RESTORATION OF SOUTHWESTERN FREQUENT FIRE FORESTS:
MIXED CONIFER CONSIDERATIONS

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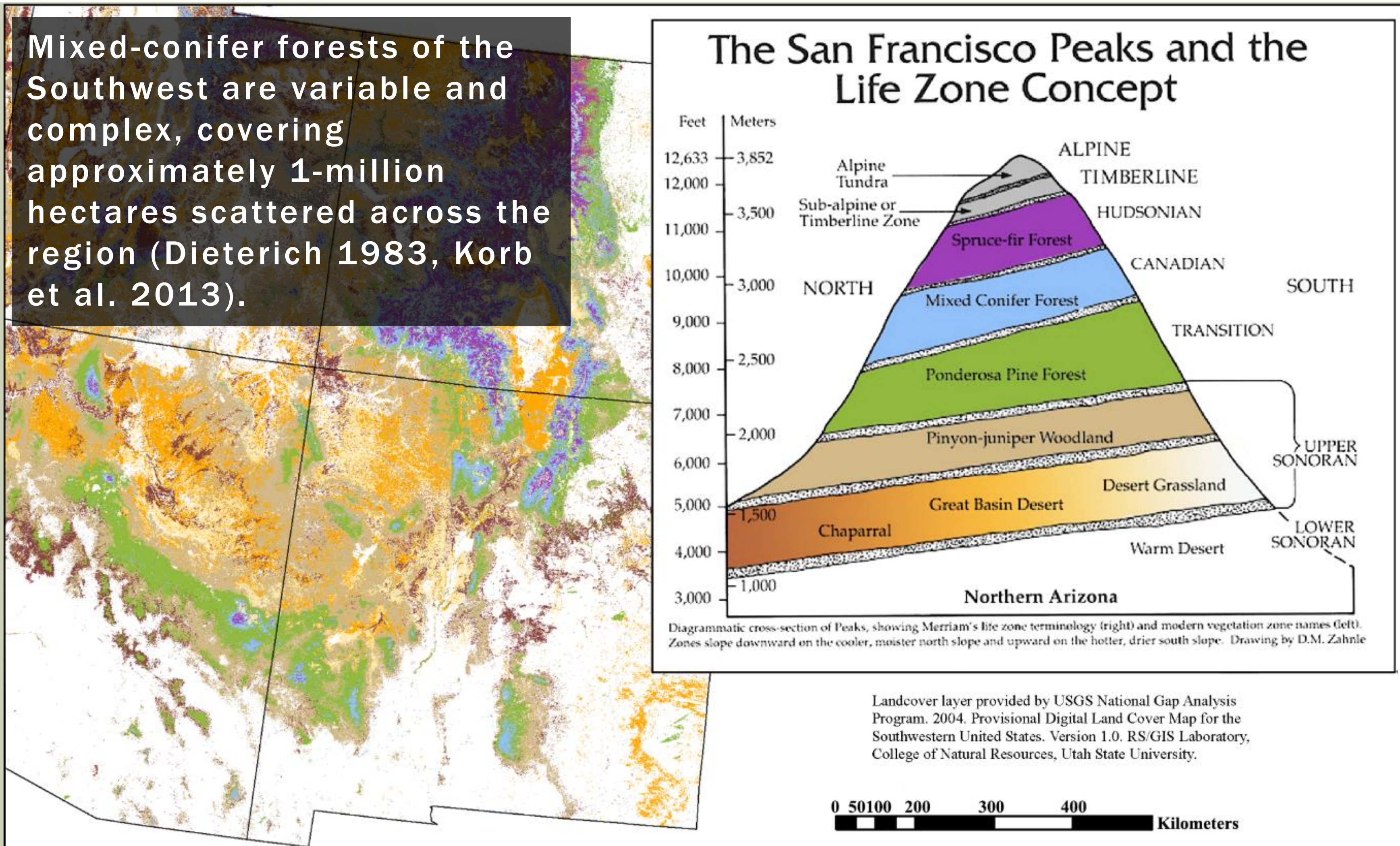
Desired conditions workshop participants look around a mixed conifer forest on the Santa Fe NF, NM.
photo: Sánchez Meador

OVERVIEW

- What is Mixed Conifer?
- Reference conditions in Mixed Conifer
- Following-up on GTR-310
- Future Directions

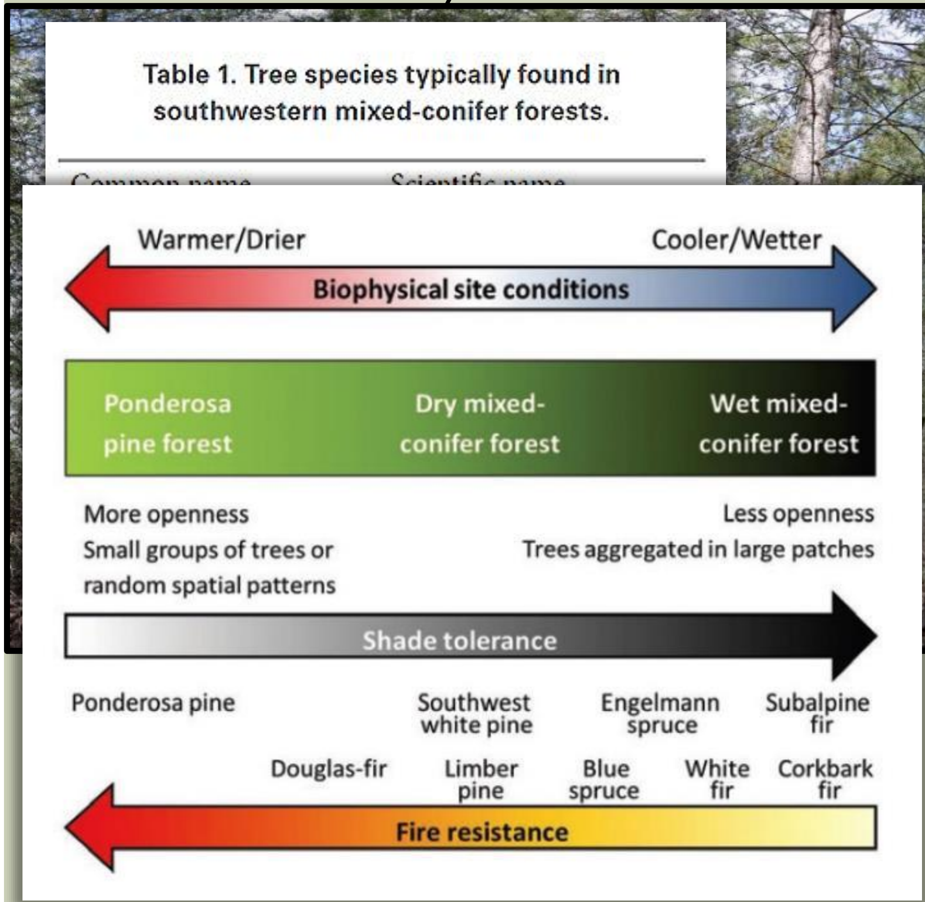
WHAT IS MIXED-CONIFER…?

Mixed-conifer forests of the Southwest are variable and complex, covering approximately 1-million hectares scattered across the region (Dieterich 1983, Korb et al. 2013).



SOUTHWESTERN MIXED-CONIFER

Cool/Moist



Warm/Dry

Margolis, E.Q., Huffman, D.W., and J.M. Iniguez. 2013. Working Paper 28: Southwestern Mixed-Conifer Forests: Evaluating Reference Conditions to Guide Ecological Restoration Treatments. Ecological Restoration Institute, NAU, Flagstaff, AZ. 12 pp.

Reynolds, R.T., Sánchez Meador, A.J., Youtz, J.A., Nicolet, T., Matonis, M.S., Jackson, P.L., DeLorenzo, D.G., and A.D. Graves. 2013. Restoring composition and structure in southwestern frequent-fire forests: a science-based framework for improving ecosystem resiliency. United States Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, United States.

GTR-310 AND STRUCTURE

Table 9. Historical forest structure of dry mixed-conifer forests of the Southwest, arranged by parent material and average tree density.

