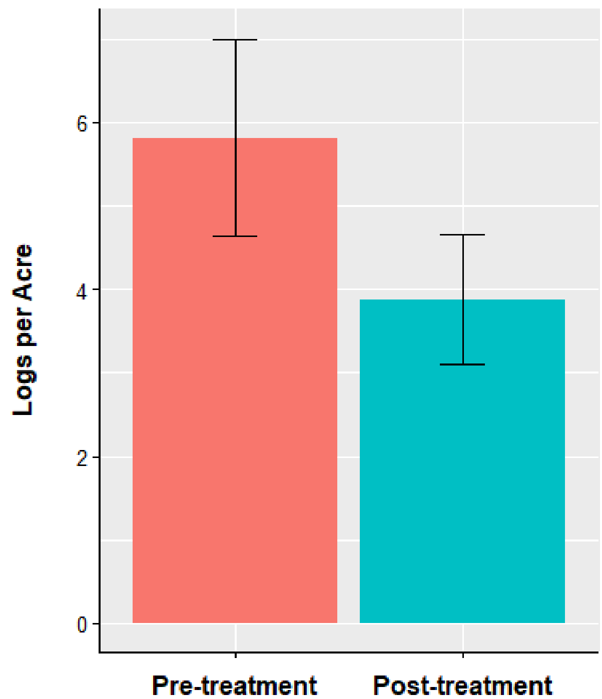

Figure 28. *Logs per Acre- bar chart where the top of each bar corresponds to the mean number of logs per acre, while the error bars show the standard error (SE) around the mean.*

Woody fuels

We summarized fuel loads in fine woody fuels classes (1-hour, 10-hour, and 100-hour) as the percent of total fuels quadrats (four per plot, 196 total in each treatment group) assigned to each volume category (Table 26, Figure 29). This creates a distribution somewhat similar to a diameter class distribution. Changes between pre- and post- treatment appear to be relatively modest. In all three fuels classes, there are decreases in the percentage of quadrats in the 0 tons/acre category and increases in the percentage of quadrats in the 0.13 tons/acre, 0.45 tons/acre, and 3.15 tons/acre categories. Stand estimate was assigned a volume category for 1000+ hour fuels at the plot level, and percentage of plots in each category is summarized. Changes in stand estimate appear modest as well, with slight shifts from the middle category (3-10 tons/acre) to both the upper and lower estimates (<3 tons/acre and >10 tons/acre).

Table 26. *Fine Woody Fuels and Stand Estimate- percent of quadrats (fine woody fuels) or plots (stand estimate) assigned to each volume category.*

1-hour Fuels	**0** tons/acre	**0.13** tons/acre	**0.45** tons/acre	**3.15** tons/acre	**11.25** tons/acre
Pre-treatment	20.41%	64.80%	14.80%	0%	0.00%
Post-treatment	8.16%	65.31%	25.00%	1.53%	0.00%

10-hour Fuels	**0** tons/acre	**0.13** tons/acre	**0.45** tons/acre	**3.15** tons/acre	**18** tons/acre
Pre-treatment	23.47%	50.00%	21.94%	4.59%	0.00%
Post-treatment	7.14%	58.16%	28.57%	6.12%	0.00%

100-hour Fuels	**0** tons/acre	**0.13** tons/acre	**0.45** tons/acre	**3.15** tons/acre	**24.75** tons/acre
Pre-treatment	45.92%	17.86%	25.51%	9.69%	1.02%
Post-treatment	36.73%	28.06%	25.51%	8.67%	1.02%

Stand Estimate	**<3** tons/acre	**3-10** tons/acre	**>10** tons/acre
Pre-treatment	30.61%	57.14%	12.24%
Post-treatment	38.88%	42.86%	18.37%

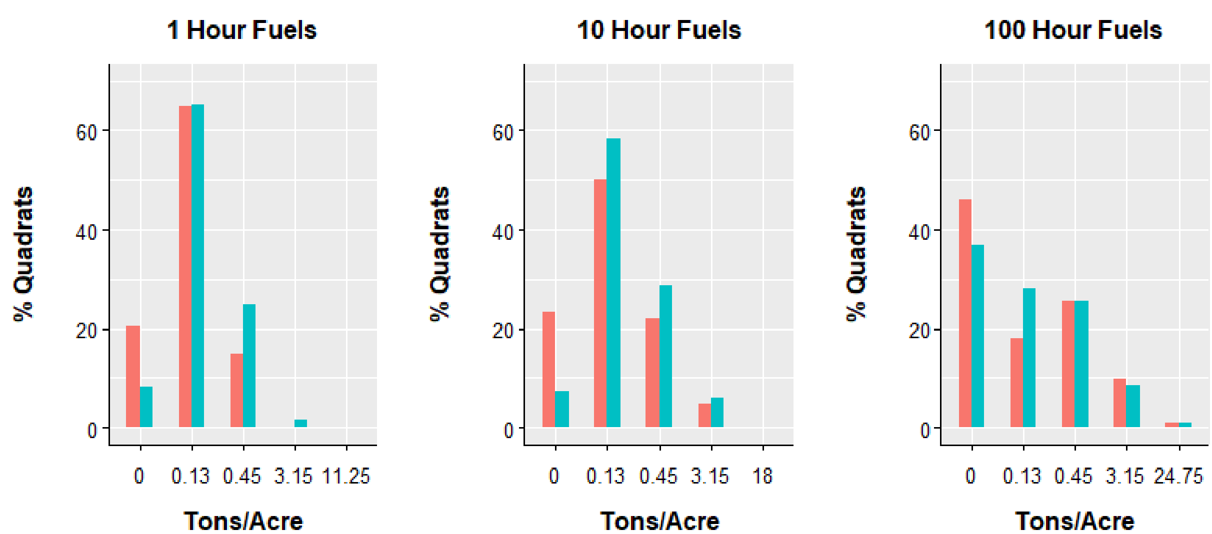

Figure 29. *Fine Woody Fuels- percent of quadrants assigned to each volume category for 1-, 10-, and 100- hour fuels classes.*

Conclusions & Recommendations

Rapid plot monitoring field data collected over the past five years has been summarized and analyzed in this report to address two objectives. First, to describe the pre-treatment condition of ponderosa pine forest overstory across the first 4FRI NEPA analysis area, and second, to determine the effects of restoration treatment by comparing multiple indicators pre-treatment and post-treatment in a case study at the Chimney Springs treatment unit.

Results from the summary of pre-treatment overstory conditions are largely consistent with expectations of unrestored ponderosa pine forests in northern Arizona. Legacies of logging, fire suppression, and grazing have led to increased density and a shift toward younger and more even-aged stands (Reynolds et al. 2013). While the main purpose of these data is to compare them to post-treatment data collected after mechanical thinning occurs, we do see some interesting spatial patterns emerge (e.g., in tree species composition) that may be of interest in future analyses.

Analyses comparing pre- and post- treatment data from Chimney Springs provide insight into the outcomes of thinning treatment on a broad suite of indicators related to forest structure, composition, and function. Significant differences detected between data collected before and after treatment generally conform with the goals of forest restoration (Reynolds et al. 2013). Across the treatment unit, we observed lower tree density and more distribution across diameter classes (but overall increase in average tree size). We also documented some increased evidence of disturbance (e.g., soil compaction, invasive species), and mixed responses in understory vegetation and ground cover. Revisiting these plots again after a few more years of recovery have passed would provide further insight into longer-term outcomes of restoration on non-tree variables.

Our primary recommendation is that the MPMB review these results and determine whether all variables in the protocol are useful in the way that they are currently being measured, recorded, stored in the database, and analyzed. This is a rapid plot monitoring protocol, and efficiency of data collection and utility of results are paramount. If there are analysis results that are not helpful in monitoring treatment effectiveness, informing adaptive management, or providing key information to stakeholders, then spending time and resources collecting and analyzing those data may not be worthwhile. Conversely, if there are results that are unclear or would require more detail to be useful, then it would be prudent to review options for adjusting the field protocol, even if more resources are required to ensure meaningful results.

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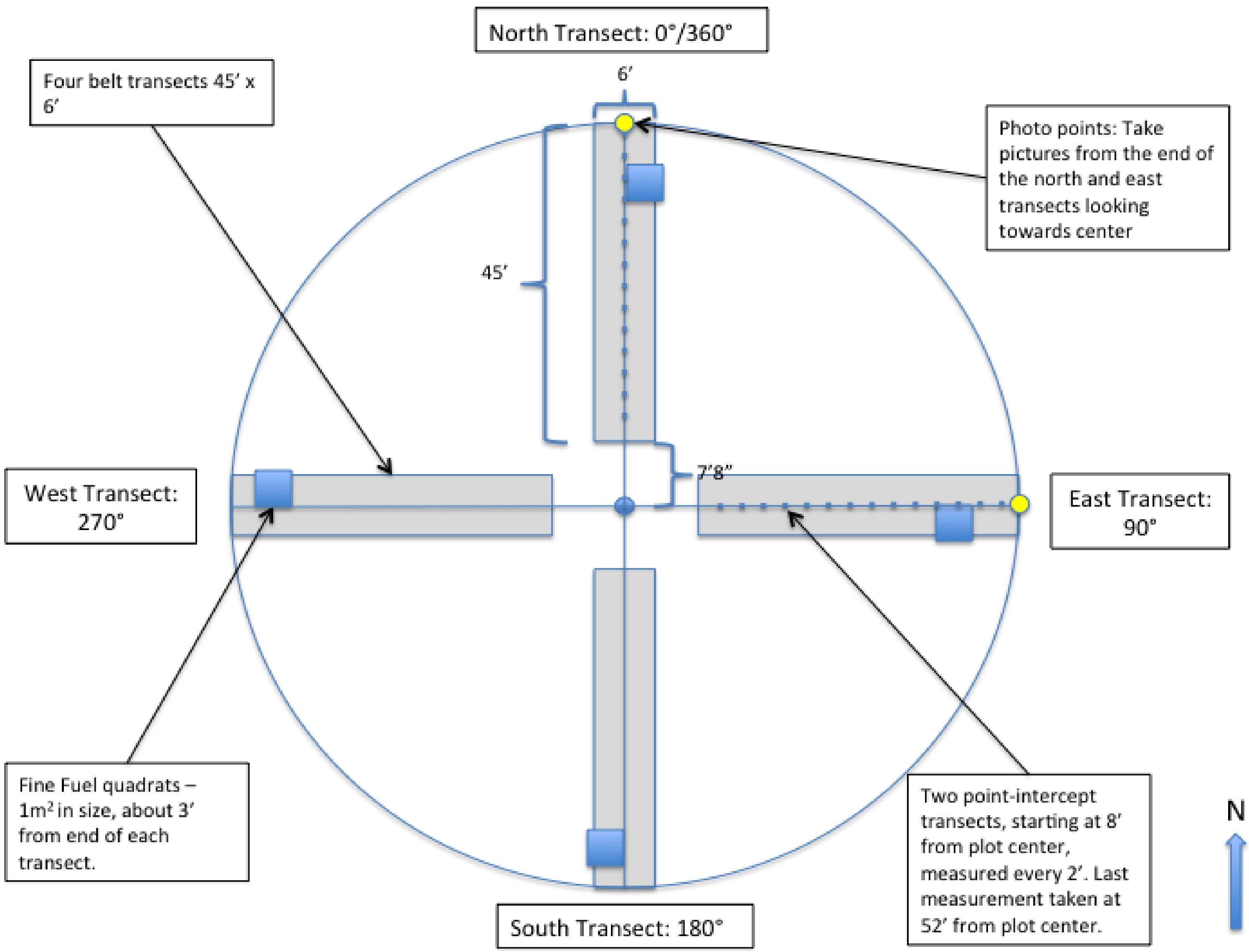
Appendix A: Data Collection Protocol and Data Sheets

