Visualization Guide to Heterogeneous Forest Structures Following Treatment in the southern Rocky Mountains

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Background

- How did we get to the current condition?

Scales of Heterogeneity

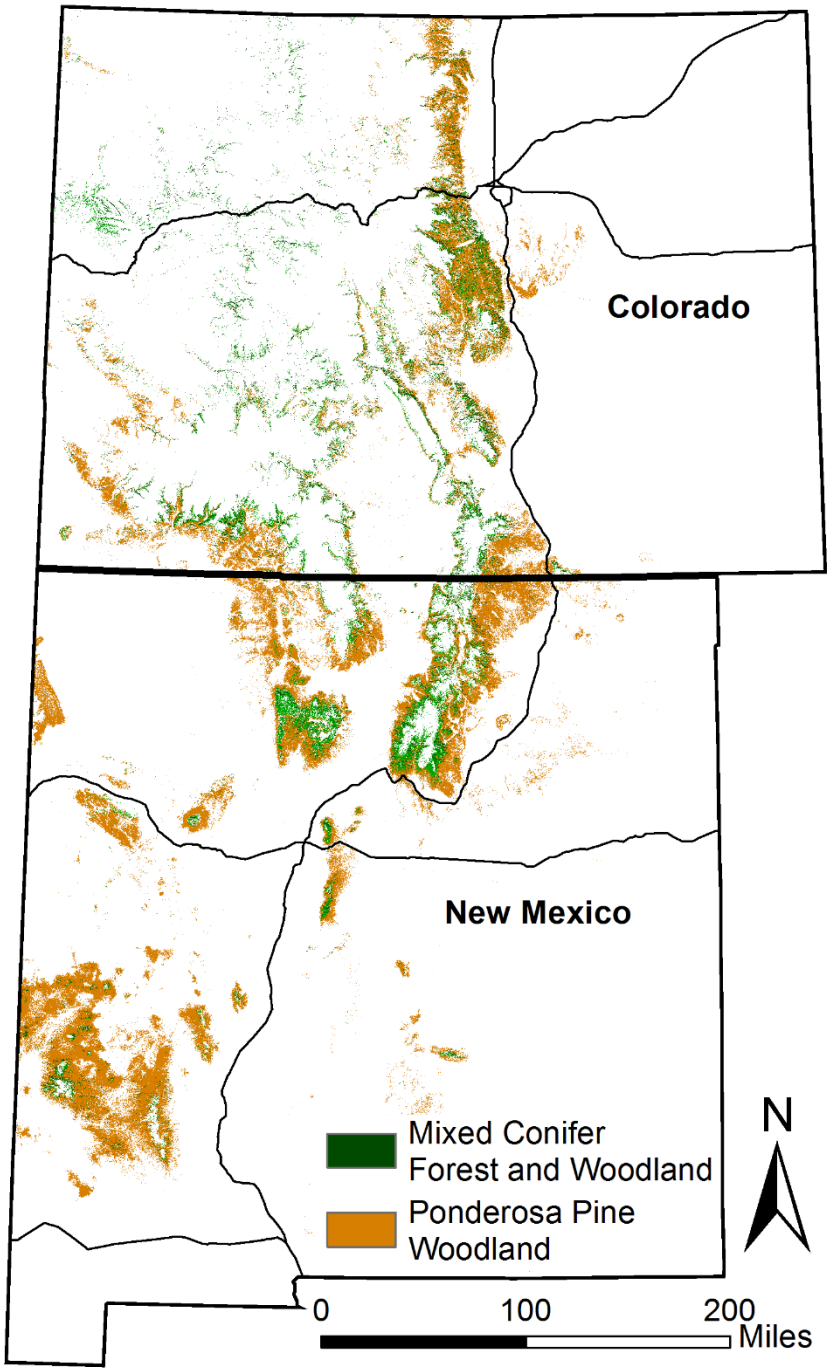
- Fine and Landscape-scales of variation

Developing the Guide

- Creating the example stands

Example Stand

- Comparison of treatment effects



Background

~16 billion acres in southern Rocky Mountains

Historical mixed-severity fire regime

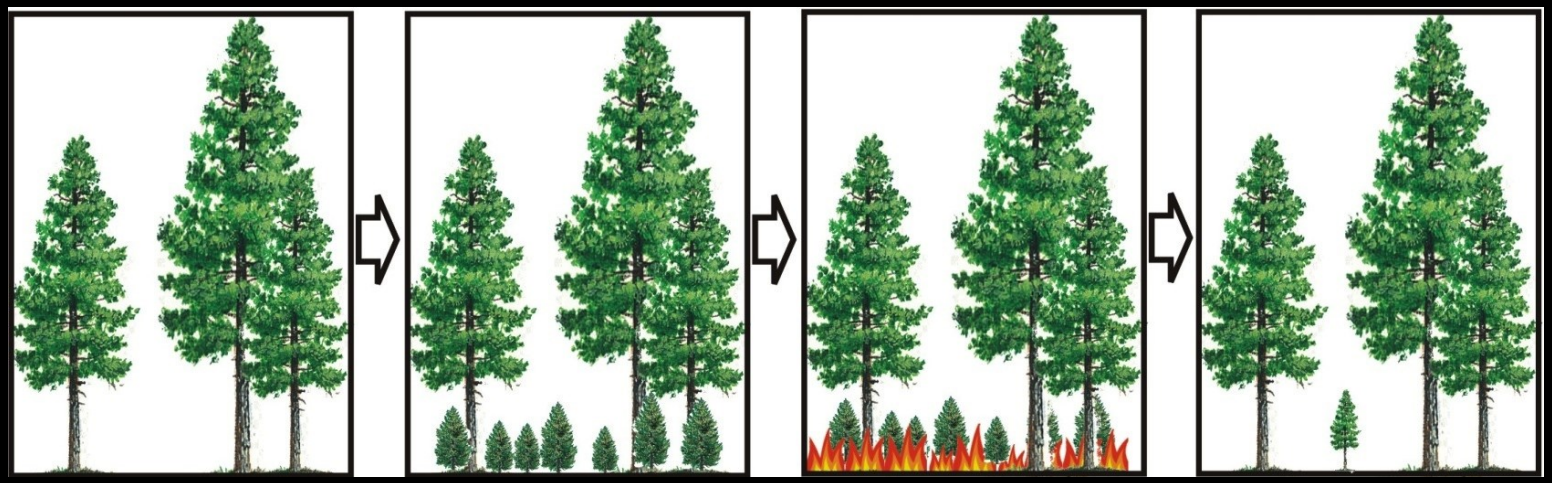
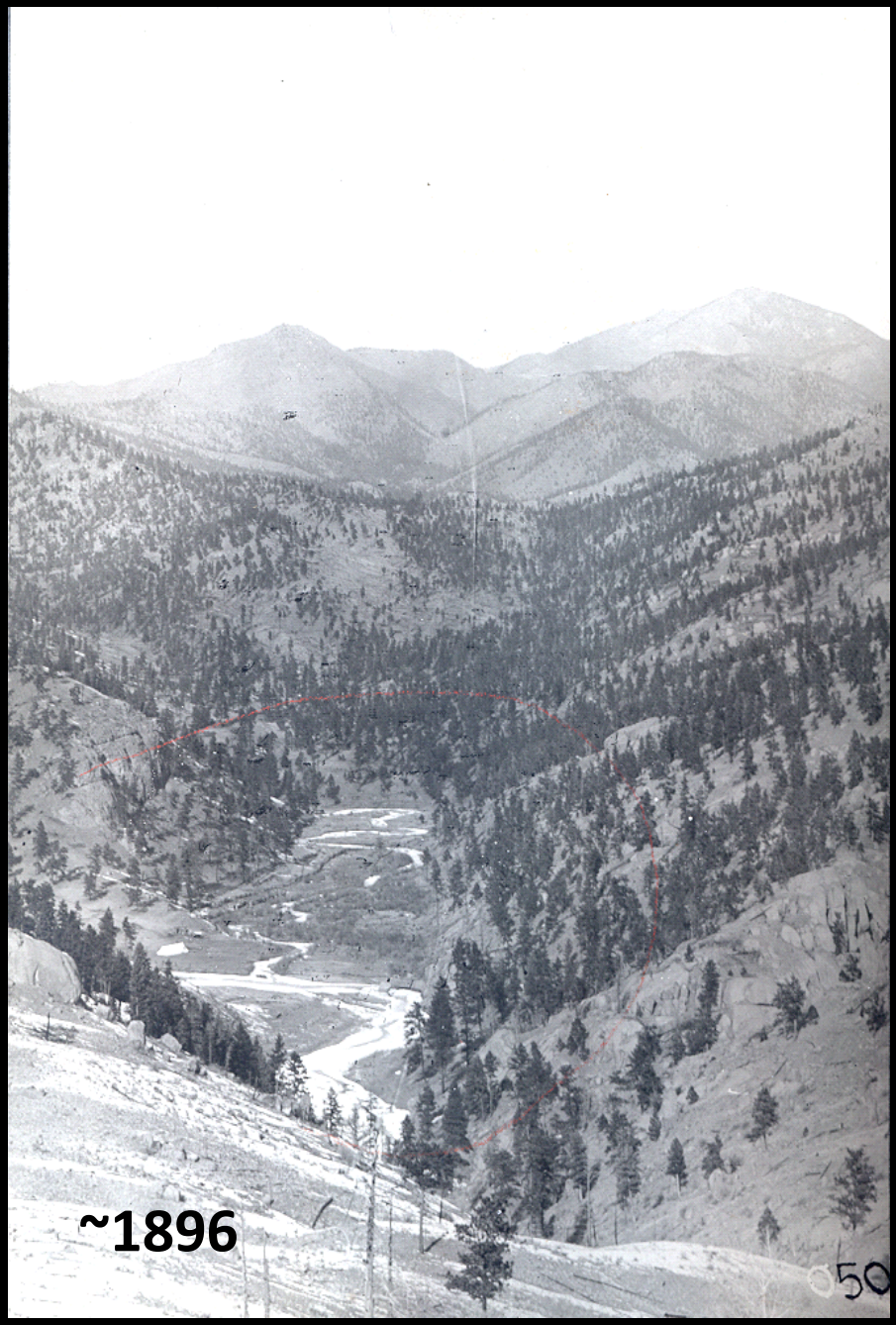