Location	Parent material	Elevation (ft)	Size/age reported	Reference date	Trees per acre			Basal area (ft^2/acre)			Citation
					Range	Mean	Std Err	Range	Mean	Std Err	
San Francisco Peaks-East, Arizona	Basalt	8318	Age	1892		20.9	3.4		39.6	3.9	Heinlein and others 2005
San Francisco Peaks-West, Arizona	Basalt	8318	Age	1876		21.0	1.7		54.0	6.1	Heinlein and others 2005
Sitgreaves National Forest, Arizona (max)[a]	Basalt	6300	Size	1910		31.0			66.9		Woolsey 1911
San Francisco Peaks, Arizona	Basalt	9200	Age	1876		65.1	6.8		77.9	12.8	Cocke and others 2005
Blue and White Mountains, Arizona[b]	Basalt	8950	Size	1912		68.7			84.4		Greenamyre 1913
Middle Mountain, Colorado	Granitic	8520	Size	1870	51-59	57.3	4.0	43-60	47.9	4.6	Fulé and others 2009
Jemez, New Mexico (max)[a]	Limestone	7013	Size	1910		35.6			91.2		Woolsey 1911
Kaibab Plateau, New Mexico[c]	Limestone	7500	Size	1909		45.3			60.7		Lang and Stewart 1910
Alamo, New Mexico (max)[a]	Limestone	8650	Size	1910		46.5			97.9		Woolsey 1911
Gila, New Mexico[a]	Limestone	9055	Age/Size	1890		65.6					Moore and others 2004

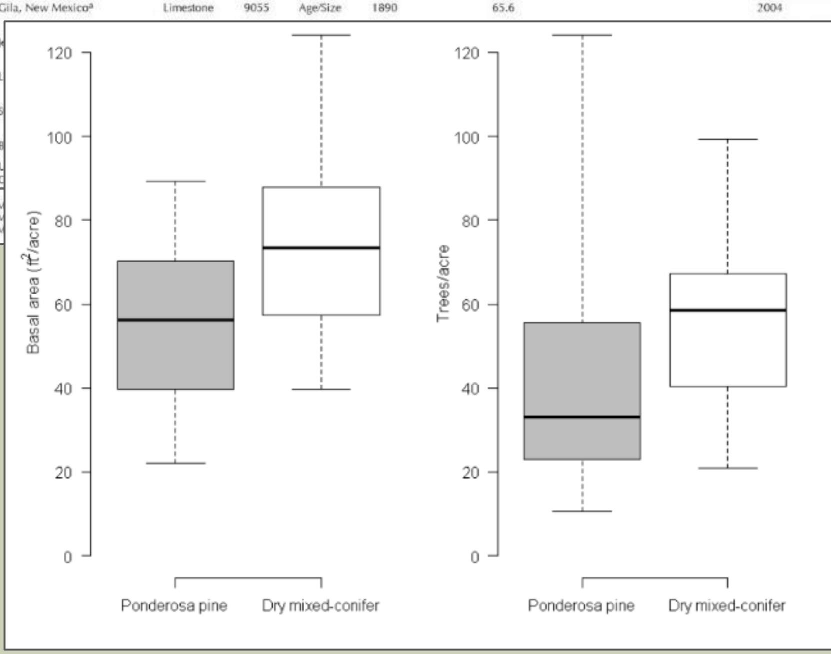
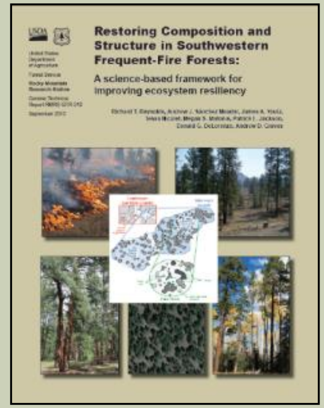
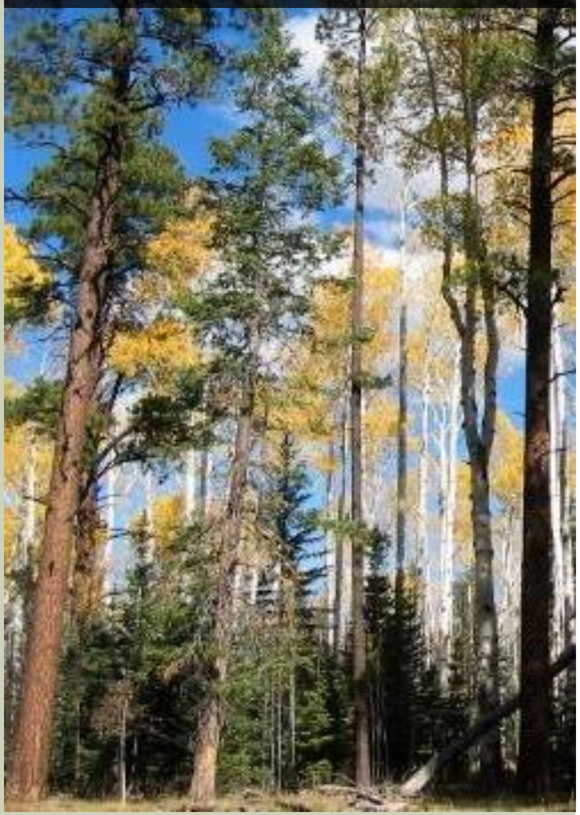


Figure 17. Distribution of reference conditions reported in Tables 6 and 9 for basal area and trees per acre in ponderosa pine and dry mixed-conifer forests. Lines bisecting boxes represent median values; lower and upper borders of boxes represent first and third quartile values; and whiskers (i.e., endpoints of dashed lines) represent maximum and minimum reported values.



Reynolds, R.T., Sánchez Meador, A.J., Youtz, J.A., Nicolet, T., Matonis, M.S., Jackson, P.L., DeLorenzo, D.G., and A.D. Graves. 2013. Restoring composition and structure in southwestern frequent-fire forests: a science-based framework for improving ecosystem resiliency. United States Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, United States.

photo: Sánchez Meador



GTR-310 AND SPATIAL PATTERNS

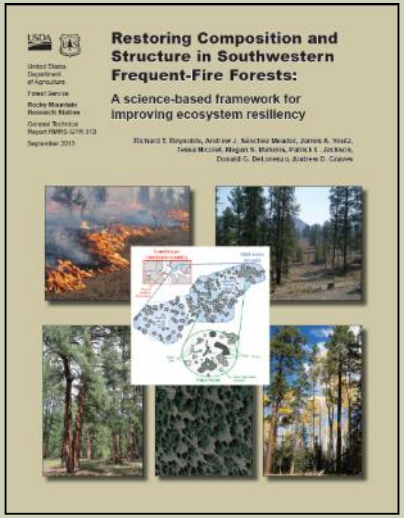
Table 3. Historical spatial patterns and tree group characteristics in frequent-fire forests of the Southwest, arranged by forest type (PP: ponderosa pine, PO: pine-oak, DMC: dry mixed-conifer).