4FRI Rapid Plot Protocol

Equipment List:

- **Trimble** GPS Unit (for marking plots and fine-scale navigation to plots)
    - **Garmin** GPS unit **OR** smartphone with the **Avenza** app (for coarse navigation to plots)
- **Compass** (with declination adjustment)
- **U-stakes**
- **Hammer**
- **Tree tags** (aluminum)
- **Nails** (aluminum)
- **DBH tape**(s) (English units)
- 3 **transect tapes** (200 ft. - one can be shorter, feet and inches – not 10ths of feet)
- **Clinometer** OR **laser rangefinder**
- **Camera** plus white erase board & marker **OR smartphone** with camera and annotation capability
- **Chaining pins** (6)
- **Flagging tape**
- **1m^2 quadrat** (4 1m sections of PVC and four elbows)
- **Marking chalk**
- **Clipboard** and **datasheets**

Plot Diagram



1. Navigate to plot using Garmin GPS or smartphone with Avenza. If plot is unsafe or unsuitable for measurement (e.g., falls within a campsite or road), notify the project manager and move on to the next plot.
2. Set up plot (52’8” radius circle, .2 acre)
    a. Lay out two tapes to 105’4”, one N-S, one E-W (tapes cross at plot center at the 52’8” mark). Set “0” end of the tape on the North end and East end of the transects.
    b. Rebar or wire stake at plot center with tag with project area (unit) name, plot #, and date
3. Fill out top of data sheet
    a. Date with year, crew last names or initials, project area, and plot #
    b. For establishing new plots or re-establishing post-treatment plot centers that could not be located:
        * Set up Trimble GPS at plot center. From pen TerraSync and select “Data” from top drop-down.
            1. When starting in a new project area or switching project areas (e.g., moving from Clark to Clover), create a new data file by selecting “New” in second drop-down menu. Leave file type as “Rover”, location as “Default”, and dictionary name as “GenericDictionary”. Name the file using the following format: four-digit year (2021) followed by two-digit month (05 for May), two digit day (12 for the 12th day), and project area name (A1South, Clark, Clover, ParksWest, or ChimSpgs) with no spaces. Ex: 20210512Clark
                a. Click “Create” and then “Ok” for “Confirm Antenna Height” screen
            2. Once file has been created for the day and/or project area, for each point you’ll be collecting, create a new “Generic Point”: While still in the “Data” view from the top drop-down, click “Generic Point” to start collecting “positions”. Enter the plot number into the “Comment” field, set GPS on top of the plot center marker and collect at least 200 “positions” for that point as shown by the red bullseye in the upper right-hand corner (example shows 9 positions collected)

            3. Once you have collected at least 200 “positions”, click “Done” to close that point and move onto the next one.
        * Datum: NAD83, do not change.

c. Reference trees – pick the two (2) largest, closest trees to plot center (ideally in two different quadrants of the plot)
    * Record species, DBH in inches (round to the tenth), distance in feet and inches, & azimuth from tree to plot center on data sheet
    * Record ref tree #, project area (unit) & plot #, distance in feet and inches, & azimuth from tree to plot center on reference tree tags
    * Tag trees at base facing plot center using nails and hammer

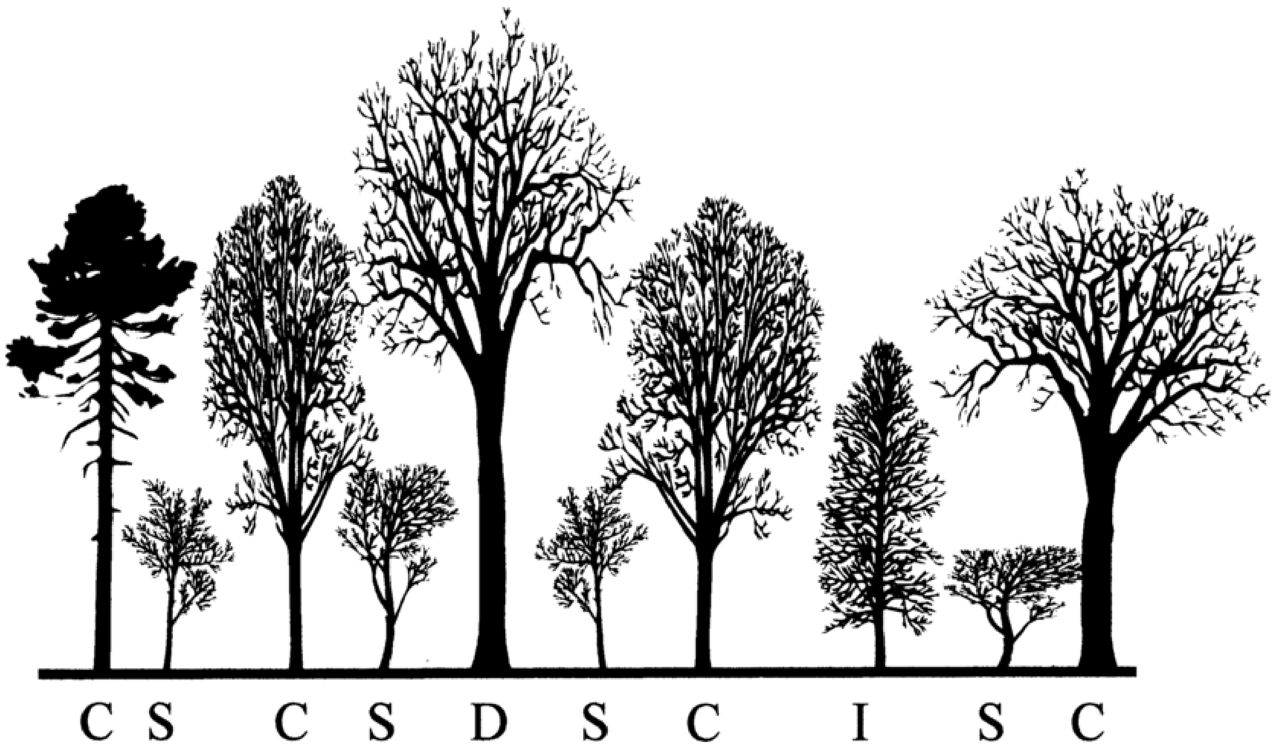
4. Take TWO pictures – one from north to plot center, one from east to plot center, photos should 1) have the horizon line dividing the top and bottom halves, 2) have the transect tape dividing the left and right halves, 3) be free of other equipment and people.
    a. Record plot number, project area (unit) and direction (N or E), either in photo annotation (on smartphone) or on white board (digital camera) in pictures.
    b. Record photo numbers (digital camera) or phone owner on data sheet.
5. Tree Sampling
    a. Height trees: Begin by using the clinometer or rangefinder to measure the height of 3 co-dominant trees (average large trees). Tag trees with H1, H2, H3 and the corresponding height measurement at breast height, facing plot center. Record species, DBH, and heights on first three lines of data sheet.
    b. Crown-base height trees: Use measuring tape, arm, or clinometer to measure CBH of 3 trees (>4" DBH) with lowest canopy height. CBH is at the lowest piece of live vegetation on the lowest branch. These trees are NOT tagged. Record species, DBH, and CBH on lines 4-6 of data sheet
        * NOTE: if a height tree is also a CBH tree, use one line on the data sheet, and record both height and CBH for that tree
    c. Tree list: Use logger's tape to measure DBH of every remaining tree (must be >4" DBH) to the nearest tenth of an inch. Record species, DBH, and live/dead. Start in NE quadrant and move clockwise around the plot.
        * Trees on plot edge are 'in' if the center of the tree is 52'8" from plot center.
        * If a tree forks below BH, measure and record DBH as two separate trees. If forks above BH, measure as one tree.
        * For branching species (e.g., junipers and oaks), if a tree has multiple stems emerging from the base, do not measure diameter at breast height. Instead, measure and calculate the diameter at root collar (DRC). For trees with more than 4 stems, identify the four largest stems, and measure their diameters at a location near the ground that is representative of the base girth of the stem (e.g., not on a bulge). If a tree has 2 or 3 stems emerging from the base, measure both or all of them using the same guidelines. In the field, calculate DRC by squaring each diameter, summing them together, and taking the square root of that value. If the calculated DRC does not exceed 4", do not record the individual as a tree in the tree data. If the DRC does exceed 4", record the DRC in the DBH column in the following format: (#stems)(DRC)