Image: Dr. Peter Brown, Rocky Mountain Tree-Ring Research



Images: Dr. Mike Battaglia, USFS Rocky Mountain Research Station

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Current situation

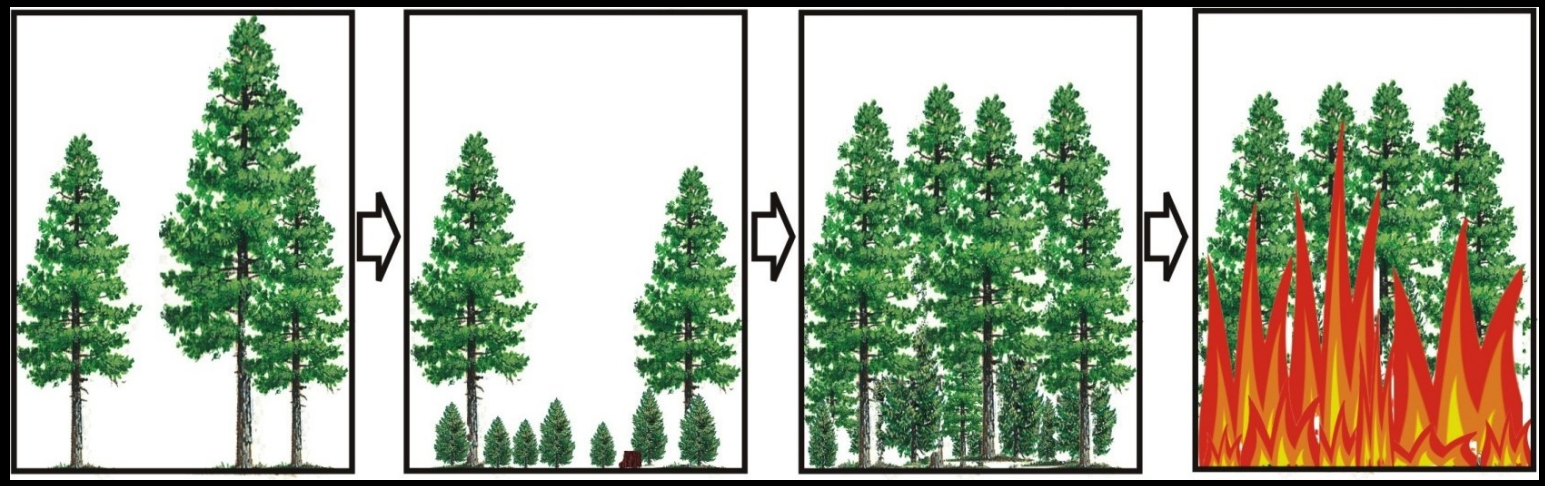


Image: Dr. Peter Brown, Rocky Mountain Tree-Ring Research

Year	Size (acres)	Name
1989	2,100	Black tiger fire
1996	11,900 (10 structures)	Buffalo creek fire
2000	10,800 (51 structures)	Hi meadow fire
2000	10,599 (18 structures)	Bobcat gulch
2002	137,760 (600 structures and 5 deaths)	Hayman fire
2010	6,388 (>174 structures)	Four mile canyon fire
2012	7,685	Hewlett gulch
2012	87,284 (>250 structures and 1 death)	High park fire
2012	18,247 (346 homes and 2 deaths)	Waldo canyon fire
2013	14,280 (486 homes)	Black forest fire

“Traditional” hazardous fuels mitigation

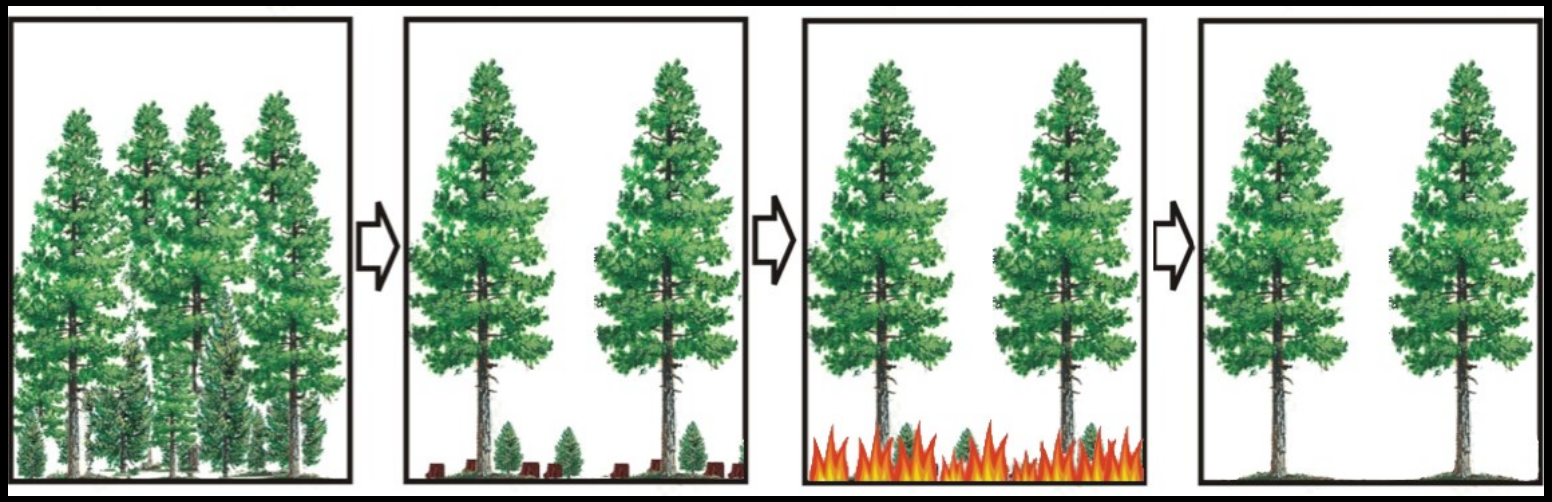
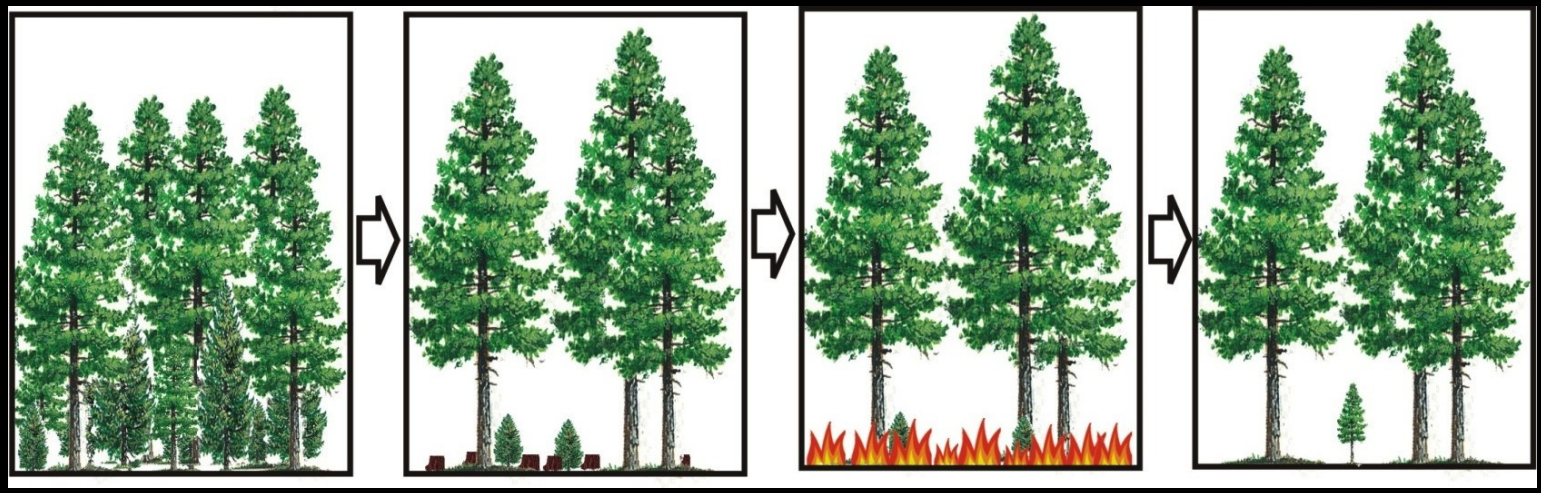


Image adapted from Dr. Peter Brown, Rocky Mountain Tree-Ring Research

“Groupy-clumpy” restoration



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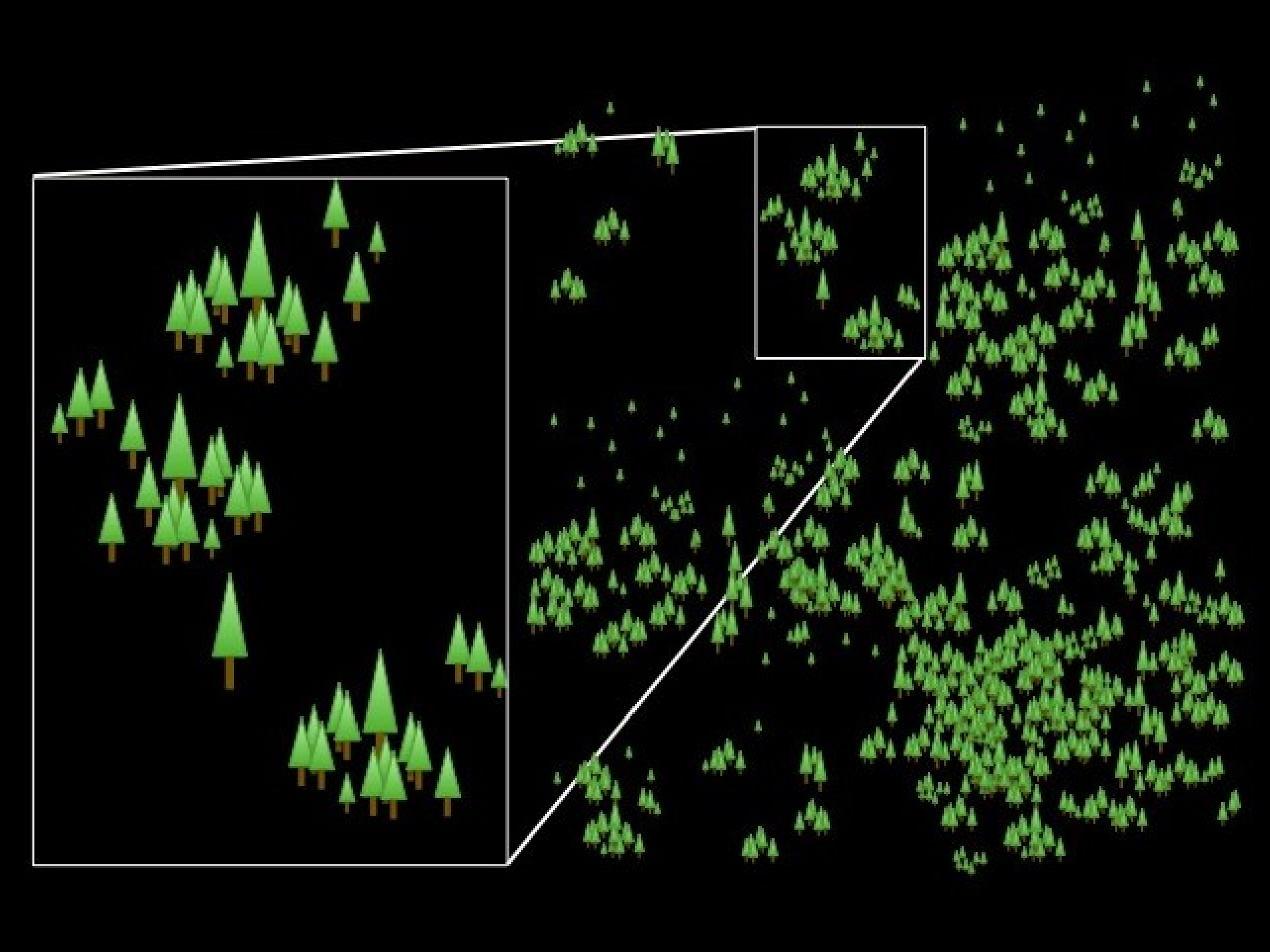