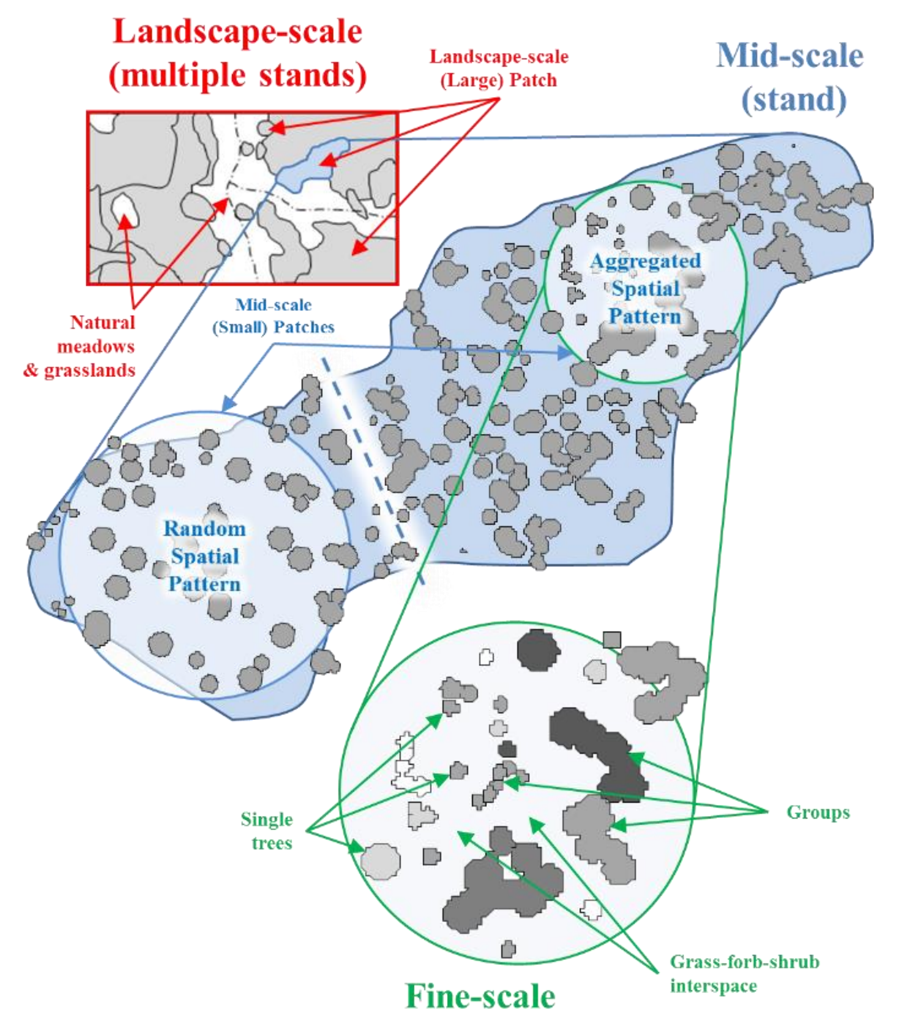
Location	Parent material	Elevation (ft)	Forest type	Reference date	Tree sizes (dbh in inch.)	Group density (groups/acre)	Group size (acres)	Trees per group[a]	Percent basal area in groups	Citation
Malay Gap, Arizona	Basalt	7200	PP	1952	≥ 4.0		0.16-0.32			Cooper 1960
Gus Pearson Natural Area, Arizona	Basalt	7398	PP	1875	Unknown		0.05-0.72	3-44		White 1985
Flagstaff, Arizona	Varying	7800	PP	1880	Unknown	1-33		2-25	28%-74%	Abella and Denton 2009
Woolsey Plots, Arizona	Basalt	7052	PP	1874	≥ 3.5	25-67	0.003-0.09	3-24	62%-75%	Sánchez Meador and others 2011
Coulter Ranch, Arizona	Basalt	7520	PO	1913	≥ 3.5		0.01-0.1			Sánchez Meador and Moore 2010
Uncompahgre Plateau, Colorado	Shale	8000	PP / DMC	1875	Unknown		0.1-0.25			Binkley and others 2008
Numerous national forests in Arizona and New Mexico	Varying	8650	PP / PO / DMC	1910	≥ 3.5	24-80	0.01-0.32	2-72	51%-85%	Sánchez Meador and others unpublished data[b]

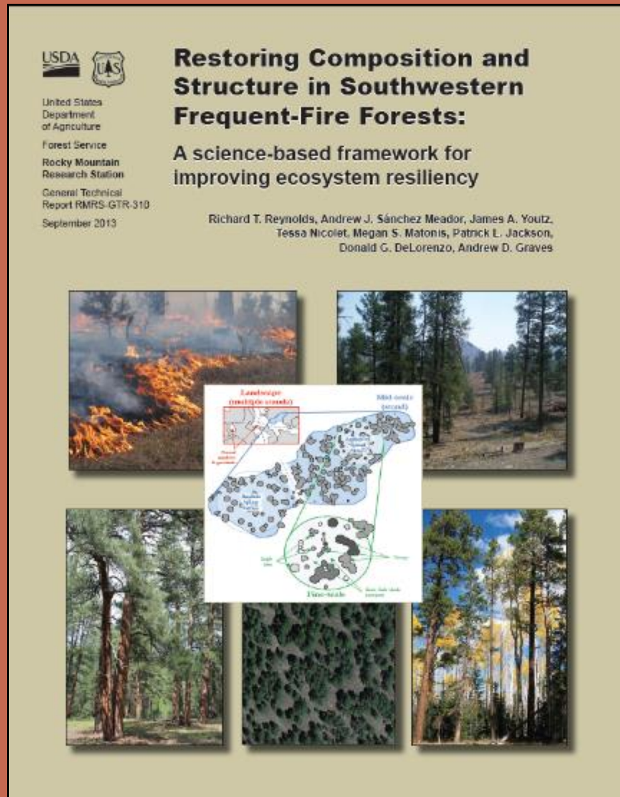
[a]Values should be not interpreted as "strict" densities of trees within groups as authors used different definitions and methods to define and characterize "groups." We suspect that as the number of species and site productivity increase the metric of "tree group" becomes less useful than this metric at the mid- to landscape-scale. For example, when tree density is fixed and numbers of tree species varies (i.e., compare ponderosa pine vs. ponderosa-pine Gambel oak vs. dry-mixed conifer forests), the area available to a "tree group" will likely decrease.

[b]Data based on 2.47-acre plots reconstructed prior to Euro-American settlement (1876-1890) in Arizona (n = 17 plots) and New Mexico (n = 7 plots) using the same methods as Sánchez Meador and others (2010, 2011). Historical and contemporary field methods, as well as contemporary conditions, are detailed in Sánchez Meador and others (2010) and Moore and others (2004) who reported forest structural reference conditions (size distributions, tree density ranges, spatial patterns, etc.) on a subset of these same plots. In brief, all live and dead tree structures were measured, including stumps, snags, and wind-fallen trees, that grew to at least breast height (4.5 ft). All tree structures were located using historical stem-maps and measured spatial coordinates, and dendrochronological reconstructions were used to quantify structural and spatial reference conditions (Baker and others 2008; Sánchez Meador and others 2010). Spatial attributes (e.g., group size and density) were quantified using methods described in Sánchez Meador and others (2011).

Figure 16. Aerial photo of a dry mixed-conifer forest on a north-facing slope in the Cibola National Forest. In this stand, about 60-70 percent of the area is under mid- to old-age tree cover and 30-40 percent is in grass-forb-shrub interspaces.







FOLLOWING-UP ON GTR-310

Although much is known about historical forest composition, structure, and disturbance in frequent-fire forests, our knowledge of the mechanisms of spatial pattern formation and maintenance is limited, indicating a research need (Larson and Churchill 2012). A limited understanding of reference conditions on different parent material, especially in dry mixed-conifer, is an important data limitation for designing and implementing appropriate resource management. While the number of reference data sets is increasing, existing data have focused largely on tree density. There is a clear need for studies on spatial patterns and the sizes and shapes of grass-forb-shrub interspaces, as well as the mechanisms for the formation and maintenance of spatial patterns. Additional research needs are:

- Increased understanding of reference conditions and the natural range of variation across ecological gradients such as latitude and longitude, soils, topography, and climate in Southwest frequent-fire forests, especially in dry mixed-conifer.
- Increased understanding of differences between ponderosa pine and dry mixed-conifer forests in reference conditions and the historical types, frequencies, severities of disturbances, and responses of vegetation. Of particular need are:

  (1) A greater understanding of variation of reference conditions (composition, structure, and spatial pattern) in forest subtypes and different plant associations.

  (2) How reference conditions influenced the effects of fire on tree regeneration and mortality in forest subtypes and in the transition zones between subtypes.

  (3) The effectiveness of restoration treatments at achieving desired objectives, especially on avoiding the conversion of these subtypes to alternative plant associations.
- Increased understanding of ecosystem processes and functions as they respond to restoration of the composition and structure of frequent-fire forests.