6. Seedlings and saplings: Count number of all live seedlings (trees <4.5’ tall) and saplings (trees >4.5’ tall but <4”DBH) in the four 6’ x 45’ belt transects.
    - ∗ If seedlings of a species are too numerous to count in an efficient way (>50 in a small area), stop counting individually and estimate the total number in the plot to the nearest 50.
7. Ground cover sampling (line-point intercept): Use the two established transects, one NS and one EW. Sampling beings at the end of the tape 1 foot mark and proceed to the 45-foot mark (total of 23 points on each transect).
    a. Record functional group/life form every 2 ft, starting from tallest to shortest.
        - ∗ Measure all herbaceous plants, shrubs, and trees beginning at 4’ above ground level.
    b. Record understory canopy cover measurements and ground cover measurements separately. Don’t double count functional groups within the canopy cover measurements, even if there are two of the same type at one point.
        - ∗ Acceptable ground cover types are: bare ground (B), rock (R), litter (L), woody debris (W), basal graminoid (G), basal forb (F), basal tree (T), basal shrub (S)
        - ∗ Litter includes pine needles, leaves, and undecomposed pieces of vegetation no longer attached to a plant. Must be < 5mm in diameter (roughly the size of a pencil)
        - ∗ Woody debris is litter > 5mm in diameter (roughly the size of a pencil)
        - ∗ Rocks must be > 5mm diameter (roughly the size of a pencil eraser)
8. Fuels
    a. Fine fuels: Place 1m^2 PVC quadrat 3 feet from the end of each transect. Estimate fine woody fuels (1hr, 10hr, and 100hr) using the provided picture guides. Identify the fuel load that matches the picture for each size class and record the value. This is an assessment of what is visible, you do not need to dig up the quadrat area or move woody materials.
        - ∗ Pine needles and pinecones are litter, not woody fuel
        - ∗ Record 0 if no fuels are present in any of the fuel categories
    b. Woody fuel tonnage: Estimate coarse woody fuel tonnage using the provided pictures. Consider downed woody debris both inside and outside the plot (all that you can see, selection should characterize the stand). Indicate one of three woody fuel categories of tons/acre.
    c. Log tally: Count all large logs in the plot. To qualify, at least 8’ of the log must lie in the plot, and midpoint of the portion of the log lying in the plot must be greater than 12” in diameter.
9. Disturbance sampling: Count number of plot quadrants in which each disturbance occurs – values recorded on data sheet can be 0, 1, 2, 3, or 4
    a. Invasive species (see invasive species guide, record species)
    b. Soil disturbance (erosion, or compaction (trails, roads, bare areas > 1ft^2))
    c. Grazing (cow pies)

    d. Recent fire (do not note evidence of old fire, such as old fire scars)

10. Small mammals: Look across entire plot, record Y for presence of sign, N for absence of sign
    - Vole sign (runways, grass clippings, or droppings)
    - Squirrel sign (eaten cones, bud clippings, or stripped twigs)
11. Record coordinates of averaged waypoint from Trimble as latitude and longitude -- degrees, minutes, seconds.

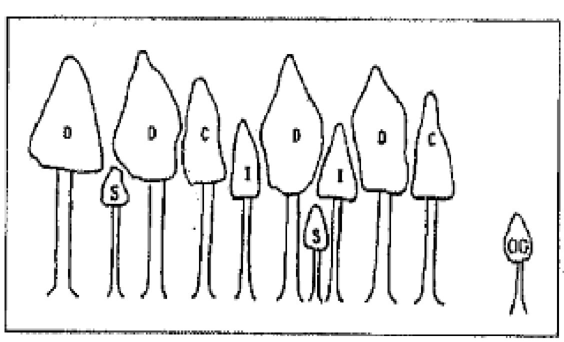
Codominant tree guidance:



Classifications: D-dominant; C-codominant; I-intermediate; S-suppressed

Crown class is a qualitative measure of a tree’s position in the canopy relative to its neighbors. The upper canopy of a forest is composed of dominant and codominant trees (D&C). Upper canopy trees have well- developed crowns that receive direct sunlight from above and partly on the side. Intermediate and suppressed trees (I&S) form the lower canopy. Intermediate trees only receive direct sunlight from above and not on the sides. Suppressed trees are found under the other crown classes and receive no direct sunlight, except for occasional sunflecks.

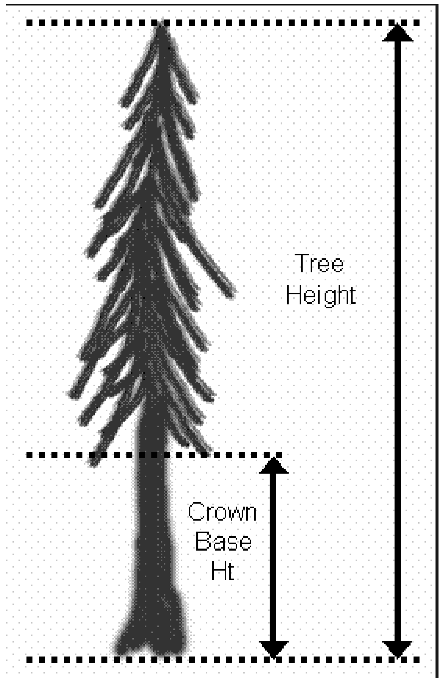
Ward, Jeffrey & Anagnostakis, S. & Ferrandino, Francis. (2006). Stand dynamics in Connecticut hardwood forests: the old series plots (1927-1997).



Crown Position Classes: D = dominant, C = codominant, I = intermediate, S = suppressed, OG = open–grown.

The dominance of a tree refers to the position of its crown relative to other trees in the canopy. Dominant trees have relatively large crowns and are taller than most other trees in the stand. Co-dominant trees make up the general canopy level.

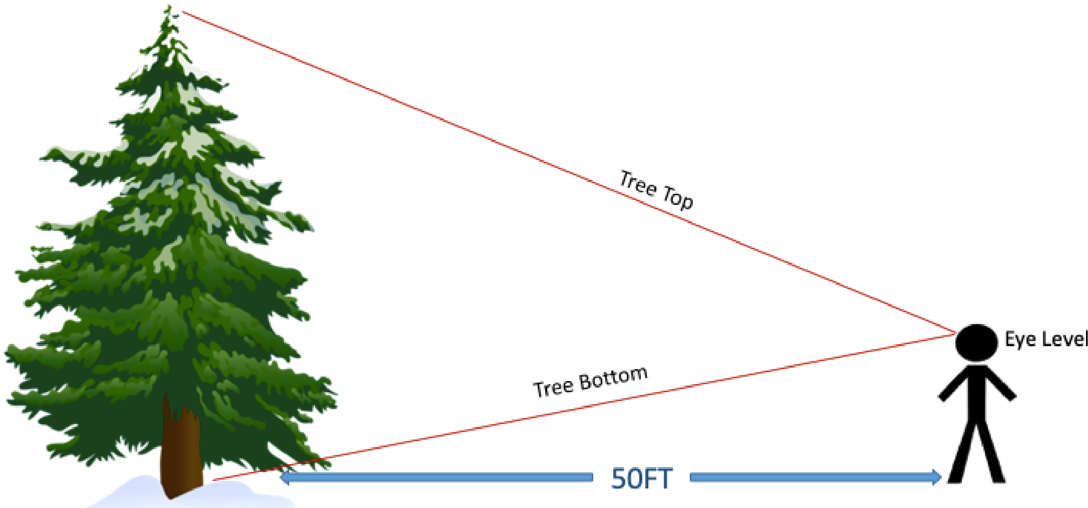
Crown base height guidance:



Crown base height is the lowest height above the ground on an individual tree to the starting point by which there is canopy that can sufficiently fuel a fire vertically. Crown base height is represented by:

- If the lowest branches and foliage span more than 90° around the trunk
- If the lowest branches extend from two separate but adjacent points
- If the lowest branches extend from two separate and opposite points
- **NOT** if the lowest branches and foliage do not span more than 90° around the trunk

Tree height with clinometer:

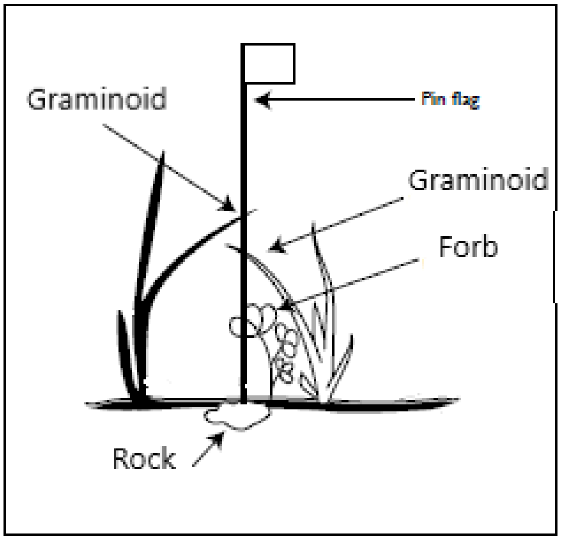


$$\text{Tree Height} = \frac{\text{Tree Top} + \text{Tree Bottom}}{2}$$

Clinometer guidance:

1. Walk 50ft from the base of the tree and turn around to face it.
2. Look through the clinometer with one eye and look at the tree with the other, then line the crosshair on the scales so that they both read 0.
3. Point the clinometer at the top of the tree and record the number on the right hand scale that corresponds to your line of sight of the top of the tree.
4. Without moving your head, point the clinometer at the base of the tree and record the corresponding value from the right-hand scale.
5. Add the absolute values of the two values together and then divide by 2 to get the height of the tree in feet.
6. If you are standing on a slope below the tree, then subtract the value from the bottom of the tree from the value at the top and divide by 2.