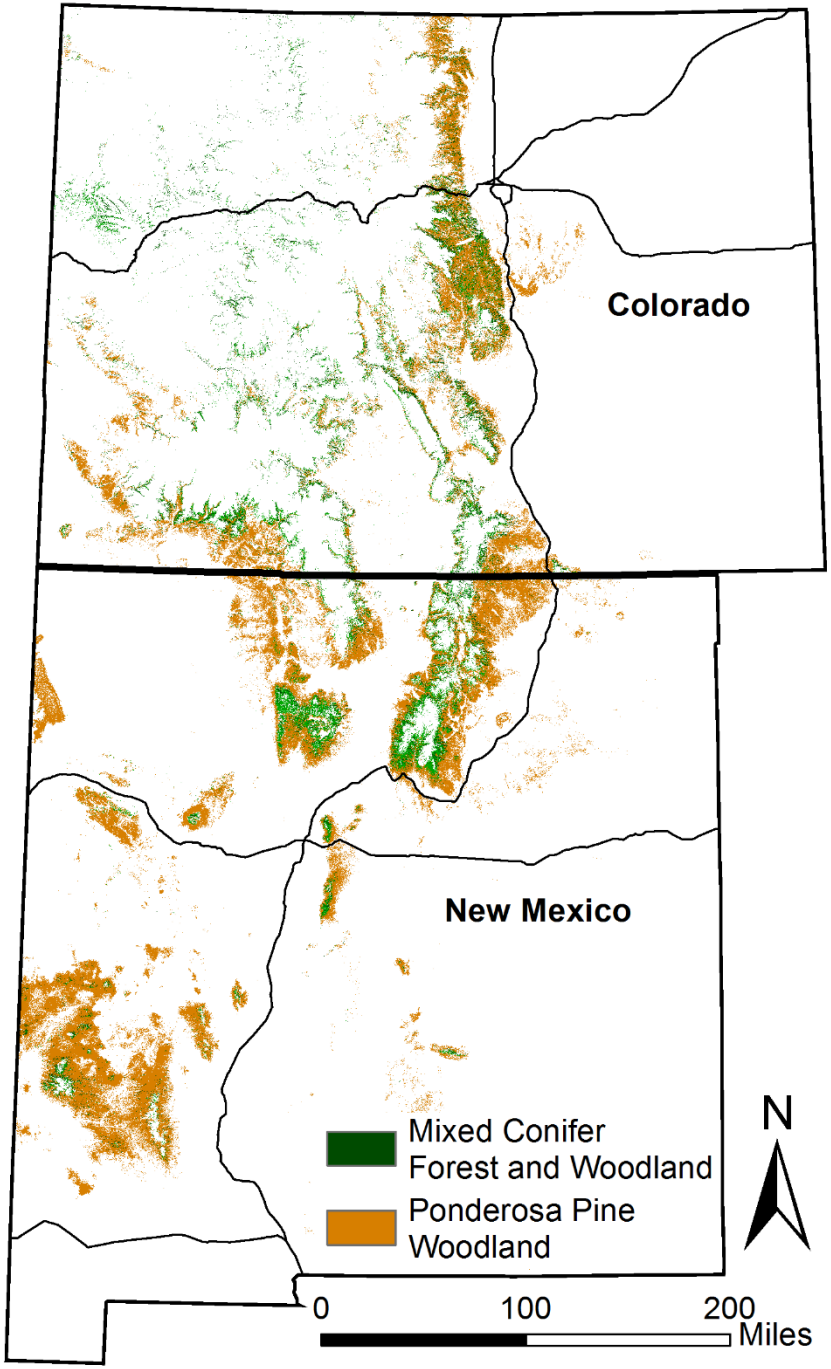

Collaborative Forest Landscape Restoration Program

5 – CFLRP Projects in southern Rocky Mountain ponderosa pine systems

Targeting landscapes totaling 2.1 million hectares

Intended to increase fine- and landscape scale heterogeneity

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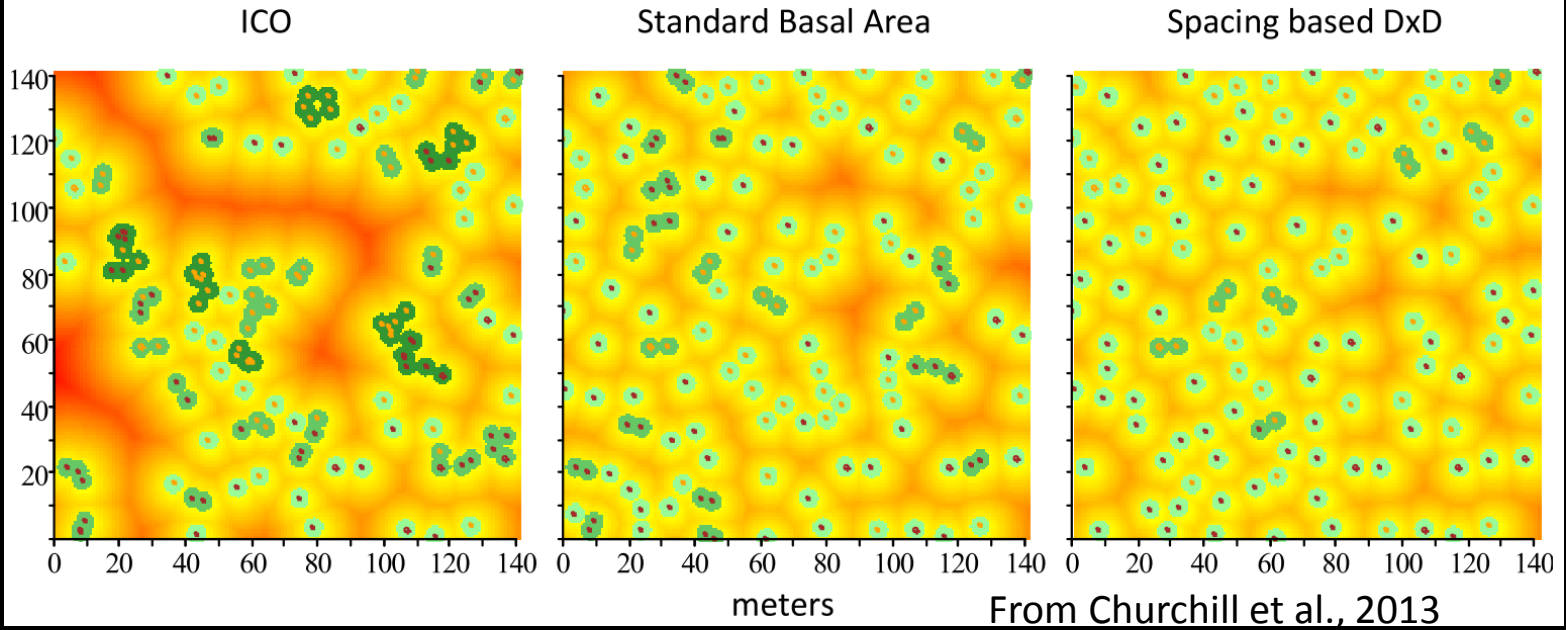
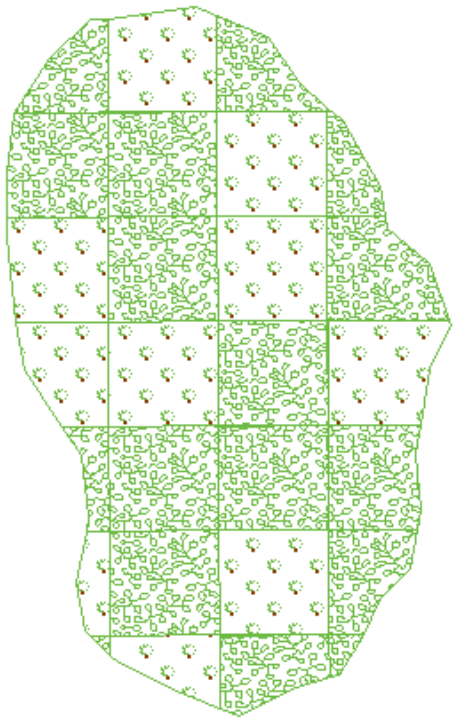
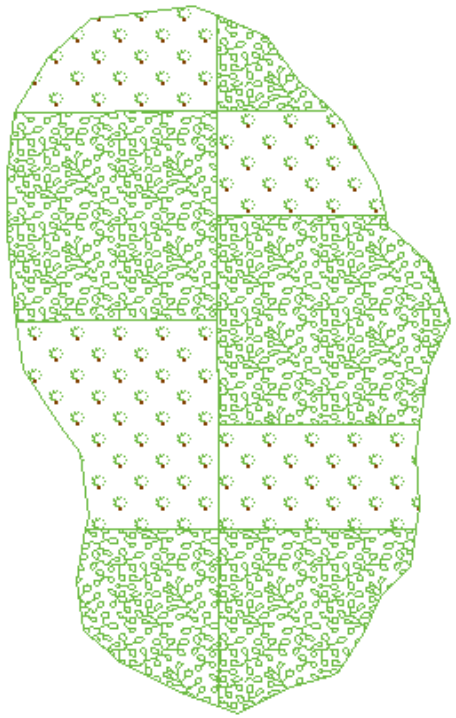
Fine-Scale Forest Structure