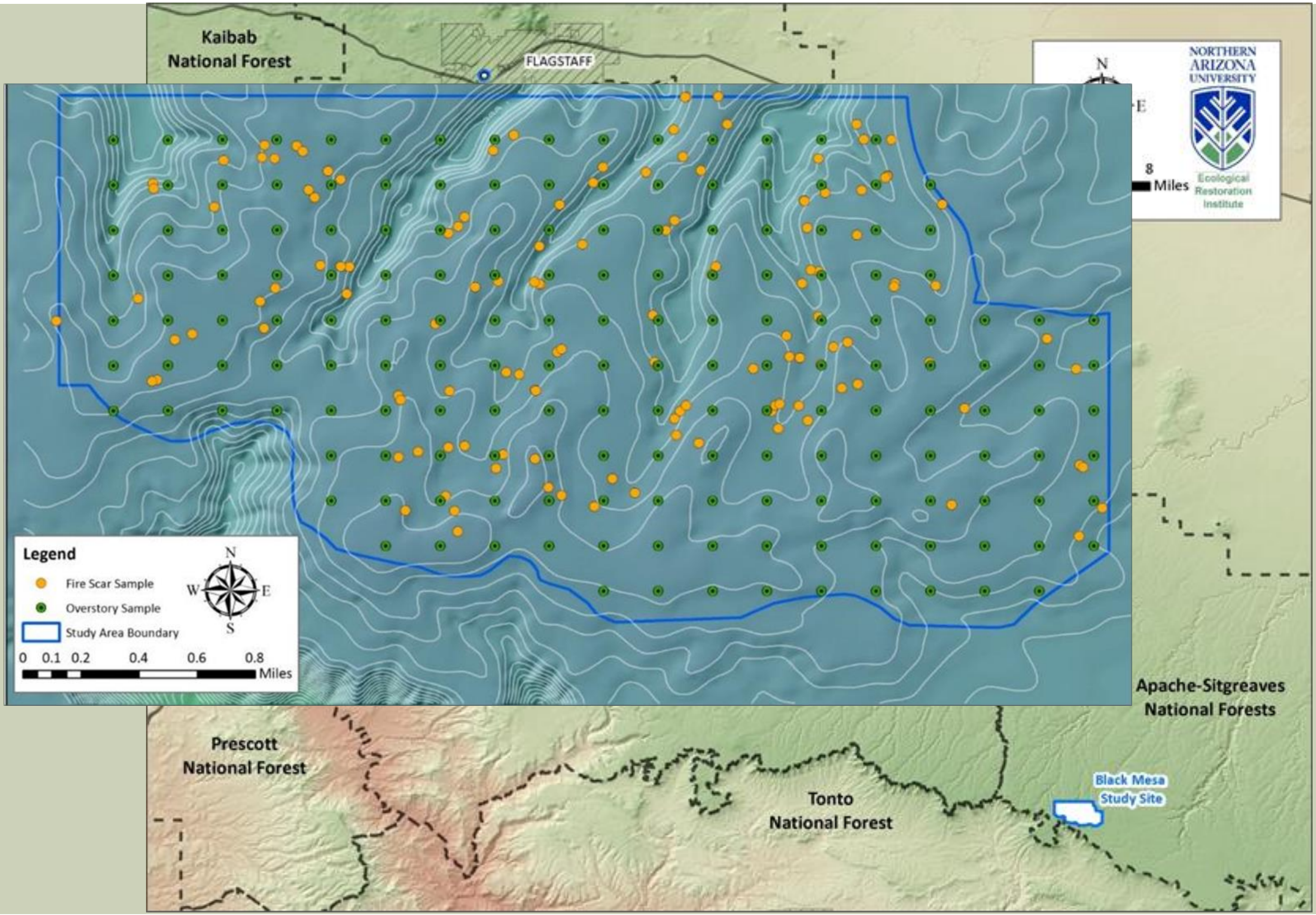
GENERAL OUTLINE

- Historical Conditions and Recent Changes
  - Black Mesa
  - Southwestern Patterns
- Responses to Restoration Treatments
  - Pagosa (LEARN)
  - Wallow Fire
- Anticipated Future Conditions
  - Pagosa (Again)
- Future Directions

Mineral LEARN site Rx –the study was terminated following 2014 San Juan Fire
photo: JP. Roccaforte

View of the Rockies through a Mixed conifer forest on the San Juan NF, Co.
photo: M. Stoddard

BLACK MESA: STUDY SITE



BLACK MESA: FIRE CHRONOLOGY

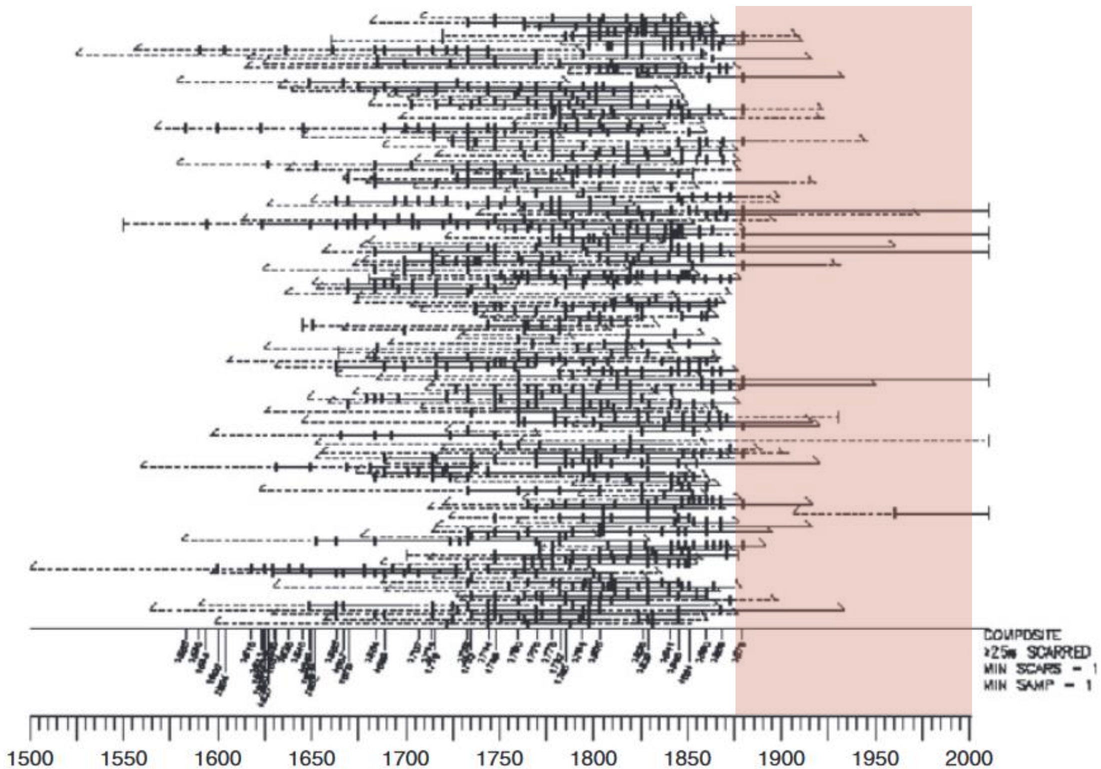


Fig. 1. Composite fire history showing all years for which fire scars (vertical lines) were found on partial cross-section samples from individual trees (horizontal lines). Dates shown below composite dataset are for fires scarring ≥25% of the recording samples. Recording years (solid horizontal lines) began with earliest fire date identified on a sample and continued through subsequent years presumed to be susceptible to further fire scarring (see Methods for details).