Line-point Intercept:



Point I

For this example, you would record:

G, F, R on the data sheet

Growth forms & ground cover:

Graminoid = G
Grasses and grass like plants such as sedges and rushes. Sedges have edges on their stem. Rushes are round stemmed. And grasses have jointed stems down to the ground.

Forb = F
Any non-woody flowering plant that is not a grass. Forbs are broad-leafed, non-woody plants with net like veins in the leaves. Stems die back to the base of the plant each year.

Shrub = S
A woody plant which is smaller than a tree and has several main stems arising at or near the ground. Aboveground stems remain alive during the winter.

Tree = T
A woody perennial plant, typically having a single stem or trunk bearing lateral branches at some distance from the ground.

Bare Soil = B
An area of ground that is bare and has no plants growing on it.

Woody Debris = W
Pinecones and large sticks. Typically material from trees or shrubs like branches and roots.

Rock = R
Must be >5mm diameter (about the size of a pencil eraser)

Moss/Lichen = M
An often green colored organism that can be found growing on rocks and trees.

Litter = L
Leaves, pine needles, dead plant materials, sticks. A decomposing material, but recognizable leaves and other debris that form a layer on top of the soil.

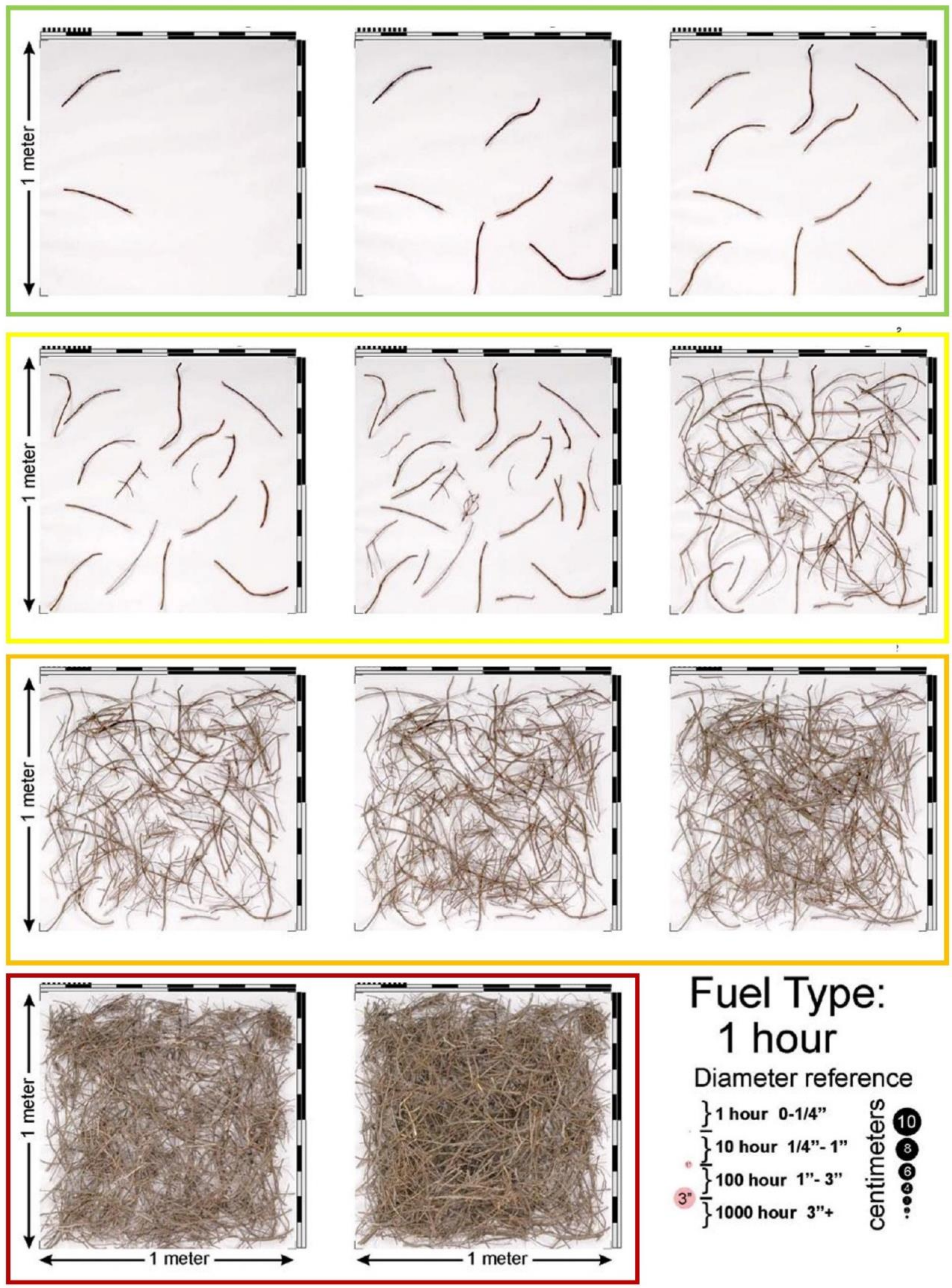
1 hour

0.13 tons/acre

0.45 tons/acre

3.15 tons/acre

11.25 tons/acre



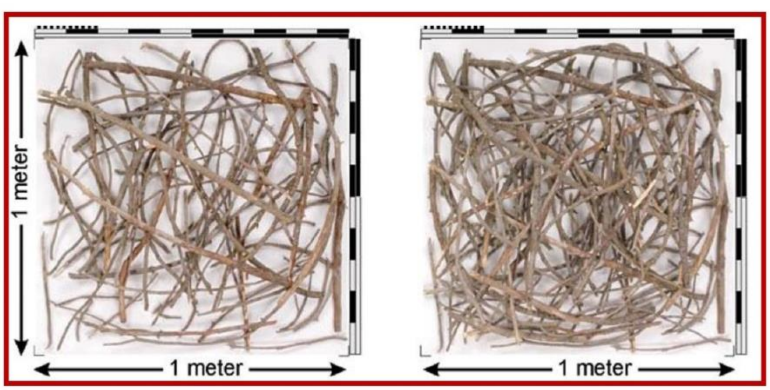
10 hour

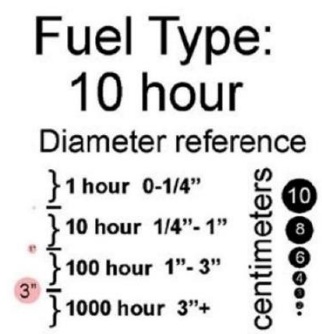
0.13
tons/acre

0.45
tons/acre

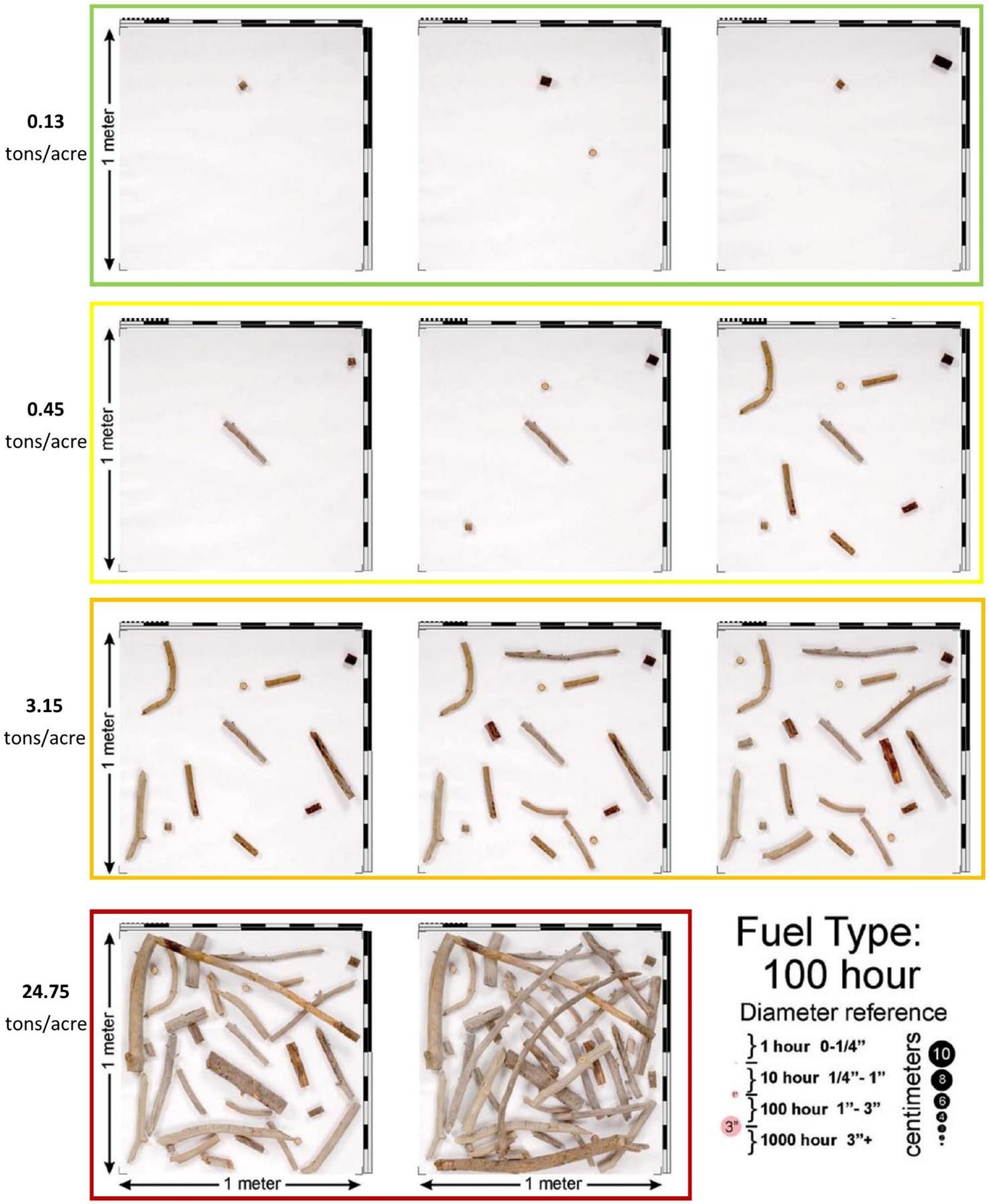
3.15
tons/acre

18
tons/acre





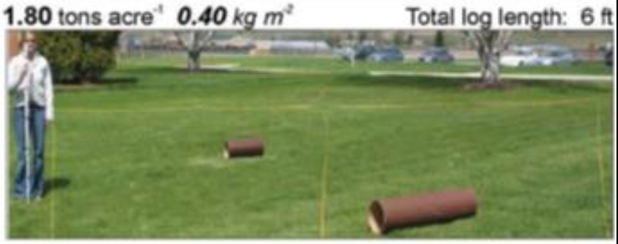
100 hour


0.13
tons/acre
0.45
tons/acre
3.15
tons/acre
24.75
tons/acre
1 meter
Fuel Type:
100 hour
Diameter reference
1 hour 0-1/4"
10 hour 1/4"- 1"
100 hour 1"- 3"
1000 hour 3"+
3"
centimeters
10
8
6
4