Fine-Scale Forest Structure

- Restoration treatments seek to enhance the variability of these structures within a stand.
- Individuals, Clumps, and Openings (ICO) treatments.
  - Clumpy (tree spacing)
  - Variable residual density (structure)
  - Openings (structure)







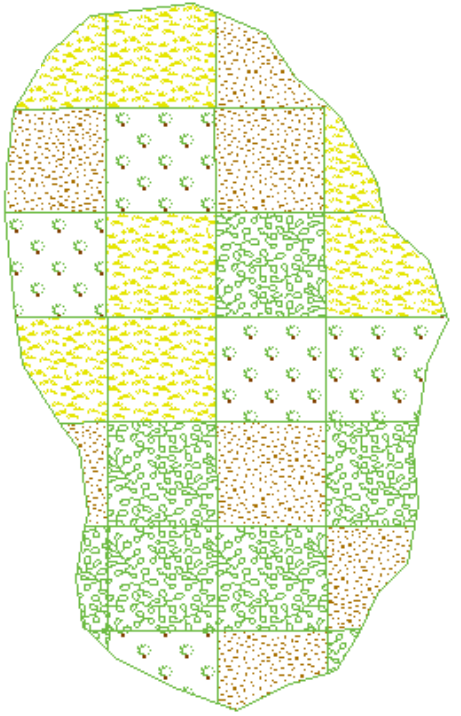
Landscape-Scale Heterogeneity

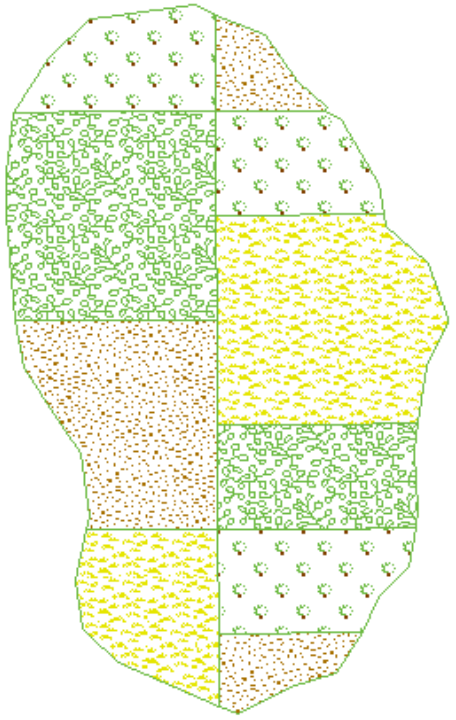
- **Stand type diversity**
  - Controlled by abiotic environmental factors

  Left = low diversity – Right = high diversity
- **Stand scale variability**
  - Artifact of past management and disturbance patterns

  Top = low variability – Bottom = high variability

The mixing of stand types and scales in a landscape must be considered when planning treatments, as they inform the range of possible future conditions.





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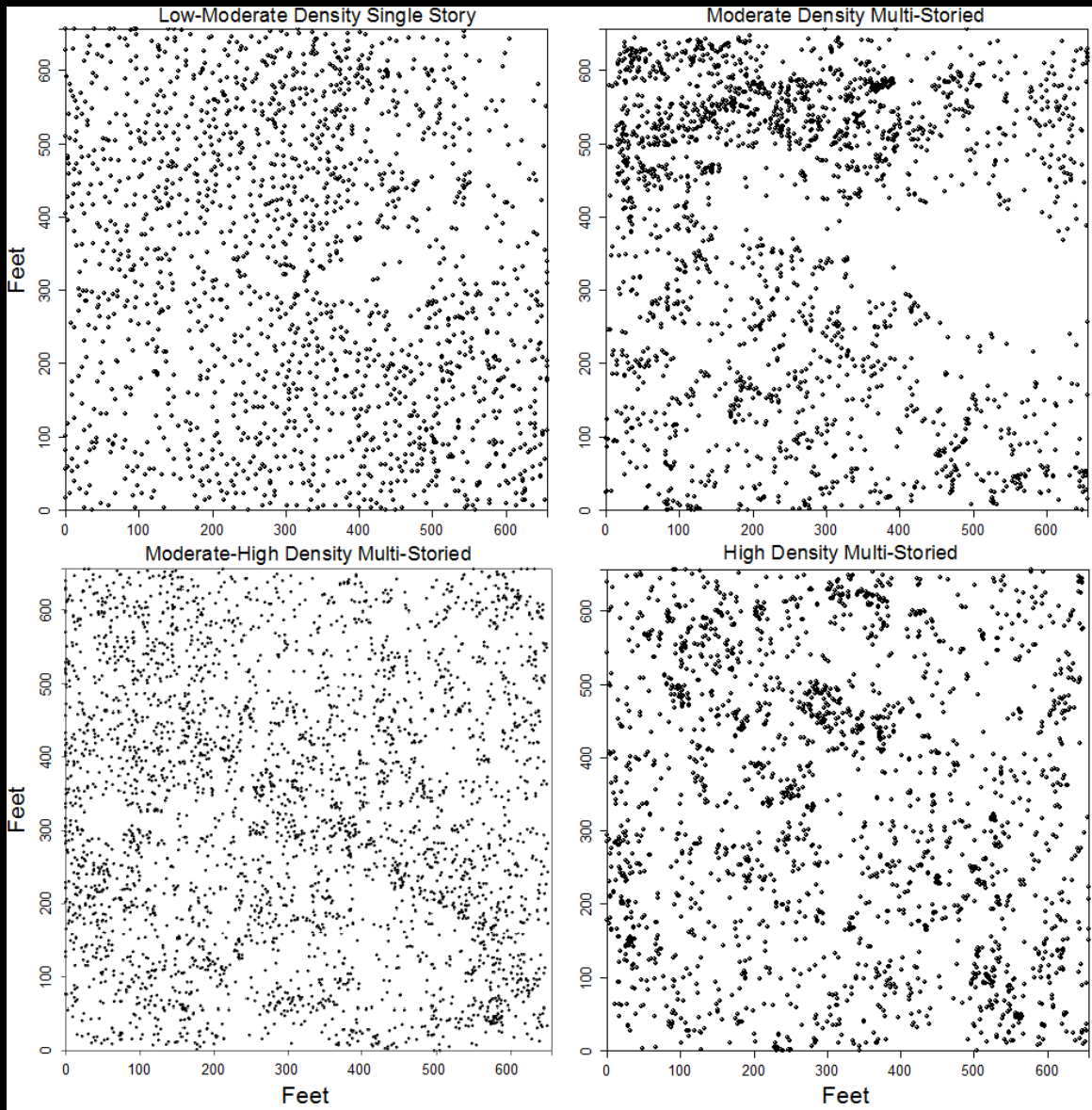
Developing the Guide

Reference Stands

- 4 – 10 acre ponderosa pine dominated sites were stem-mapped.
- Each was identified for restoration treatments.
- Represented a range of stand complexities.



Thinning Scenarios

Traditional Approaches

- Thinning from below – where trees were removed starting with the smallest basal area tree until the target basal area was reached.
- Thinning throughout the diameter range – where trees were randomly selected from the tree list and removed until the residual basal area target was reached.

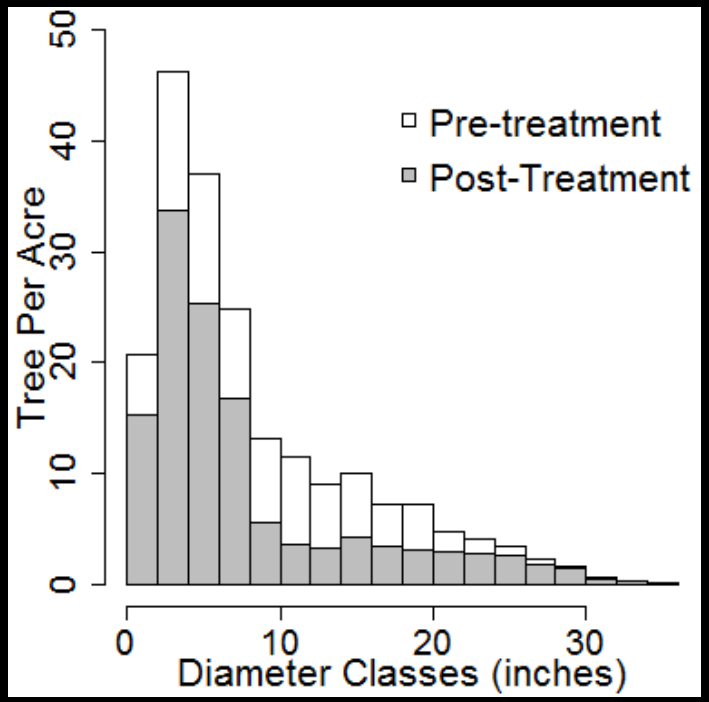
Spatially Explicit Approaches (ICO)

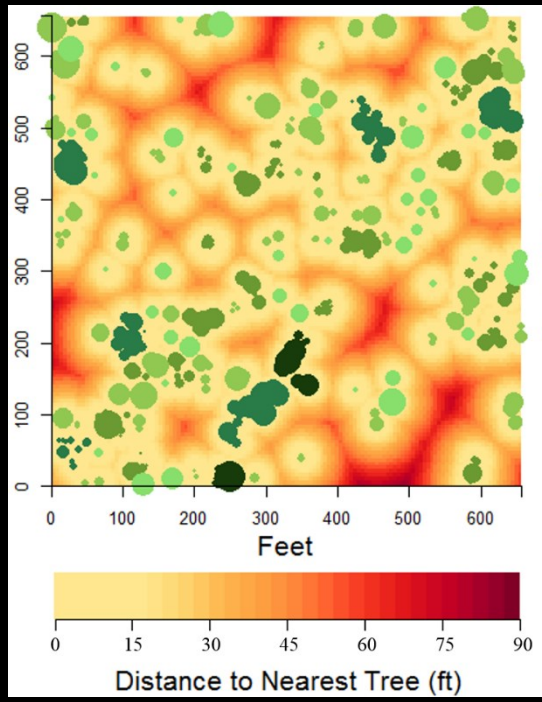
- Two ICO treatments were simulated at different target levels of clumping using Python.
  - All scenarios were thinned to 40 ft^2 of basal area pre acre