- Composite Fire Scars (1670-1879):
  - n = 133
  - 1023 fire scars;
  - 104 unique fire dates;
- Descriptive Statistics:
  - 25% scarred:
  - MFI 8.5 (5.4 SD);
  - Weibull Median Probability Interval 8.0 (range 2-23)

Huffman, D.W., T.J. Zegler, and P.Z. Fulé. 2015. Fire history of a mixed conifer forest on the Mogollon Rim, northern Arizona, USA. *International Journal of Wildland Fire* 24:680-689

BROWN ET AL. 2001

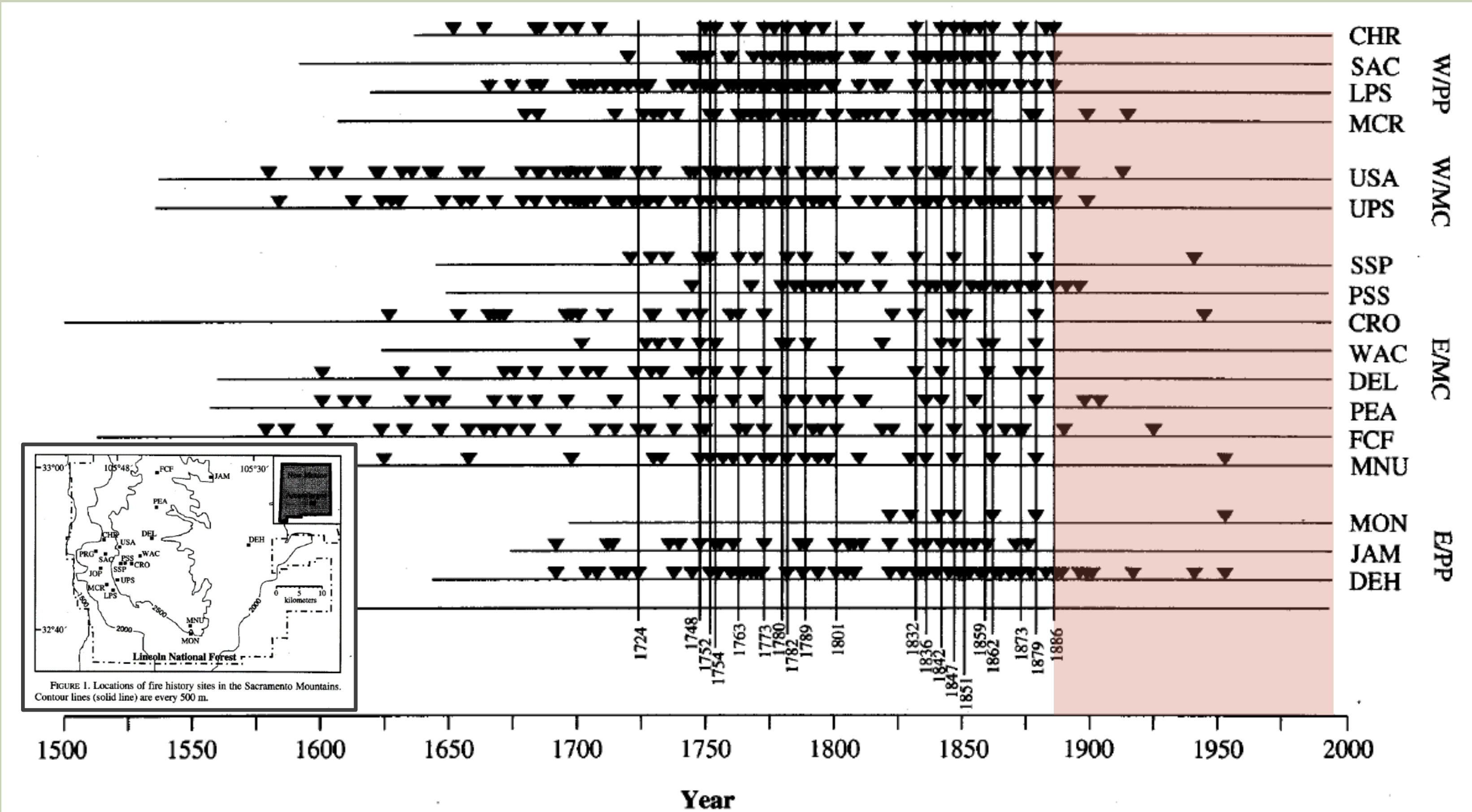


FIGURE 5. Landscape fire years (vertical lines) recorded by trees in ≥ 25% of the 17 ponderosa pine (PP) and mixed-conifer (MC) sites on the west (W) and east (E) sides. Time spans of fire chronologies are represented by horizontal lines with fire dates represented by inverted triangles.

Brown, P.M., M.W. Kaye, L. Huckaby, and C. Baisan. 2001. Fire history along environmental gradients in the Sacramento Mountains, New Mexico: Influences of local patterns and regional processes. Écoscience 8:115-126.

BLACK MESA: STRUCTURE AND FUNCTION

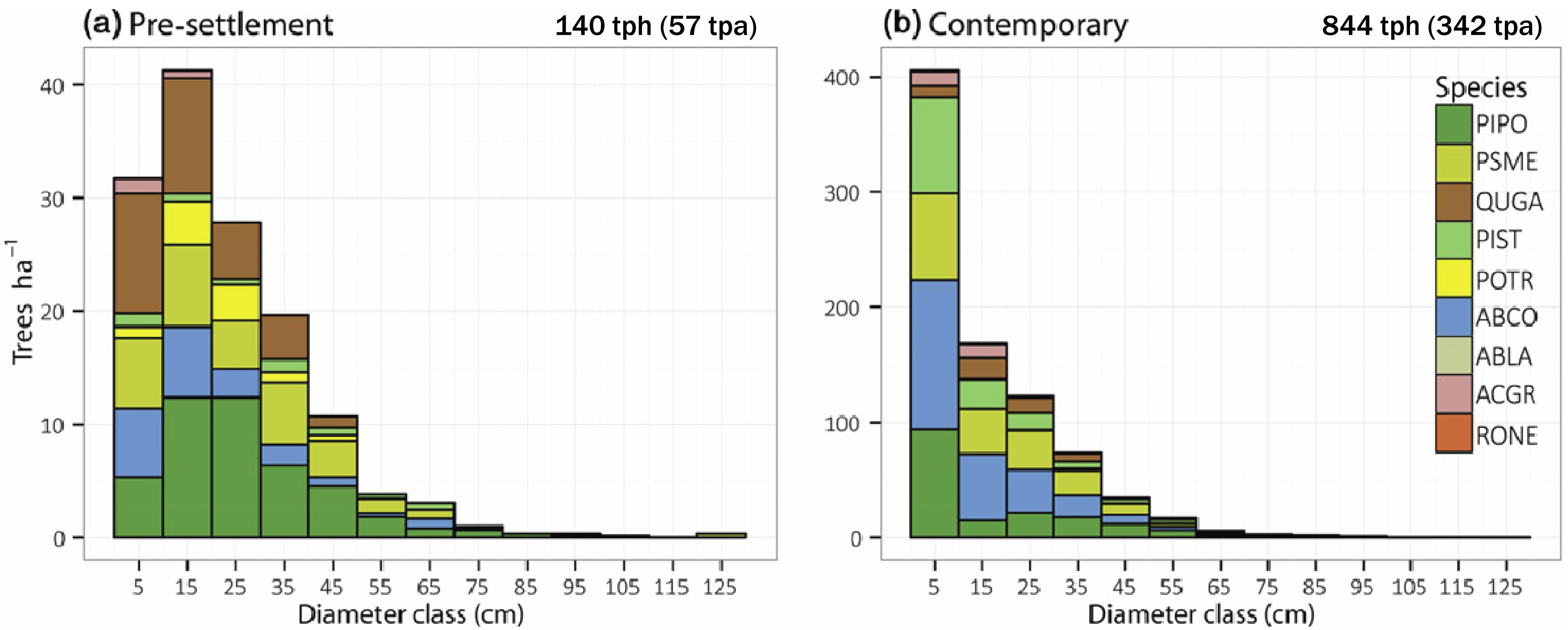


Fig. 2. Species-specific diameter distributions in (a) pre-settlement (1880) and (b) contemporary (2011) time periods. The list of species is sorted by fire tolerance from highest to lowest. Note the order of magnitude difference between y-axes in panels a and b.