< 3 Tons/ Acre

1.80 tons acre^{-1} ***0.40*** *kg m^{-2}* Total log length: 18 feet

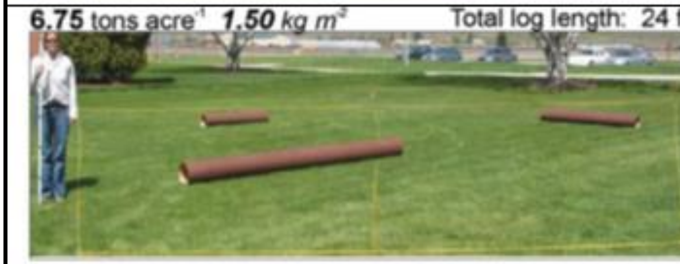
1.80 tons acre^{-1} ***0.40*** *kg m^{-2}* Total log length: 6 ft



3 – 10 Tons/ Acre

6.75 tons acre^{-1} ***1.50*** *kg m^{-2}* Total log length: 66 ft

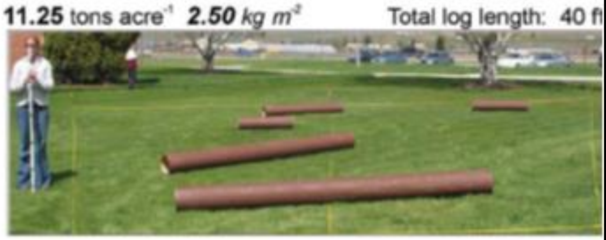
6.75 tons acre^{-1} ***1.50*** *kg m^{-2}* Total log length: 24 ft



>10 Tons/ Acre

11.25 tons acre^{-1} ***2.50*** *kg m^{-2}* Total log length: 110 ft

11.25 tons acre^{-1} ***2.50*** *kg m^{-2}* Total log length: 40 ft



4FRI rapid plot worksheet

Project and plot #: Date: Crew: 5/12/21

Lat: Long:

Checklist	
◯ Tag & GPS point plot center	
◯ Plot photos – with project name and plot #, direction	
◯ Ref trees (2) – Dist, azimuth, DBH, tag @ stump height	
◯ Tree heights (3, tag at BH), CBH (3)	
◯ Measure trees	
◯ Seedling/sapling transects	
◯ Vegetation & ground cover transects	
◯ Estimate fuels (quadrats (4), woody fuel tonnage)	
◯ Log count	
◯ Invasives	
Species	Quadrants
Russian Thistle	
Other Thistle	
Cheatgrass	
Knapweed Spp	
Dalmation Toadflax	
Other	
◯ Soil disturbance	
Erosion	
Compaction	
◯ Grazing	
◯ Recent fire	
◯ Small mammal	
Squirrel	Y or N
Vole	Y or N

Woody Fuels				
	1 hr	10 hr	100 hr	stand
N				< 3
E				3-10
S				> 10
W				

Log count:

Seedlings (< DBH)		Saplings (Up to 4" DBH)	
Sp.	Total Live	Sp.	Total Live

N-S Vegetation Transect						E-W Vegetation Transect					
Foot	Vegetation				Grnd	Foot	Vegetation				Grnd
1						1					
3						3					
5						5					
7						7					
9						9					
11						11					
13						13					
15						15					
17						17					
19						19					
21						21					
23						23					
25						25					
27						27					
29						29					
31						31					
33						33					
35						35					
37						37					
39						39					
41						41					
43						43					
45						45					

G = graminoid; F = forb; S = shrub; T = tree; B = bare soil; W = woody debris > 5mm; R = rock > 5mm; M = moss/lichen; L = litter

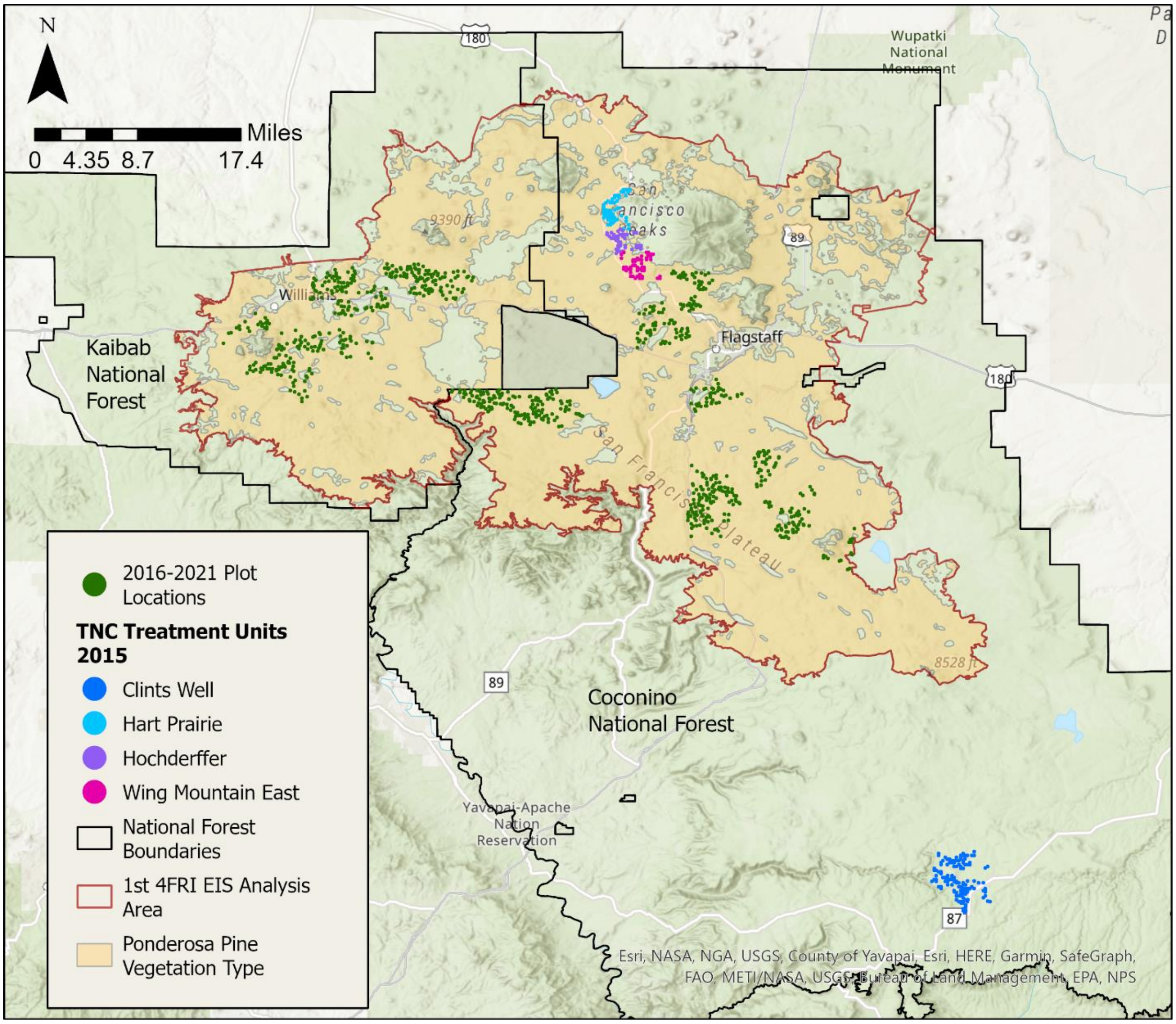
Ref tree 1	new?	Ref tree 2	new?
Dist:	Spp:	Dist:	Spp:
Azi:	DBH:	Azi:	DBH:

Project and plot #:			Date:		
Tree Data (Live and dead trees > 4" DBH)					
Tree #	**Species**	**DBH (in.)**	**Status (L/D)**	**Height (ft)**	**CBH (ft)**
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					
25					
26					
27					
28					
29					
30					
31					
32					
33					
34					
35					
36					
37					
38					
39					
40					

Status: L = live (at least one green leaf persists), D = dead (no green leaves remain)

Appendix B: TNC Rapid Plot Monitoring 2015

Treatment Unit	Year(s) Collected	Pre-treatment Plots
Clints Well	2015	128
Hart Prairie	2015	63
Hochderffer	2015	42
Wing Mountain East	2015	54
Total		**287**