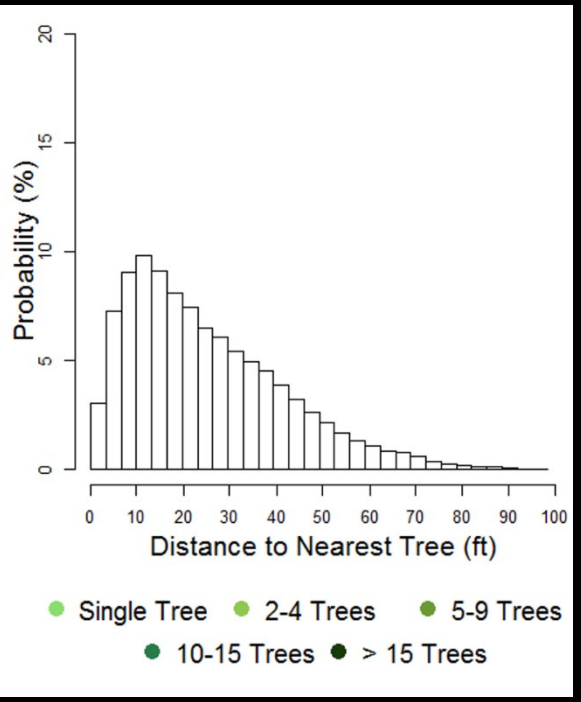
Structure	Moderate Clumping	High Clumping
Single Trees	35%	10%
2-4 Tree Clump	30%	30%
5-9 Tree Clump	20%	35%
10-15 Tree Clump	10%	15%
> 15 Tree Clump	5%	10%

Characterizing Structure

- Stands were assessed for pre- and post-thinning forest structure and spatial arrangement, including:
  - Traditional measures like DBH distribution, QMD, and mean height.
    - Along with a measure of their variability throughout the stand.
  - Spatial arrangement of tree clumping and opening sizes was also summarized.

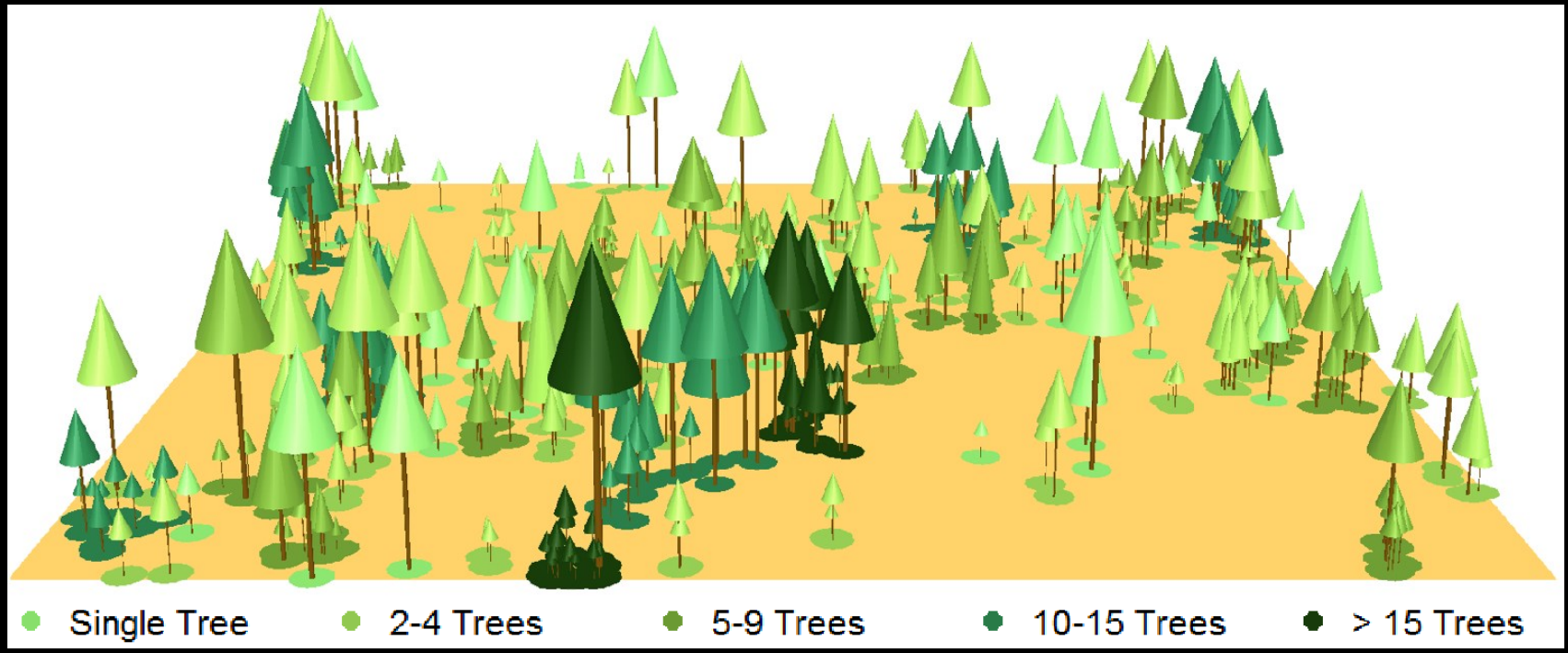






Visualizing Structure

- Each stand virtually rendered using SmokeView.
  - Trees were located and scaled according to their inventoried parameters.
  - Each tree was colored according to the clump size it belonged to.



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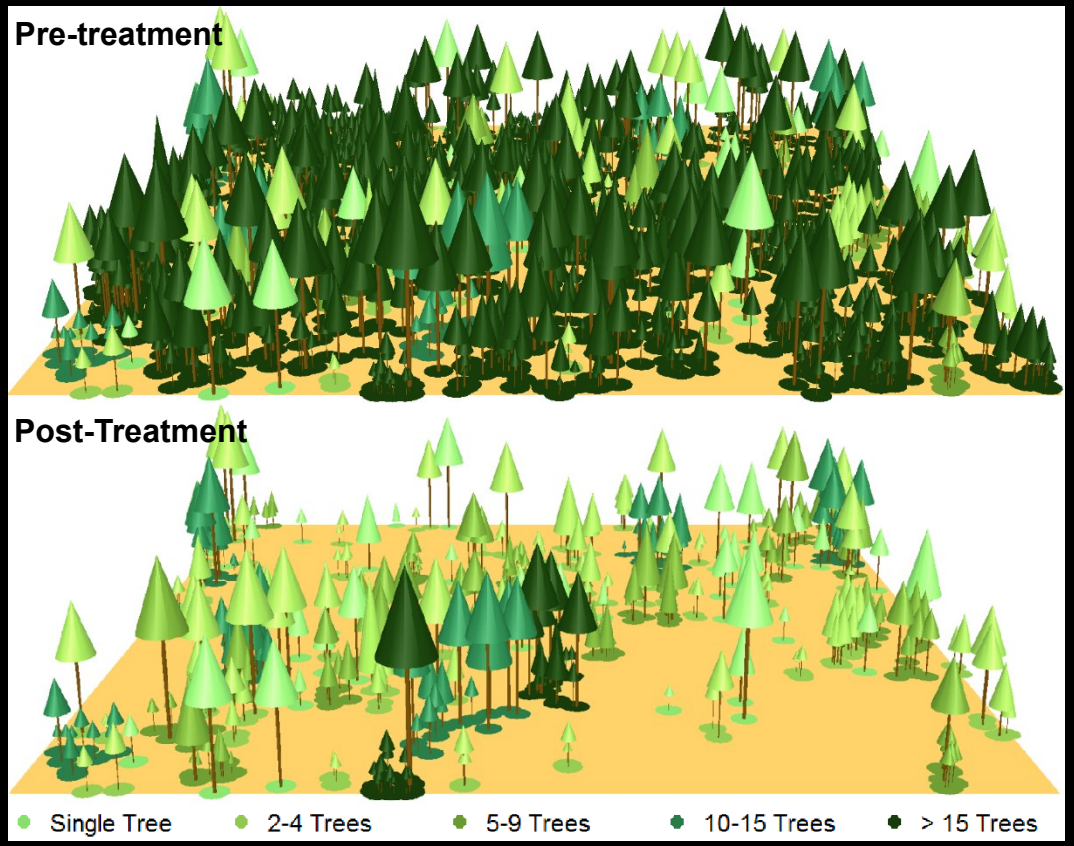
The Guide's Purpose

- Links quantitative descriptions & graphic visualizations of pre- and post-treatment forest structure.
  - Two purposes:
    - Identifying silvicultural targets related to spatial forest structure.
    - Facilitating communication of desired spatial structures among managers, stakeholders, and contractors.