Strahan, R.T., Sánchez Meador, A.J. Huffman, D.W., and D.C. Laughlin. 2016. Shifts in community-level traits and functional diversity in a mixed conifer forest: a legacy of land-use change. Journal of Applied Ecology. doi:10.1111/1365-2664.12737

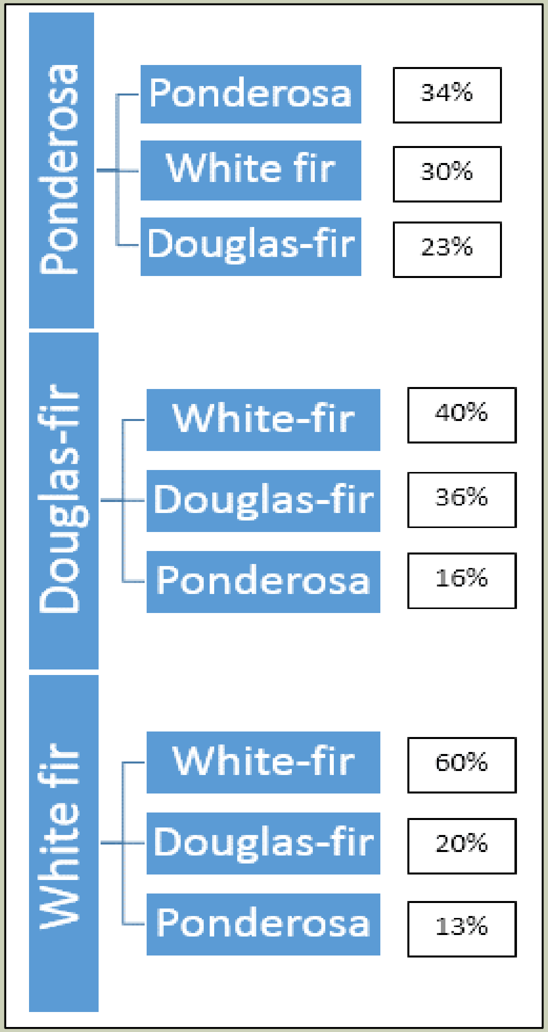
BLACK MESA:
STRUCTURE AND FUNCTION

Dense mixed conifer forest on the Black mesa RD, Apache-Sitgreaves NF AZ.
photo: D. Huffman

53% -> 23%

17% -> 26%

10% -> 38%



Strahan, R.T., Sánchez Meador, A.J. Huffman, D.W., and D.C. Laughlin. 2016. Shifts in community-level traits and functional diversity in a mixed conifer forest: a legacy of land-use change. Journal of Applied Ecology. doi:10.1111/1365-2664.12737

BLACK MESA:
STRUCTURE AND FUNCTION

Presettlement remnant on the Mogollon Rim RD, AZ
photo: Sánchez Meador

Strahan, R.T., Sánchez Meador, A.J. Huffman, D.W., and D.C. Laughlin. 2016. Shifts in community-level traits and functional diversity in a mixed conifer forest: a legacy of land-use change. Journal of Applied Ecology. doi:10.1111/1365-2664.12737

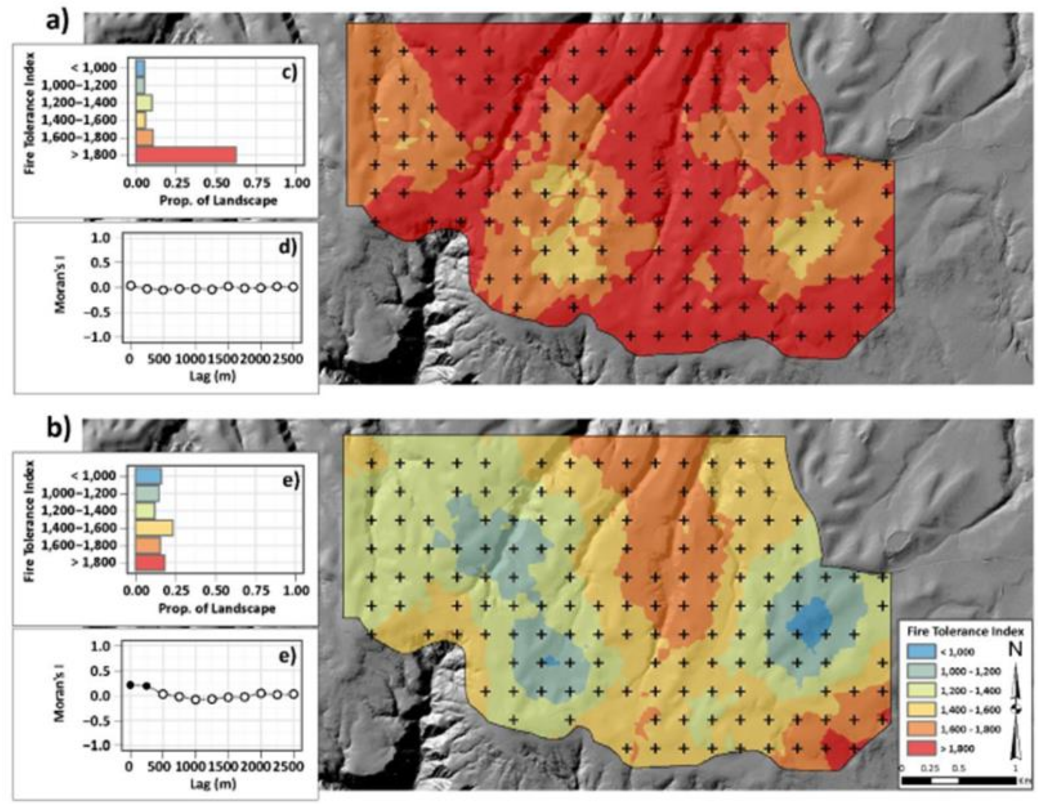


Fig. 3. Inverse distance weighted interpolation of fire tolerance index in 1880 (a) and 2011 (b) and corresponding plot-level landscape proportions (n = 146) and spatial autocorrelograms for six classes of fire tolerance index. For the latter, black circles indicate significance in autocorrelation ($p < 0.001$) for the given lag.

SOUTHWESTERN PATTERNS

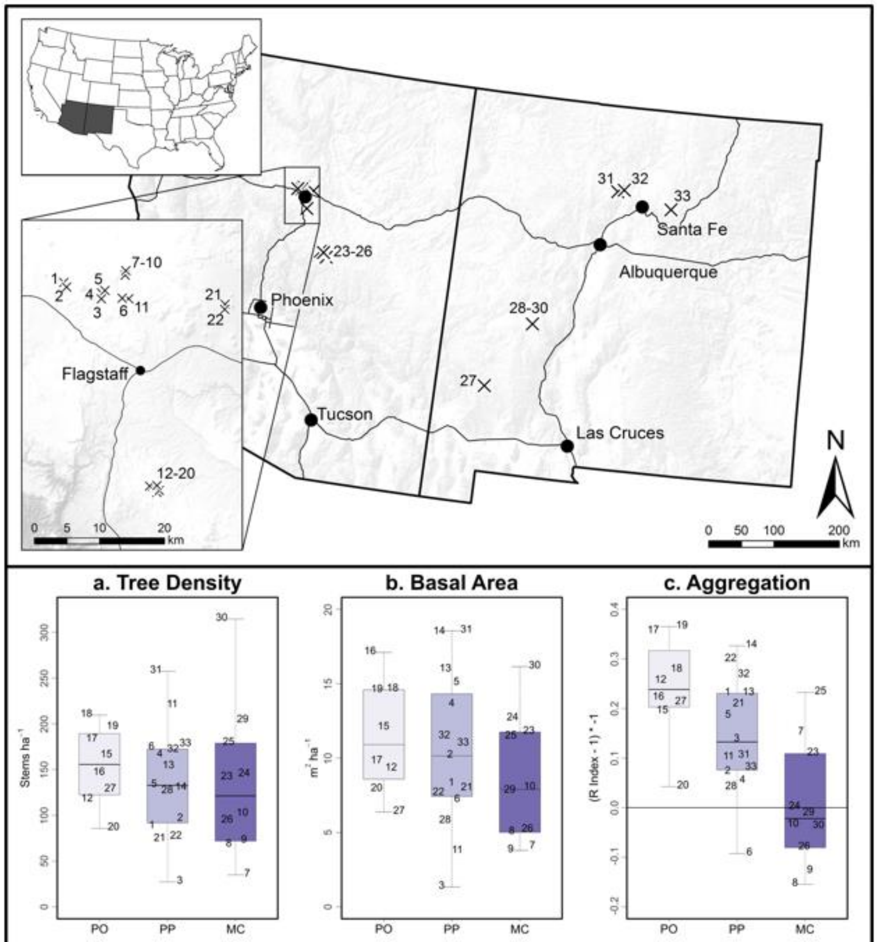


Figure 1 – Map of study area and plot locations in Arizona and New Mexico, USA, and summary boxplots showing estimated historical ranges in density (a, b) and spatial pattern (c). Boxplots are separated by forest types - pine-oak (PO), ponderosa pine (PP), and mixed-conifer (MC). Numbers 1-33 are centered upon individual plot values for density and spatial pattern and correspond with numbers on site map.