Appendix C: Diameter Class and Species Distribution Tables

4-inch Diameter Class Distribution: Live Trees Per Acre

Treatment Unit (# plots)	**4 - 8 in** mean (SE)	**8 - 12 in** mean (SE)	**12 - 16 in** mean (SE)	**16 - 20 in** mean (SE)	**20 - 24 in** mean (SE)	**24 - 28 in** mean (SE)	**28 - 32 in** mean (SE)	**32 - 36 in** mean (SE)	**36 - 40 in** mean (SE)
A1 North (14)	30.36 (11.16)	40.36 (14.64)	23.93 (3.71)	16.07 (2.52)	5.00 (1.28)	3.93 (1.07)	0 (0)	0 (0)	0 (0)
A1 South (47)	41.60 (10.21)	54.47 (9.55)	28.40 (2.79)	13.09 (1.86)	3.51 (0.94)	1.49 (0.43)	0.53 (0.23)	0 (0)	0 (0)
Beacon (36)	30.69 (6.17)	22.78 (4.43)	24.44 (3.41)	18.47 (2.71)	7.64 (1.04)	2.08 (0.54)	0.56 (0.33)	0.42 (0.23)	0.28 (0.19)
Bootleg (29)	96.72 (12.78)	61.03 (6.09)	38.10 (4.03)	18.79 (2.86)	3.79 (1.21)	1.03 (0.63)	0.17 (0.17)	0 (0)	0 (0)
Chimney Springs (58)	37.24 (7.51)	42.93 (5.39)	31.72 (2.73)	15.60 (1.71)	7.50 (1.12)	2.07 (0.48)	0.86 (0.30)	0.17 (0.12)	0 (0)
Clark (34)	65.74 (11.27)	52.06 (5.67)	45.44 (4.58)	21.32 (2.45)	4.85 (1.07)	2.35 (0.68)	0.88 (0.33)	0.15 (0.15)	0.15 (0.15)
Cloverdog (69)	56.96 (5.98)	51.30 (4.17)	31.88 (2.54)	13.84 (1.49)	5.58 (0.78)	1.81 (0.37)	0.43 (0.20)	0.22 (0.12)	0.14 (0.1)
Cougar (10)	48.50 (16.62)	33.00 (13.99)	24.50 (10.26)	7.00 (3.74)	5.00 (1.97)	2.50 (1.12)	0.50 (0.50)	0 (0)	0 (0)
Coyote (35)	72.43 (8.1)	41.57 (5.21)	24.71 (2.96)	9.43 (2.03)	2.00 (0.69)	0.71 (0.36)	0.14 (0.14)	0 (0)	0 (0)
Double Springs (15)	82.33 (8.24)	58.33 (8.36)	49.00 (5.1)	18.67 (2.51)	3.67 (1.5)	1.33 (0.59)	1.67 (0.63)	0 (0)	0 (0)
Dude (22)	32.50 (6.1)	40.00 (5.24)	26.59 (3.23)	17.05 (2.65)	6.36 (1.72)	1.14 (0.46)	0.23 (0.23)	0 (0)	0 (0)
Dutton (86)	79.24 (7.94)	70.93 (4.91)	40.58 (2.49)	14.71 (1.52)	3.78 (0.67)	0.99 (0.26)	0.17 (0.10)	0.06 (0.06)	0 (0)
Ham (16)	55.94 (15.23)	39.06 (5.69)	25.00 (4.21)	17.81 (2.81)	6.25 (1.74)	4.06 (1.39)	0 (0)	0.62 (0.62)	0 (0)
Johnny's (28)	52.14 (9.67)	50.00 (5.81)	40.89 (4.64)	16.79 (2.06)	6.43 (1.50)	1.79 (0.53)	1.07 (0.47)	0 (0)	0 (0)
LOP Mooney (60)	44.42 (6.40)	43.33 (4.34)	31.67 (2.64)	16.00 (1.44)	5.75 (0.74)	1.83 (0.36)	0.67 (0.25)	0.08 (0.08)	0 (0)
Moonset (30)	41.50 (9.62)	47.50 (7.16)	32.00 (3.70)	15.50 (1.70)	4.67 (1.15)	2.33 (0.71)	0.17 (0.17)	0 (0)	0.17 (0.17)
Newman (67)	86.19 (9.66)	70.00 (5.23)	41.94 (3.11)	14.03 (1.32)	2.69 (0.51)	1.19 (0.34)	0.15 (0.10)	0.07 (0.07)	0 (0)
Parks West (78)	31.54 (3.68)	39.17 (4.22)	35.71 (2.78)	19.62 (1.62)	5.71 (0.89)	1.22 (0.29)	0.13 (0.09)	0.06 (0.06)	0 (0)
Southside Airport (41)	27.07 (4.92)	27.20 (3.23)	29.27 (3.41)	16.95 (1.91)	8.17 (1.17)	3.29 (0.79)	0.85 (0.34)	0.24 (0.17)	0.12 (0.12)
Willard (51)	80.88 (8.23)	60.78 (5.04)	41.18 (2.99)	12.35 (1.47)	2.55 (0.49)	0.88 (0.33)	0.29 (0.17)	0.1 (0.1)	0 (0)
Zorro (41)	42.32 (6.19)	35.85 (4.50)	22.56 (2.89)	13.05 (1.65)	6.95 (1.21)	1.46 (0.44)	0.37 (0.21)	0 (0)	0 (0)

4-inch Diameter Class Distribution: Dead Trees Per Acre

Treatment Unit (# plots)	4 - 8 in mean (SE)	8 - 12 in mean (SE)	12 - 16 in mean (SE)	16 - 20 in mean (SE)	20 - 24 in mean (SE)	24 - 28 in mean (SE)	28 - 32 in mean (SE)	32 - 36 in mean (SE)	36 - 40 in mean (SE)	40 - 44 in mean (SE)	52 - 56 in mean (SE)
A1 North (14)	22.14 (21.00)	3.57 (3.21)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
A1 South (47)	1.28 (0.47)	0.64 (0.29)	0.11 (0.11)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Beacon (36)	3.19 (1.57)	0.56 (0.33)	0.42 (0.23)	0 (0)	0.28 (0.19)	0 (0)	0.14 (0.14)	0 (0)	0 (0)	0 (0)	0 (0)
Bootleg (29)	19.48 (3.53)	2.07 (0.47)	1.03 (0.46)	0.69 (0.41)	0.34 (0.34)	0.17 (0.17)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Chimney Springs (58)	1.38 (0.68)	0.78 (0.30)	0.52 (0.27)	0.26 (0.15)	0.52 (0.24)	0.09 (0.09)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Clark (34)	4.26 (1.68)	1.32 (0.61)	0.59 (0.28)	0.29 (0.20)	0 (0)	0.15 (0.15)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cloverdog (69)	1.88 (0.66)	0.94 (0.35)	0.43 (0.20)	0.43 (0.17)	0.14 (0.10)	0 (0)	0 (0)	0.14 (0.10)	0 (0)	0 (0)	0 (0)
Cougar (10)	8.00 (3.43)	2.50 (1.12)	2.00 (1.53)	1.50 (0.76)	3.50 (1.67)	2.00 (1.11)	0.50 (0.50)	0 (0)	1.00 (0.67)	0 (0)	0 (0)
Coyote (35)	16.86 (3.88)	2.71 (0.88)	1.43 (0.60)	0.14 (0.14)	0.14 (0.14)	0.29 (0.29)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Double Springs (15)	8.00 (2.62)	0.67 (0.45)	0.67 (0.45)	0.33 (0.33)	0.67 (0.45)	0 (0)	0.33 (0.33)	0.33 (0.33)	0 (0)	0 (0)	0 (0)
Dude (22)	0 (0)	0 (0)	0 (0)	0.23 (0.23)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Dutton (86)	6.69 (1.12)	2.09 (0.57)	0.76 (0.24)	0.23 (0.11)	0.06 (0.06)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Ham (16)	15.31 (5.29)	2.50 (1.12)	2.50 (1.29)	2.19 (1.12)	1.88 (0.77)	0.62 (0.43)	0 (0)	0.31 (0.31)	0 (0)	0.31 (0.31)	0 (0)
Johnny's (28)	1.96 (0.74)	0.18 (0.18)	0.18 (0.18)	0.54 (0.39)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
LOP Mooney (60)	2.58 (0.63)	0.50 (0.20)	0.17 (0.12)	0.25 (0.14)	0.25 (0.14)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Moonset (30)	2.33 (1.14)	1.33 (0.63)	1.17 (0.39)	3.33 (0.91)	2.67 (0.86)	3.17 (0.88)	1.83 (0.56)	0.67 (0.32)	0.50 (0.28)	0.17 (0.17)	0.17 (0.17)
Newman (67)	14.78 (3.74)	3.96 (1.42)	1.19 (0.35)	0.30 (0.15)	0.15 (0.1)	0.15 (0.10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Parks West (78)	2.82 (0.83)	1.03 (0.32)	0.26 (0.13)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Southside Airport (41)	0.61 (0.40)	0.24 (0.24)	0.12 (0.12)	0.12 (0.12)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Willard (51)	10.88 (2.21)	4.12 (1.10)	1.86 (0.86)	0.69 (0.28)	0.20 (0.14)	0.10 (0.10)	0.10 (0.10)	0 (0)	0 (0)	0 (0)	0 (0)
Zorro (41)	7.68 (2.61)	1.46 (0.80)	0.49 (0.29)	0.24 (0.17)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Species Distribution: Trees Per Acre