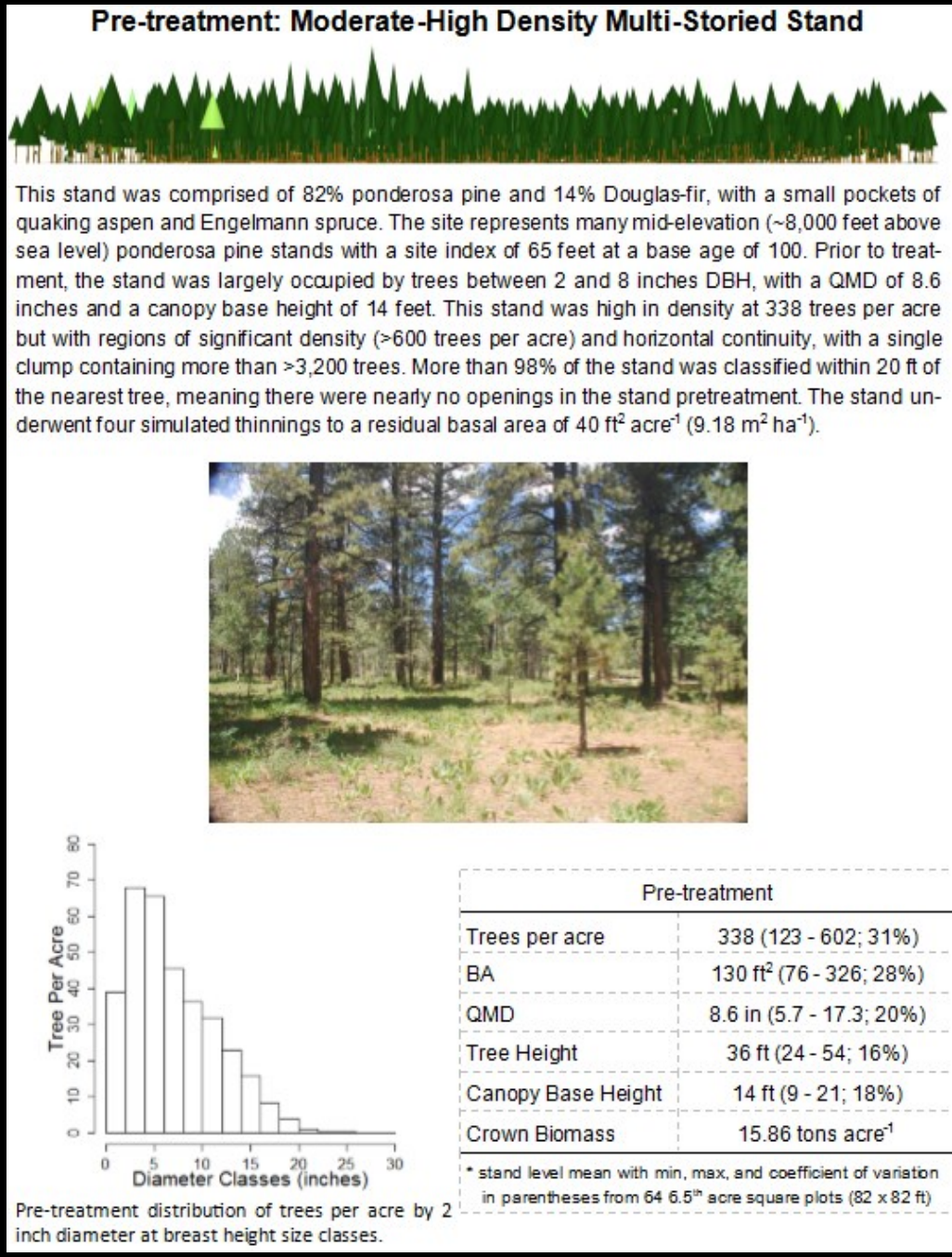
	Pre-Treatment	Post-Treatment
Trees per acre	204 (58 - 537; 48%)	48 (0 - 136; 67%)
BA per acre	131 ft^2 (15 - 249; 53%)	44 ft^2 (0 - 193; 76%)
QMD	11.4 in (5.2 - 20.1; 53%)	10.2 in (0.0 - 26.2; 76%)
Total Height	40 ft (24 - 72; 24%)	44 ft (24 - 85; 34%)
CBH	20 ft (13 - 38; 25%)	21 ft (3 - 40; 33%)
SDI	229	71
Crown Biomass	15.21 tons $acre^{-1}$	4.80 tons $acre^{-1}$

* stand level mean with min, max, and coefficient of variation in parentheses from 64 6.5th acre square plots (82 x 82 ft)



Pre-Treatment Stand

- 2 page description
  - Stand's position within the broader ecological context
  - Distribution of tree and stand structure metrics
  - Depiction of stand opening sizes
  - Distribution of clump sizes
  - Visualization of stand structure



Pre-treatment: Moderate-High Density Multi-Storied Stand

This stand was comprised of 82% ponderosa pine and 14% Douglas-fir, with a small pockets of quaking aspen and Engelmann spruce. The site represents many mid-elevation (~8,000 feet above sea level) ponderosa pine stands with a site index of 65 feet at a base age of 100. Prior to treatment, the stand was largely occupied by trees between 2 and 8 inches DBH, with a QMD of 8.6 inches and a canopy base height of 14 feet. This stand was high in density at 338 trees per acre but with regions of significant density (>600 trees per acre) and horizontal continuity, with a single clump containing more than >3,200 trees. More than 98% of the stand was classified within 20 ft of the nearest tree, meaning there were nearly no openings in the stand pretreatment. The stand underwent four simulated thinnings to a residual basal area of 40 ft^2 $acre^{-1}$ (9.18 m^2 ha^{-1}).

Pre-treatment distribution of trees per acre by 2 inch diameter at breast height size classes.

	Pre-treatment
Trees per acre	338 (123 - 602; 31%)
BA	130 ft^2 (76 - 326; 28%)
QMD	8.6 in (5.7 - 17.3; 20%)
Tree Height	36 ft (24 - 54; 16%)
Canopy Base Height	14 ft (9 - 21; 18%)
Crown Biomass	15.86 tons $acre^{-1}$

* stand level mean with min, max, and coefficient of variation in parentheses from 64 6.5th acre square plots (82 x 82 ft)

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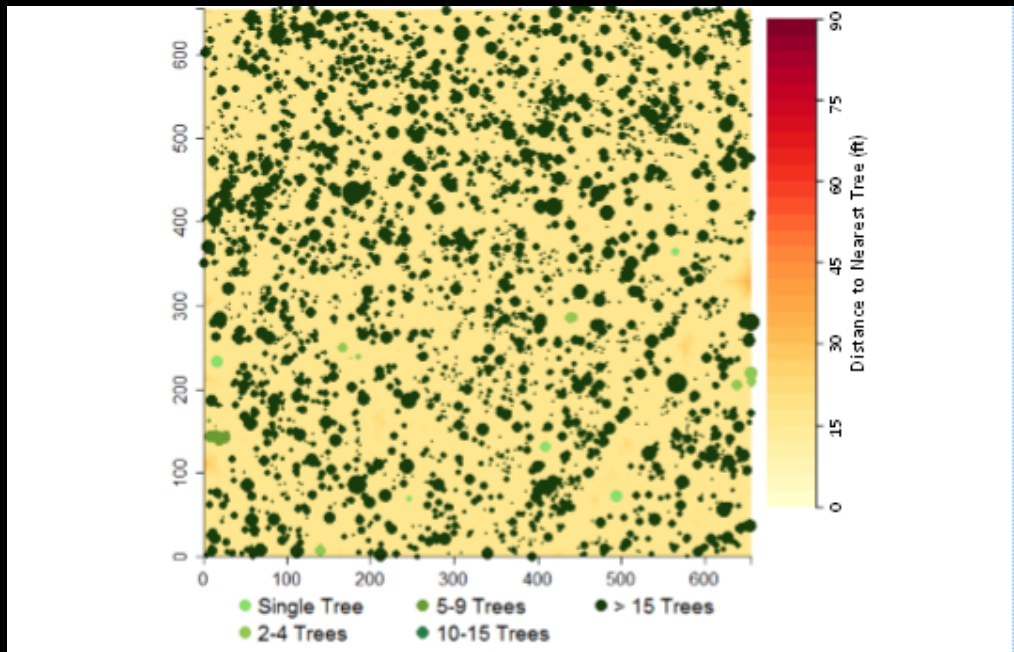
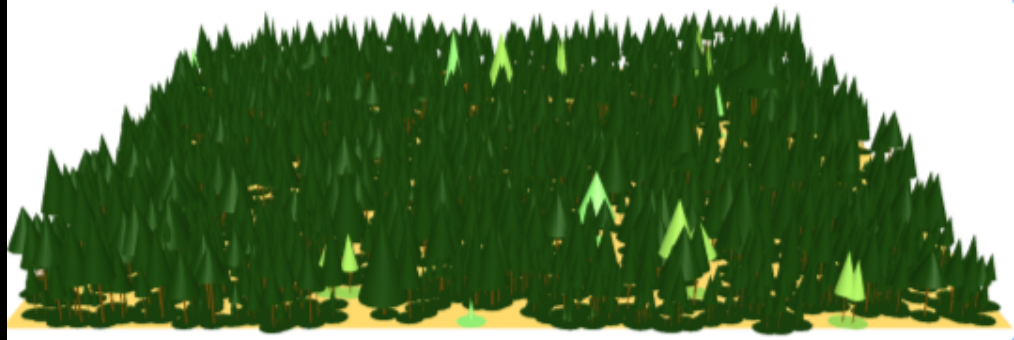


Clump Size	#/acre	% TPA	% BA
Single Tree	0.5	0.1	0.2
2-4 Trees	0.5	0.3	0.9
5-9 Trees	0.1	0.1	0.3
10-15 Trees	0.0	0.0	0.0
> 15 Trees	0.2	99.4	98.6

Visualization of the 9.9 acre stand, where the tree spatial pattern is projected with crown radii that represent field measured crown diameters and clump sizes are portrayed by different dot colors. The background coloring represents the distance to the nearest tree from the center of a 3.28 ft (1 m) cell grid (or the empty space function), in order to portray openings.

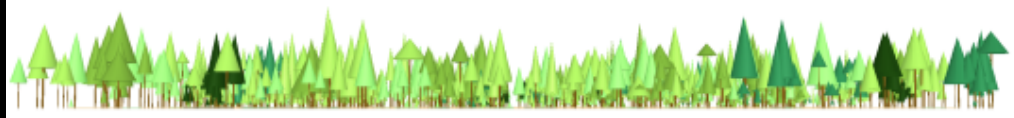


Virtual rendering of stand structure over the 9.9 acre area, where trees are scaled according to inventoried height, DBH, CBH, and crown widths and colored following the clumping scheme above.

Example Treatment

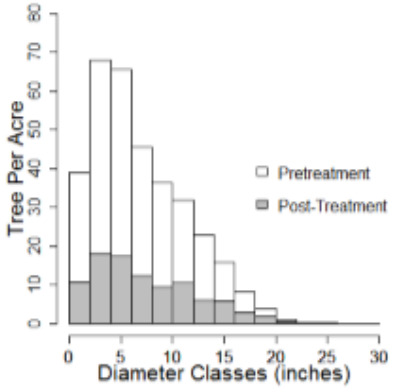
- 2 page description for each treatment alternative
  - Description of stand changes
  - Changes in distribution of tree and stand structure metrics
  - Changes in distribution of clump sizes
  - Comparison of stand openings
  - Comparison of stand visualizations

ICO Moderately Clumped Thinning to 40 ft^2 of Basal Area



A moderate clumping scenario following individual, clump, and opening thinning approaches attempts to increase the number of small clumps, and in this case resulted in a proportional removal of trees throughout the range of diameters and a small increase in stand level QMD from 8.6 to 8.9 inches. Following completion of the thinning, the stands canopy cover shifted from 94 to 60% and the variability in local basal area nearly doubled from 28 to 47%. Local variability in both horizontal and vertical tree structures saw small increases, which is in-line with the goals of ICO prescriptions. The horizontal continuity of the stand was greatly reduced as a result of the thinning.

- The stand went from being dominated by a single large clump to having single tree and clumps up to 9 trees occupy 83% of the trees in the stand.
- The thinning only resulted in a small shift in the proportion of the stand within openings, going from ~2 to 7%.



Comparison of trees per acre distribution within 2 inch diameter at breast height size classes.