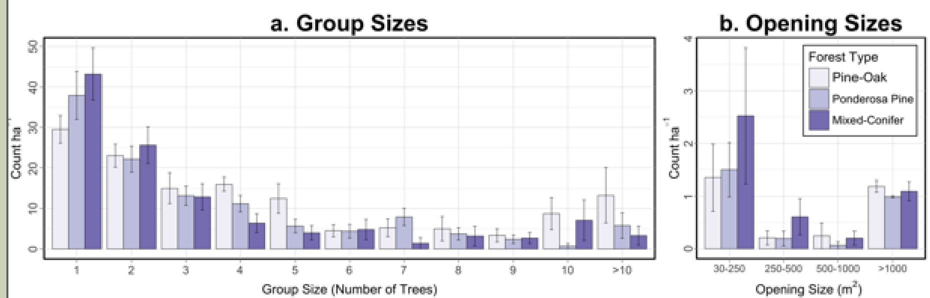
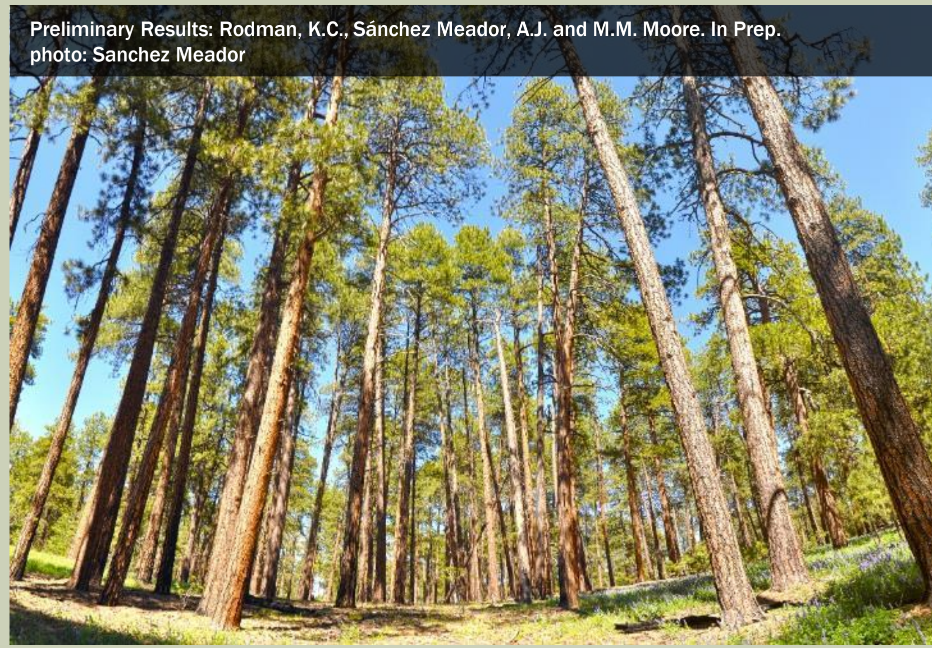


Figure 3 – The estimated historical distributions of group sizes (a) and opening sizes (b) within stem-mapped plots (n = 33) in Arizona and New Mexico, USA. Error bars are +/- one standard error for plot values within each size class and within a given forest type.



PAGOSA (LEARN)

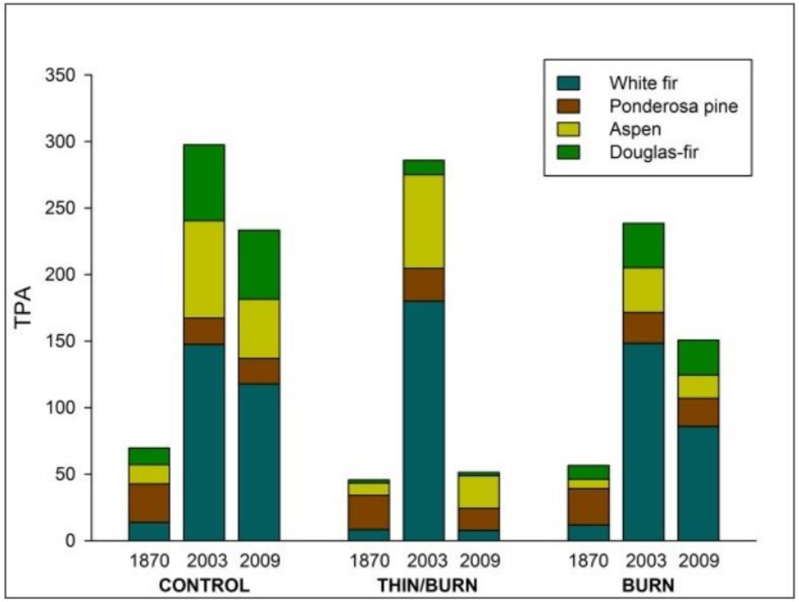


Figure 1. Trees per acre (TPA) by species for 1870 (reconstructed reference condition), pre-treatment (2003), and post-treatment (2009).

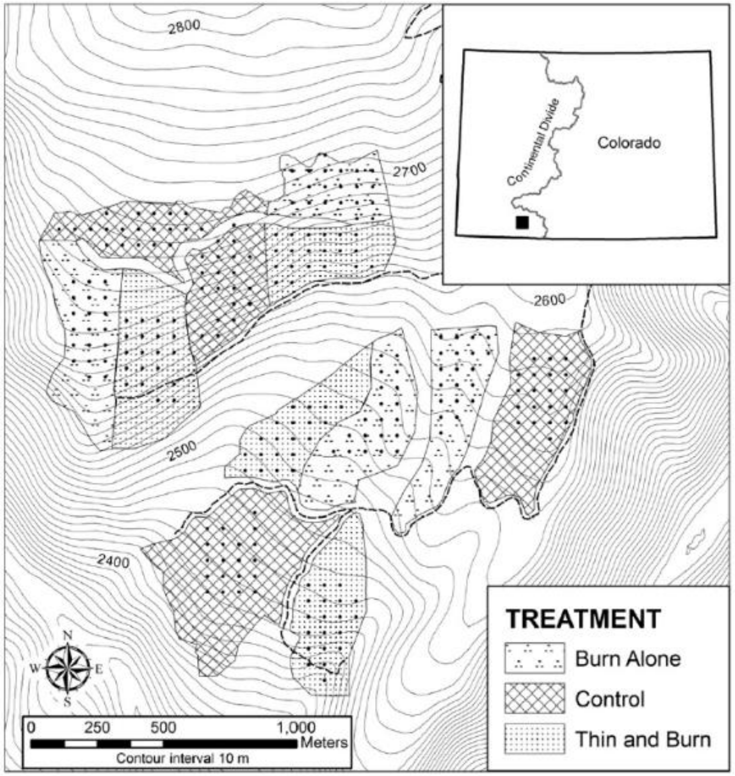


Fig. 1. Study site at Lower Middle Mountain, San Juan National Forest, Colorado. Research blocks (1–4) and restoration treatments (Control, Thin/Burn, Burn Alone) are shown. Black circles represent individual plots (*N* = 20/treatment unit).