Treatment Unit (# plots)	PIPO mean (SE)	QUGA mean (SE)	JUDE mean (SE)	ABCO mean (SE)	PIED mean (SE)	PSME mean (SE)	PIST mean (SE)	JUMO mean (SE)	POTR mean (SE)
A1 North (14)	119.29 (25.66)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.36 (0.36)
A1 South (47)	142.98 (17.44)	0 (0)	0 (0)	0 (0)	0 (0)	0.11 (0.11)	0 (0)	0 (0)	0 (0)
Beacon (36)	86.94 (8.68)	12.36 (6.19)	7.92 (3.25)	0 (0)	0 (0)	0 (0)	0 (0)	0.14 (0.14)	0 (0)
Bootleg (29)	146.9 (10.27)	71.72 (13.04)	0.86 (0.70)	0.17 (0.17)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Chimney Springs (58)	137.5 (12.02)	0 (0)	0 (0)	0.26 (0.15)	0.17 (0.12)	0 (0)	0.17 (0.17)	0 (0)	0 (0)
Clark (34)	179.26 (15.19)	13.68 (3.72)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Cloverdog (69)	127.97 (9.52)	28.19 (3.93)	3.84 (1.14)	2.10 (1.75)	0 (0)	0.07 (0.07)	0 (0)	0 (0)	0 (0)
Cougar (10)	88.00 (26.53)	23.50 (11.16)	9.50 (7.17)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coyote (35)	99.86 (10.04)	39.14 (7.56)	11.29 (3.02)	0 (0)	0 (0)	0.71 (0.36)	0 (0)	0 (0)	0 (0)
Double Springs (15)	162.00 (18.64)	48.00 (6.90)	4.33 (2.62)	0.33 (0.33)	0 (0)	0.33 (0.33)	0 (0)	0 (0)	0 (0)
Dude (22)	112.27 (12.12)	0 (0)	11.36 (5.49)	0 (0)	0.23 (0.23)	0 (0)	0 (0)	0 (0)	0 (0)
Dutton (86)	191.34 (10.97)	17.91 (3.68)	1.16 (0.44)	0 (0)	0.06 (0.06)	0 (0)	0 (0)	0 (0)	0 (0)
Ham (16)	107.81 (15.78)	39.69 (15.19)	1.25 (0.56)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Johnny's (28)	147.14 (13.41)	21.96 (7.43)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
LOP Mooney (60)	136.75 (11.25)	5.33 (2.34)	1.67 (0.46)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Moonset (30)	116.67 (10.25)	19.83 (9.22)	7.33 (4.27)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Newman (67)	166.79 (12.89)	48.13 (5.55)	1.34 (0.47)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Parks West (78)	131.09 (7.54)	0 (0)	2.05 (0.81)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Southside Airport (41)	112.07 (9.54)	0 (0)	1.1 (0.45)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Willard (51)	159.90 (10.29)	35.39 (5.95)	3.63 (1.71)	0 (0)	0.10 (0.10)	0 (0)	0 (0)	0 (0)	0 (0)
Zorro (41)	109.76 (10.17)	0.24 (0.17)	11.95 (4.13)	0 (0)	0.61 (0.40)	0 (0)	0 (0)	0 (0)	0 (0)

Appendix D: 2-inch Diameter Class Figures & Tables

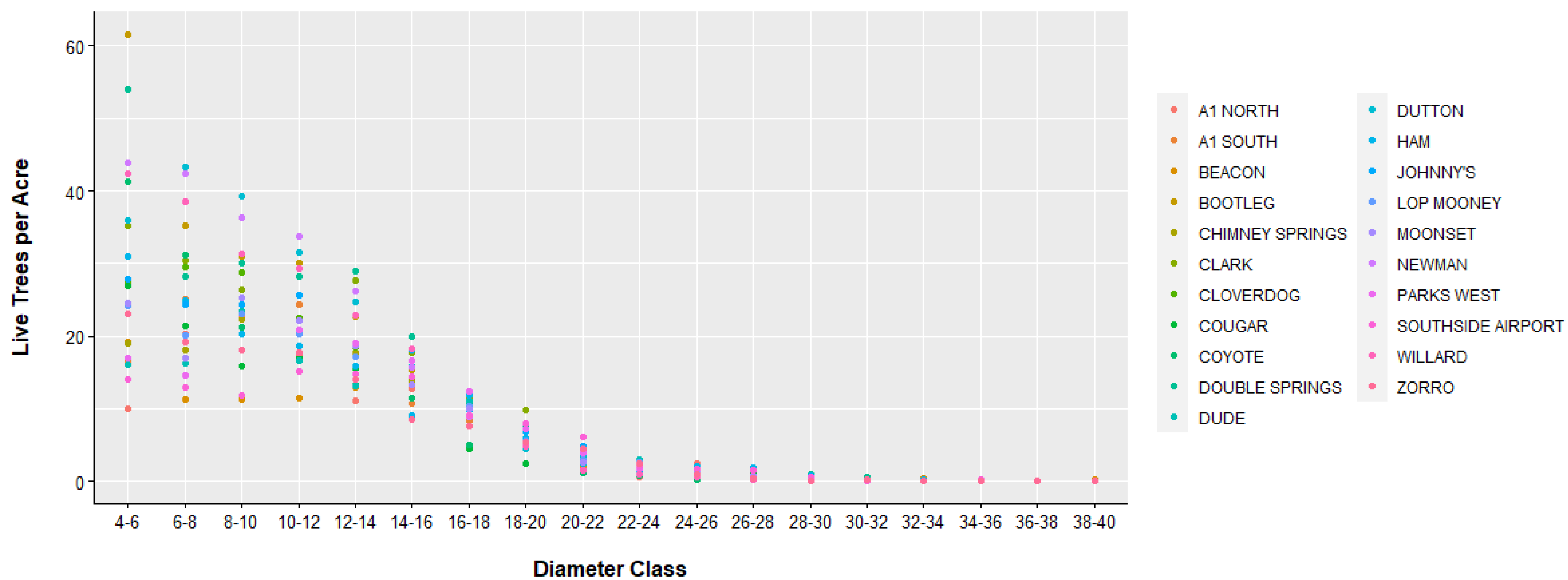


***Figure D1**. Live Tree 2-inch Diameter Class Distribution- Points correspond to the mean number of live trees per acre from each treatment unit in each 2-inch diameter class. A full table of mean and standard error values for all treatment units and diameter classes is presented in on the next pages.*

2-inch Diameter Class Distribution: Live Trees Per Acre

Treatment Unit (# plots)	**4-6 in** mean (SE)	**6-8 in** mean (SE)	**8-10 in** mean (SE)	**10-12 in** mean (SE)	**12-14 in** mean (SE)	**14-16 in** mean (SE)	**16-18 in** mean (SE)	**18-20 in** mean (SE)	**20-22 in** mean (SE)	**22-24 in** mean (SE)	**24-26 in** mean (SE)	**26-28 in** mean (SE)	**28-30 in** mean (SE)	**30-32 in** mean (SE)	**32-34 in** mean (SE)	**34-36 in** mean (SE)	**36-38 in** mean (SE)	**38-40 in** mean (SE)
A1 North (14)	10.00 (3.52)	20.36 (8.79)	22.86 (8.69)	17.50 (6.22)	11.07 (2.83)	12.86 (2.50)	10.36 (2.43)	5.71 (1.37)	4.29 (1.27)	0.71 (0.49)	2.50 (0.87)	1.43 (0.63)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
A1 South (47)	16.49 (6.02)	25.11 (5.19)	30.11 (6.09)	24.36 (3.87)	17.66 (2.19)	10.74 (1.42)	8.30 (1.32)	4.79 (0.90)	2.13 (0.69)	1.38 (0.39)	1.06 (0.37)	0.43 (0.21)	0.43 (0.21)	0.11 (0.11)	0 (0)	0 (0)	0 (0)	0 (0)
Beacon (36)	19.31 (4.47)	11.39 (2.10)	11.25 (2.69)	11.53 (2.19)	12.92 (2.22)	11.53 (1.92)	10.69 (1.73)	7.78 (1.46)	4.72 (0.72)	2.92 (0.70)	1.39 (0.47)	0.69 (0.35)	0.28 (0.19)	0.28 (0.19)	0.42 (0.23)	0 (0)	0 (0)	0.28 (0.19)
Bootleg (29)	61.55 (10.82)	35.17 (3.99)	31.03 (3.71)	30.00 (3.39)	22.76 (2.61)	15.34 (1.82)	11.72 (1.74)	7.07 (1.44)	2.24 (0.91)	1.55 (0.66)	0.52 (0.38)	0.52 (0.29)	0.17 (0.17)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Chimney Springs (58)	19.05 (4.31)	18.19 (3.52)	22.41 (3.30)	20.52 (2.53)	17.84 (1.91)	13.88 (1.27)	10.17 (1.24)	5.43 (0.78)	4.83 (0.75)	2.67 (0.61)	1.47 (0.35)	0.60 (0.25)	0.6 (0.22)	0.26 (0.15)	0.09 (0.09)	0.09 (0.09)	0 (0)	0 (0)
Clark (34)	35.29 (6.94)	30.44 (4.99)	26.47 (2.84)	25.59 (3.20)	27.65 (3.27)	17.79 (2.17)	11.47 (1.46)	9.85 (1.67)	3.09 (0.92)	1.76 (0.51)	1.91 (0.56)	0.44 (0.25)	0.29 (0.2)	0.59 (0.28)	0 (0)	0.15 (0.15)	0 (0)	0.15 (0.15)
Cloverdog (69)	27.39 (3.22)	29.57 (3.30)	28.84 (2.58)	22.46 (2.08)	18.55 (1.75)	13.33 (1.25)	9.06 (1.11)	4.78 (0.63)	3.99 (0.60)	1.59 (0.36)	1.16 (0.28)	0.65 (0.20)	0.36 (0.16)	0.07 (0.07)	0.14 (0.10)	0.07 (0.07)	0.07 (0.07)	0.07 (0.07)
Cougar (10)	27.00 (9.04)	21.50 (8.17)	16.00 (7.26)	17.00 (7.86)	15.50 (6.64)	9.00 (4.14)	4.50 (2.63)	2.50 (1.54)	3.50 (1.50)	1.50 (0.76)	1.50 (0.76)	1.00 (0.67)	0.5 (0.5)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coyote (35)	41.29 (6.07)	31.14 (4.30)	21.29 (3.23)	20.29 (2.90)	13.29 (1.76)	11.43 (1.92)	5.00 (1.38)	4.43 (1.23)	1.14 (0.46)	0.86 (0.32)	0.29 (0.29)	0.43 (0.24)	0.14 (0.14)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Double Springs (15)	54.00 (5.90)	28.33 (4.10)	30.00 (4.31)	28.33 (4.82)	29.00 (4.03)	20.00 (3.42)	11.00 (1.77)	7.67 (2.17)	2.67 (1.28)	1.00 (0.53)	1.00 (0.53)	0.33 (0.33)	1.00 (0.53)	0.67 (0.45)	0 (0)	0 (0)	0 (0)	0 (0)
Dude (22)	16.14 (3.42)	16.36 (3.52)	23.41 (2.89)	16.59 (3.09)	13.18 (1.79)	13.41 (2.22)	11.14 (1.94)	5.91 (1.42)	3.41 (1.20)	2.95 (0.91)	0.68 (0.37)	0.45 (0.31)	0 (0)	0.23 (0.23)	0 (0)	0 (0)	0 (0)	0 (0)
Dutton (86)	35.93 (4.65)	43.31 (4.00)	39.30 (3.12)	31.63 (2.26)	24.71 (1.59)	15.87 (1.39)	10.17 (1.12)	4.53 (0.61)	2.44 (0.44)	1.34 (0.30)	0.70 (0.21)	0.29 (0.15)	0.12 (0.08)	0.06 (0.06)	0.06 (0.06)	0 (0)	0 (0)	0 (0)
Ham (16)	30.94 (8.66)	25.00 (6.82)	20.31 (3.89)	18.75 (2.68)	15.94 (2.86)	9.06 (2.00)	11.88 (2.54)	5.94 (1.60)	3.75 (1.55)	2.50 (0.91)	2.19 (0.91)	1.88 (0.90)	0 (0)	0 (0)	0.31 (0.31)	0.31 (0.31)	0 (0)	0 (0)
Johnny's (28)	27.86 (6.32)	24.29 (3.96)	24.29 (3.19)	25.71 (3.52)	22.86 (3.13)	18.04 (2.22)	9.82 (1.04)	6.96 (1.63)	4.82 (1.14)	1.61 (0.58)	1.43 (0.51)	0.36 (0.25)	0.89 (0.37)	0.18 (0.18)	0 (0)	0 (0)	0 (0)	0 (0)
LOP Mooney (60)	24.25 (3.98)	20.17 (2.79)	23.08 (2.53)	20.25 (2.36)	17.25 (1.63)	14.42 (1.48)	10.42 (1.10)	5.58 (0.71)	3.08 (0.46)	2.67 (0.51)	1.17 (0.30)	0.67 (0.22)	0.42 (0.22)	0.25 (0.14)	0.08 (0.08)	0 (0)	0 (0)	0 (0)
Moonset (30)	24.50 (6.46)	17.00 (3.94)	25.33 (4.80)	22.17 (3.16)	18.67 (2.49)	13.33 (1.85)	10.00 (1.22)	5.50 (1.16)	2.67 (0.82)	2.00 (0.62)	1.50 (0.54)	0.83 (0.42)	0.17 (0.17)	0 (0)	0 (0)	0 (0)	0 (0)	0.17 (0.17)