	Pre	Post
Trees per acre	338 (123 - 602; 31%)	96 (39 - 188; 33%)
BA per acre	130 ft^2 (76 - 326; 28%)	41 ft^2 (10 - 139; 47%)
QMD	8.6 in (5.7 - 17.3; 20%)	8.9 in (5.9 - 18.1; 23%)
Total Height	36 ft (24 - 54; 16%)	36 ft (24 - 54; 19%)
CBH	14 ft (9 - 21; 18%)	14 ft (8 - 21; 22%)
SDI	236	72
Crown Biomass	15.86 tons acre^{-1}	5.10 tons acre^{-1}

* stand level mean with min, max, and coefficient of variation in parentheses from 64 6.5th acre square plots (82 x 82 ft)

	Pre			Post		
Clump Size	#/acre	% TPA	% BA	#/acre	% TPA	% BA
Single Tree	0.5	0.1	0.2	27.2	28.5	31.8
2-4 Trees	0.5	0.3	0.9	10.3	32.4	31.2
5-9 Trees	0.1	0.1	0.3	2.9	22.4	22.2
10-15 Trees	0.0	0.0	0.0	0.8	10.9	8.5
> 15 Trees	0.2	99.4	98.6	0.3	5.7	6.4

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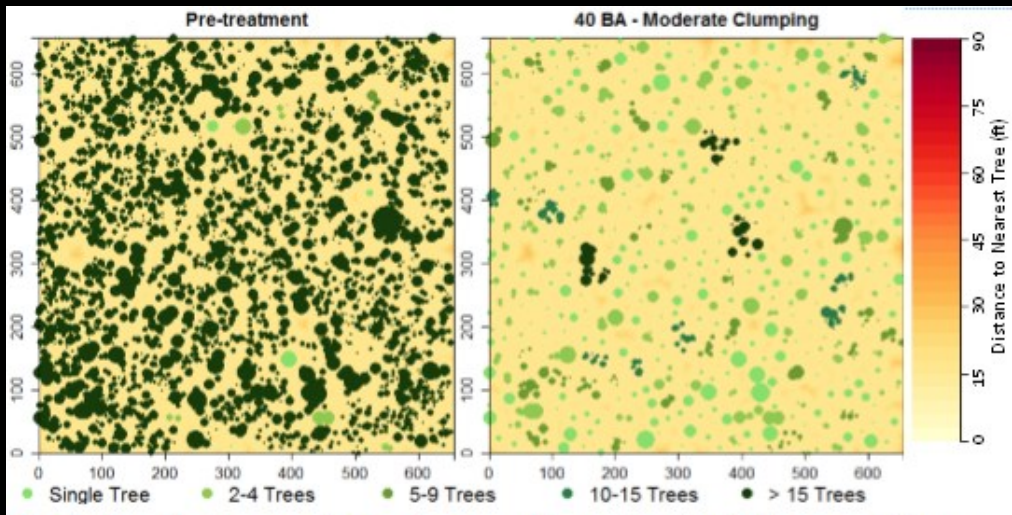
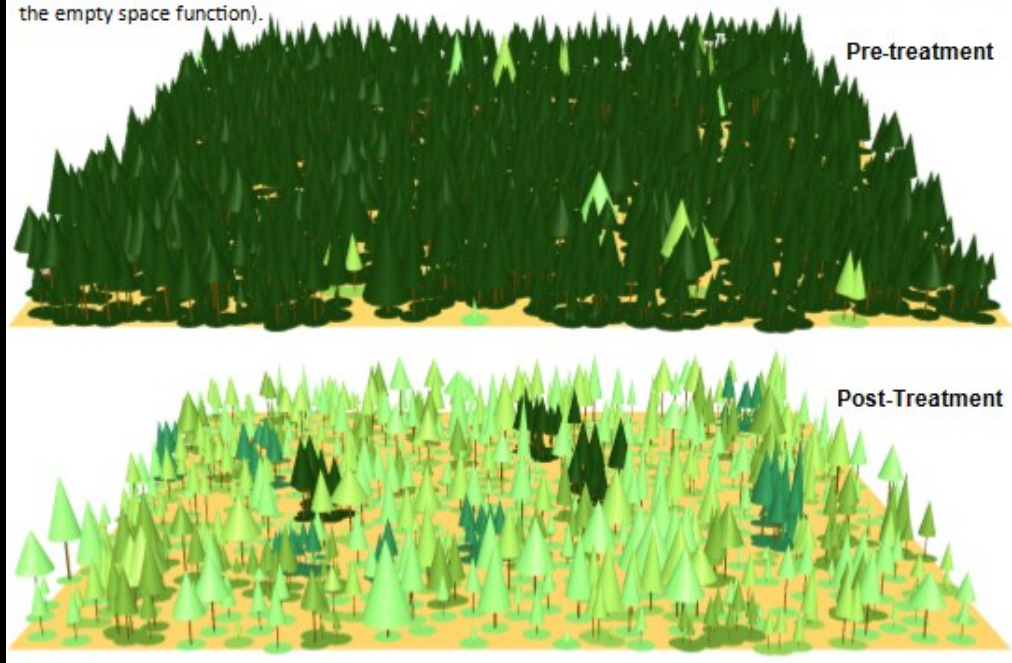


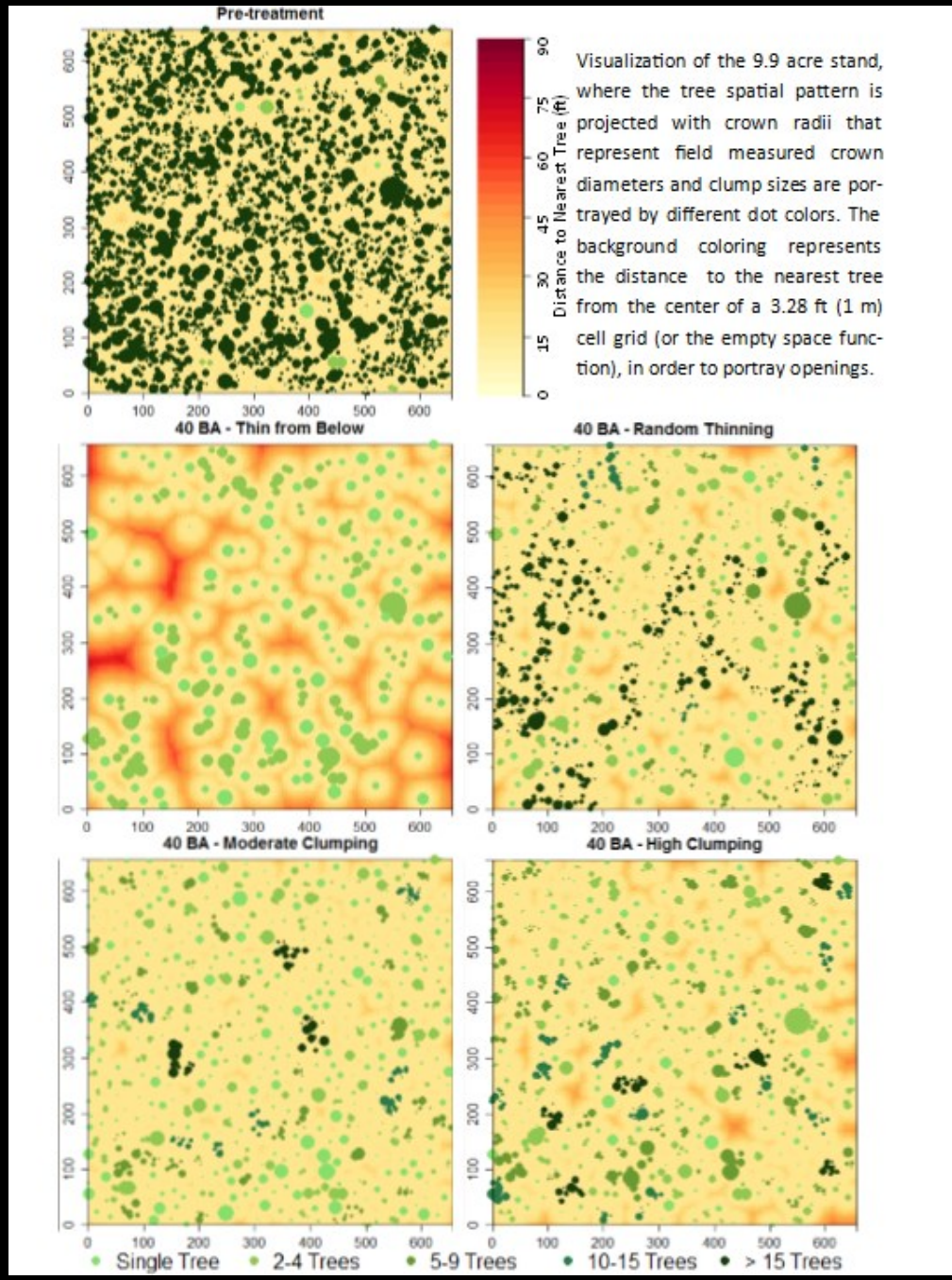
Visualization of the 9.9 acre stand, where the tree spatial pattern is projected with crown radii that represent field measured crown diameters and clump sizes are portrayed by different dot colors. The background coloring represents the distance to the nearest tree from the center of a 3.28 ft (1 m) cell grid (or the empty space function).



Virtual rendering of stand structure over the 9.9 acre area, where trees are scaled according to inventoried height, DBH, CBH, and crown widths and colored following the clumping scheme above.

Comparing Treatments

- 4 page synopsis
  - Visual comparison of stand openings and clump size distributions
  - Graphic comparison of opening sizes and description of treatment effects on stand arrangement
  - Visual comparison of stand structural variability
  - Summary of treatment effects on traditional and spatial forest structure metrics



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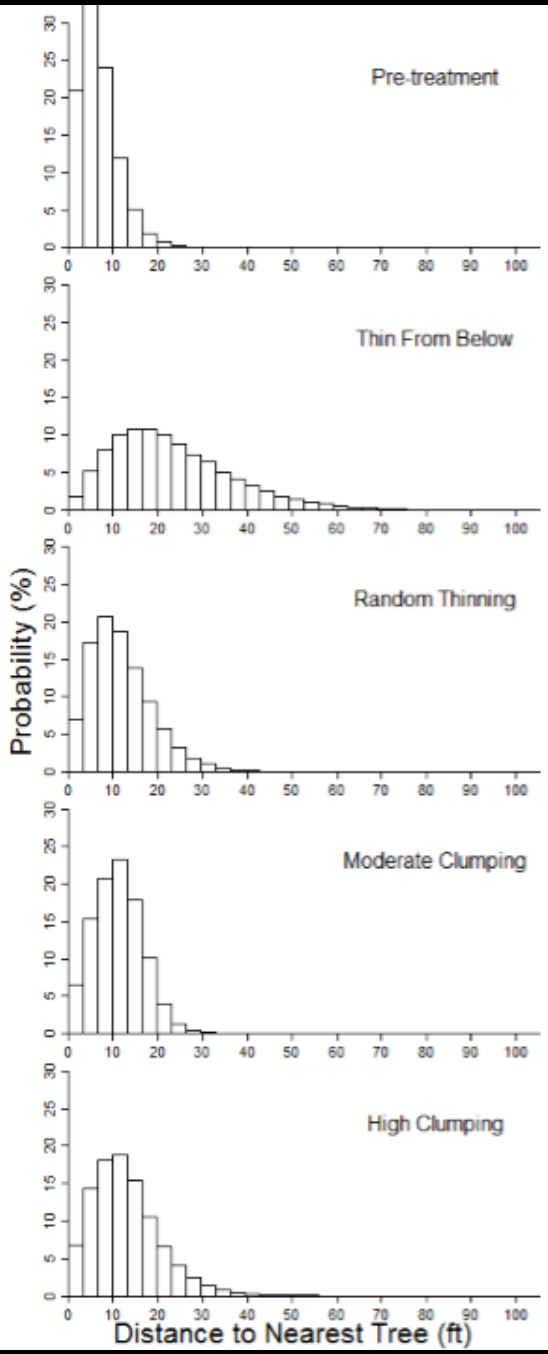

Histograms of the 3.28 ft cells used in the empty space function, showing the distribution of the distance to the nearest tree. Prior to treatment, 80% of the stand was within 10 ft of a tree, over 98% of the stand was within 20 ft of a tree, and the largest opening had a radius of 27 ft.

- Following treatment, all of the stands experienced some level of increased stand openness in terms of the number and size of openings.
- The thin from below simulation created the greatest shift in distribution, with 46 and 87% of the stand being within 20 and 40 ft of the nearest tree, respectively. However, the thin from below also produced the most simplistic vertical structure of all the treatments.
- The moderate clumping ICO treatment resulted in the smallest shift in mean stand opening sizes with only ~5% of the stand being more than 20 ft from the nearest tree.
- Both the random thinning and high clumping ICO treatments resulted in similar distributions of stand openings, with ~83 and 99% of the stand being within 20 and 40 ft of the nearest tree, respectively. The differences in these treatments is that the random thinning left over 50% of the trees in the stand in clumps of > 15 trees, while the high clumping ICO treatment distributed the remnant stand structures throughout all of the clump sizes.

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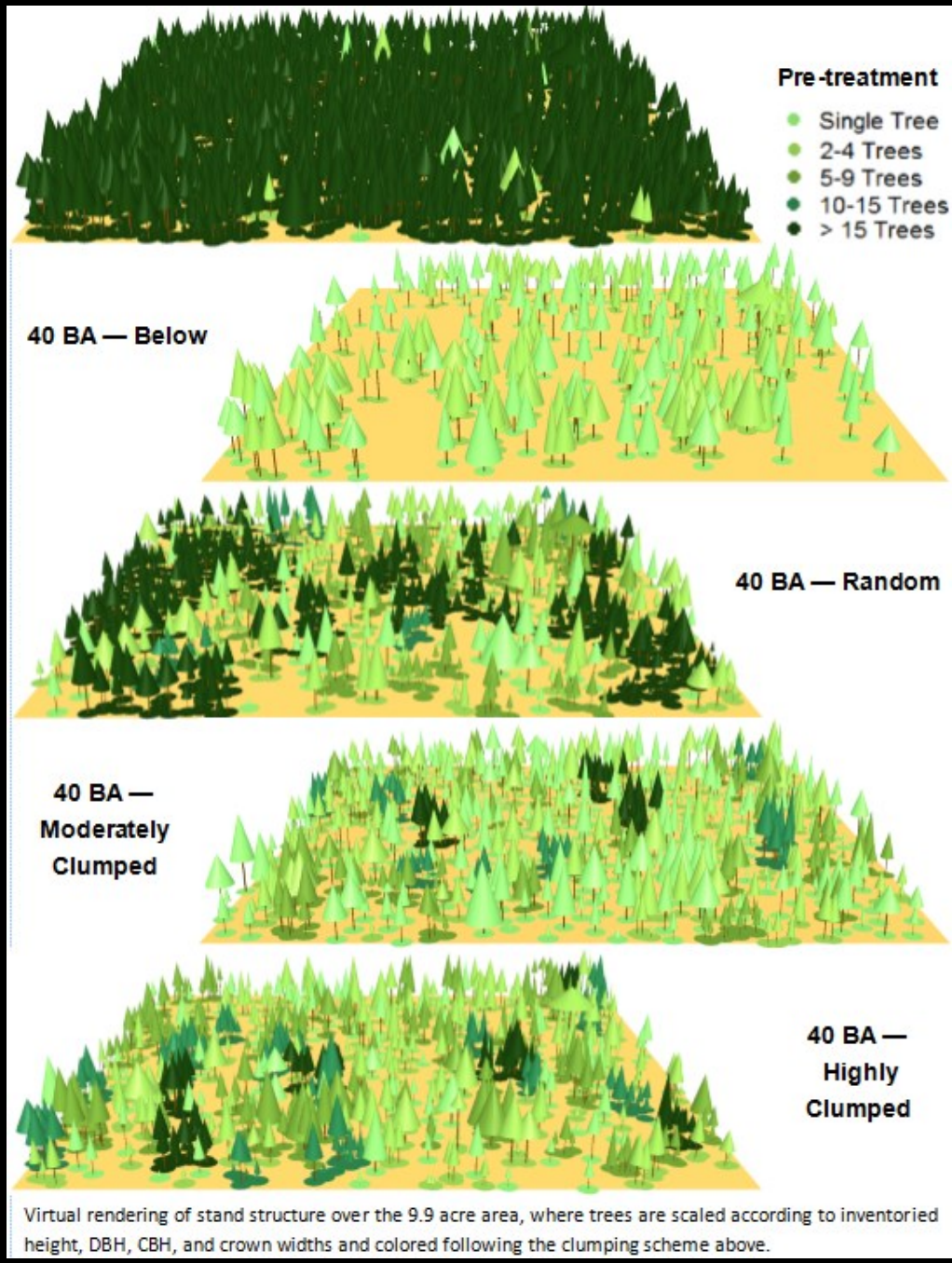

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Summary: Moderate-High Density Multi-Storied Stand

Prior to treatment, this stand had regions of significant density (>600 trees per acre) and horizontal continuity, with a single clump containing more than 3,200 trees. The stand was dominated by trees less than 8 inches DBH (64% of trees) and had a QMD of 8.6 inches. The stand also had only one opening that would meet the 20 ft requirement for stand openings.

- Following the simulated treatments, mean stand density was greatly reduced while increasing the relative variability of tree density in all but the thin from below simulations. This increase in variability is an important indicator of meeting horizontal heterogeneity treatment objectives.
- The moderate clumping ICO treatment struggled to meet both the basal area prescription and allocate trees into the prescribed clump sizes, potentially indicating that multiple entries may be needed to meet stand objectives.

	Pre-treatment	Thin from Below	Random Thinning	Moderately Clumped	Highly Clumped
Trees per acre	338 (123 - 602)	24 (0 - 52)	99 (26 - 188)	96 (39 - 188)	106 (39 - 266)
BA per acre	130 ft^2 (76 - 326)	40 ft^2 (0.0 - 259)	40 ft^2 (9 - 149)	41 ft^2 (10 - 139)	43 ft^2 (5 - 140)
QMD	8.6 in (5.7 - 17.3)	16.8 in (0.0 - 32.4)	8.7 in (4.7 - 21.7)	8.9 in (5.9 - 18.1)	8.6 in (4.3 - 19.0)
Mean Tree Height	36 ft (24 - 54)	65 ft (48 - 104)	36 ft (22 - 65)	36 ft (24 - 54)	36 ft (19 - 56)
Canopy Base Height	14 ft (9 - 21)	24 ft (12 - 41)	14 ft (7 - 29)	14 ft (8 - 21)	14 ft (7 - 21)
Crown Biomass	15.86 tons $acre^{-1}$	4.77 tons $acre^{-1}$	4.83 tons $acre^{-1}$	5.10 tons $acre^{-1}$	5.29 tons $acre^{-1}$

* stand level mean with min and max in parentheses from 64 6.5th acre square plots (82 x 82 ft)

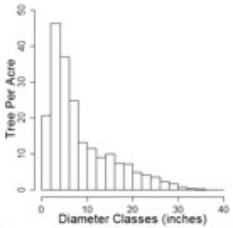
The pre-treatment stand condition placed most of the trees into a single very large and continuous clump of trees, containing more than 98% of the stands trees and basal area.

- The thin from below simulations drastically shifted the stand toward single tree or small clumps, while the random thinning left a majority of the stand (>50%) in clumps of > 15 trees.
- Following the simulated ICO treatments (Moderately and Highly Clumped) the structures within the stand were reallocated throughout all of the tree clump sizes, providing a balance of these structures helps to meet many restoration, wildlife, and fuels treatment objectives.
- The two ICO treatments differ in that the moderate clumping scenario resulted in less local variability in tree density, size, and vertical structure than the highly clumped treatment.

	Pre-treatment			Thin from Below			Random Thinning			Moderately Clumped			Highly Clumped		
Clump Size	# / acre	% TPA	% BA	# / acre	% TPA	% BA	# / acre	% TPA	% BA	#/ acre	% TPA	% BA	#/ acre	% TPA	% BA
Single Tree	0.5	0.1	0.2	11.3	47.9	44.0	7.2	7.2	11.0	27.2	28.5	31.8	10.4	9.9	10.5
2-4 Trees	0.5	0.3	0.9	4.6	52.1	56.0	6.3	17.5	20.8	10.3	32.4	31.2	8.7	29.2	33.5
5-9 Trees	0.1	0.1	0.3	0.0	0.0	0.0	2.7	17.5	19.4	2.9	22.4	22.2	5.5	34.8	33.4
10-15 Trees	0.0	0.0	0.0	0.0	0.0	0.0	0.5	5.6	5.8	0.8	10.9	8.5	10.6	15.9	13.4
> 15 Trees	0.2	99.4	98.6	0.0	0.0	0.0	1.4	52.1	43.1	0.3	5.7	6.4	0.6	10.2	9.1

Visualization guide to heterogeneous forest structures following treatment in the southern Rocky Mountains

Wade T. Tinkham, Yvette Dickinson, Chad M. Hoffman, Mike A. Battaglia, Seth Ex, and Jeff Underhill



Questions?