2-inch Diameter Class Distribution: Live Trees Per Acre

Treatment Unit (# plots)	**4-6 in** mean (SE)	**6-8 in** mean (SE)	**8-10 in** mean (SE)	**10-12 in** mean (SE)	**12-14 in** mean (SE)	**14-16 in** mean (SE)	**16-18 in** mean (SE)	**18-20 in** mean (SE)	**20-22 in** mean (SE)	**22-24 in** mean (SE)	**24-26 in** mean (SE)	**26-28 in** mean (SE)	**28-30 in** mean (SE)	**30-32 in** mean (SE)	**32-34 in** mean (SE)	**34-36 in** mean (SE)	**36-38 in** mean (SE)	**38-40 in** mean (SE)
Newman (67)	43.81 (5.60)	42.39 (4.56)	36.27 (3.24)	33.73 (2.55)	26.19 (2.22)	15.75 (1.43)	8.96 (1.01)	5.07 (0.64)	1.64 (0.34)	1.04 (0.31)	0.90 (0.28)	0.30 (0.15)	0.15 (0.10)	0 (0)	0.07 (0.07)	0 (0)	0 (0)	0 (0)
Parks West (78)	16.99 (2.22)	14.55 (1.85)	18.21 (2.22)	20.96 (2.41)	18.97 (1.95)	16.73 (1.55)	12.37 (1.13)	7.24 (0.85)	3.91 (0.66)	1.79 (0.42)	0.77 (0.26)	0.45 (0.16)	0.13 (0.09)	0 (0)	0 (0)	0.06 (0.06)	0 (0)	0 (0)
Southside Airport (41)	14.02 (3.20)	13.05 (2.04)	11.95 (2.19)	15.24 (1.69)	14.88 (1.92)	14.39 (1.85)	9.02 (1.34)	7.93 (1.08)	6.10 (0.86)	2.07 (0.58)	1.71 (0.57)	1.59 (0.44)	0.73 (0.33)	0.12 (0.12)	0 (0)	0.24 (0.17)	0.12 (0.12)	0 (0)
Willard (51)	42.35 (5.37)	38.53 (3.63)	31.37 (3.23)	29.41 (2.75)	22.84 (2.01)	18.33 (1.58)	7.55 (1.02)	4.80 (0.74)	1.47 (0.38)	1.08 (0.29)	0.59 (0.27)	0.29 (0.17)	0.10 (0.10)	0.20 (0.14)	0.10 (0.10)	0 (0)	0 (0)	0 (0)
Zorro (41)	23.05 (3.84)	19.27 (2.69)	18.17 (2.61)	17.68 (2.61)	14.02 (2.15)	8.54 (1.41)	7.56 (1.26)	5.49 (0.92)	4.51 (0.90)	2.44 (0.66)	0.98 (0.31)	0.49 (0.23)	0.12 (0.12)	0.24 (0.17)	0 (0)	0 (0)	0 (0)	0 (0)

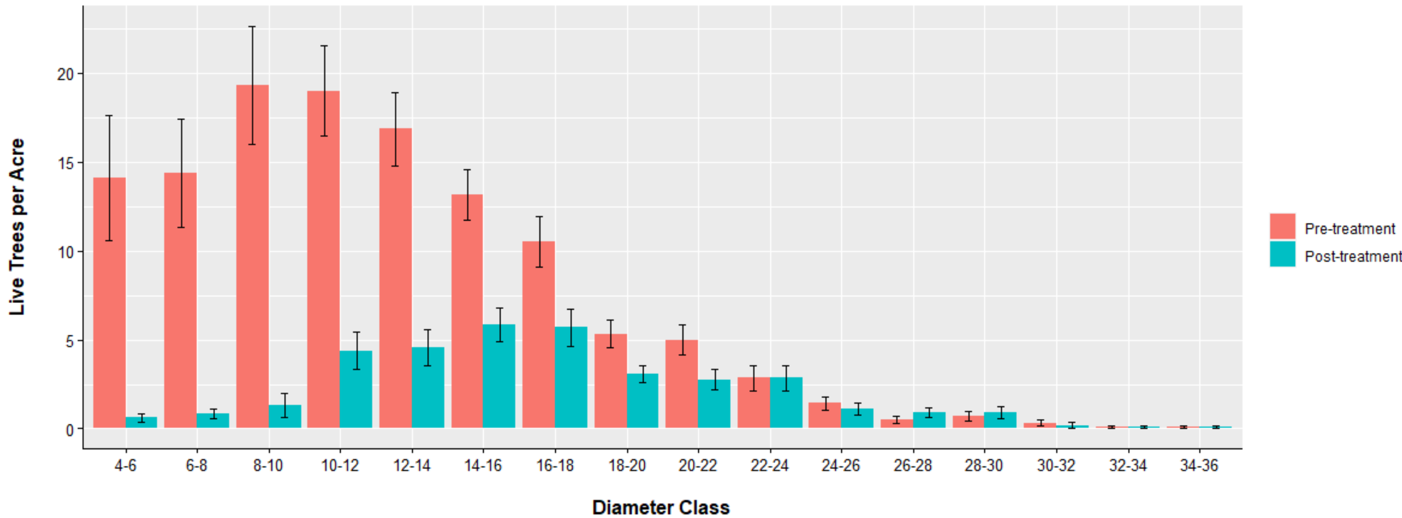


Figure D2. *Live Tree 2-inch Diameter Class Distribution- bar chart where the top of each bar corresponds to the mean live TPA value, while the error bars show the standard error (SE) around the mean.*

Chimney Springs 2-inch Diameter Class Distribution: Live Trees Per Acre

	4-6 in mean (SE)	**6-8 in** mean (SE)	**8-10 in** mean (SE)	**10-12 in** mean (SE)	**12-14 in** mean (SE)	**14-16 in** mean (SE)	**16-18 in** mean (SE)	**18-20 in** mean (SE)	**20-22 in** mean (SE)	**22-24 in** mean (SE)	**24-26 in** mean (SE)	**26-28 in** mean (SE)	**28-30 in** mean (SE)	**30-32 in** mean (SE)	**32-34 in** mean (SE)	**34-36 in** mean (SE)
Pre-treatment	0.61 (0.24)	0.82 (0.27)	1.33 (0.66)	4.39 (1.03)	4.59 (1.01)	5.82 (0.95)	5.71 (1.05)	3.06 (0.46)	2.76 (0.58)	2.86 (0.71)	1.12 (0.33)	0.92 (0.28)	0.92 (0.32)	0.20 (0.14)	0.10 (0.10)	0.10 (0.10)
Post-treatment	14.08 (3.52)	14.39 (3.03)	19.29 (3.33)	18.98 (2.54)	16.84 (2.07)	13.16 (1.41)	10.51 (1.41)	5.31 (0.78)	5.00 (0.85)	2.86 (0.70)	1.43 (0.36)	0.51 (0.22)	0.71 (0.25)	0.31 (0.17)	0.10 (0.10)	0.10 (0.10)