Korb, J.E., P.Z. Fule, and M.T. Stoddard. 2012. Forest restoration in a surface fire-dependent ecosystem: An example from a mixed conifer forest, southwestern Colorado, USA. Forest Ecology and Management 269: 10-18.

WALLOW FIRE TREATMENT EFFECTIVENESS

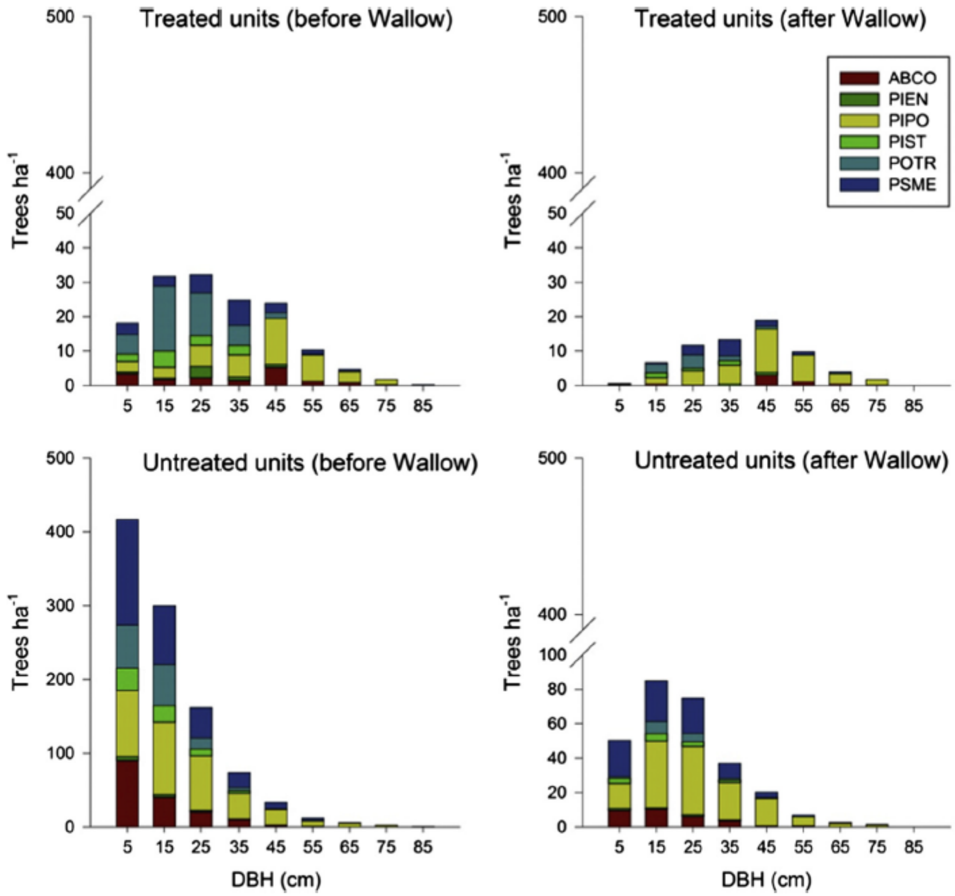


Fig. 2. Changes in diameter distribution by species for treated and untreated units. Diameter class midpoints are shown on *x*-axis. Tree survival is shown before and after the Wallow Fire.

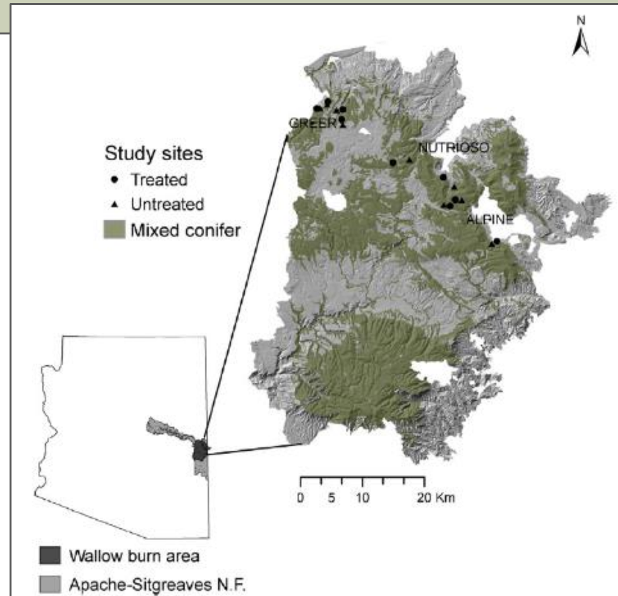


Fig. 1. Location of study sites and Wallow Fire in eastern Arizona, ASNF, U.S.

Waltz, A.E.M., Stoddard, M.T., Kalies, E.L., Springer, J.D., Huffman, D.W. and A.J. Sánchez Meador. 2014. Effectiveness of fuel reduction treatments: assessing metrics of forest resiliency and wildfire severity after the Wallow Fire, AZ. Forest Ecology and Management 334: 43-52.

PAGOSA (LEARN) AGAIN…

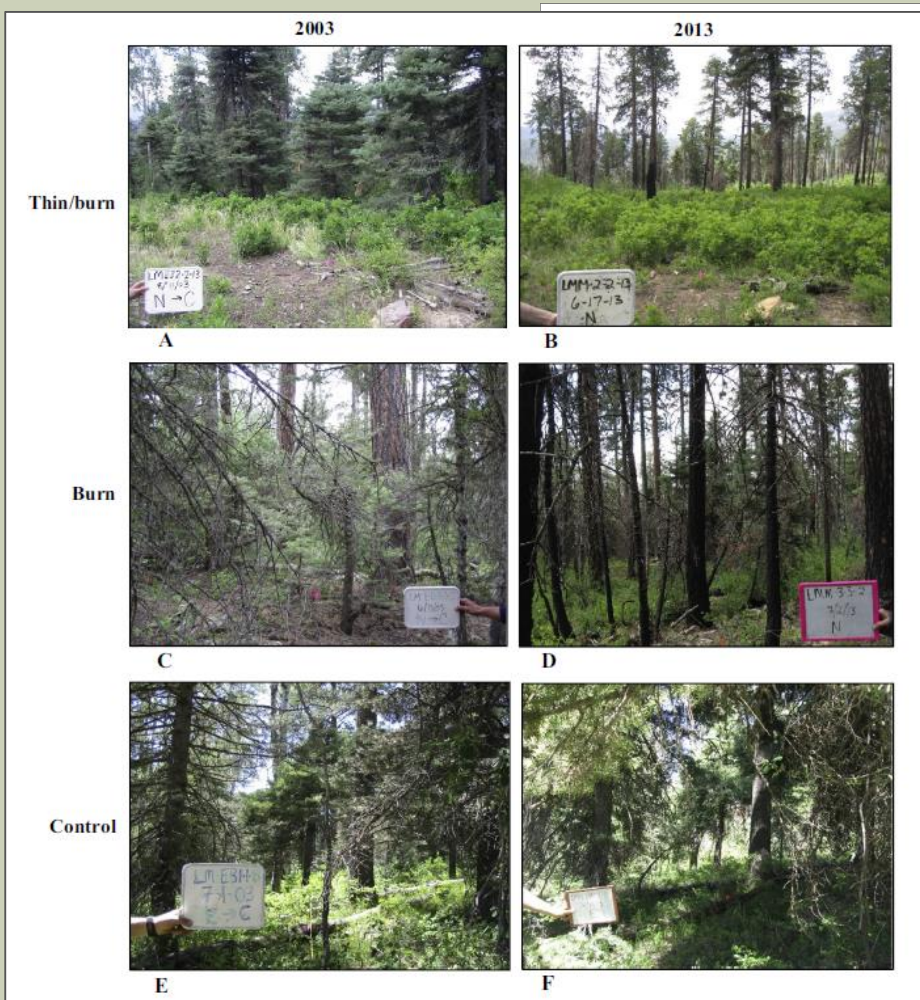
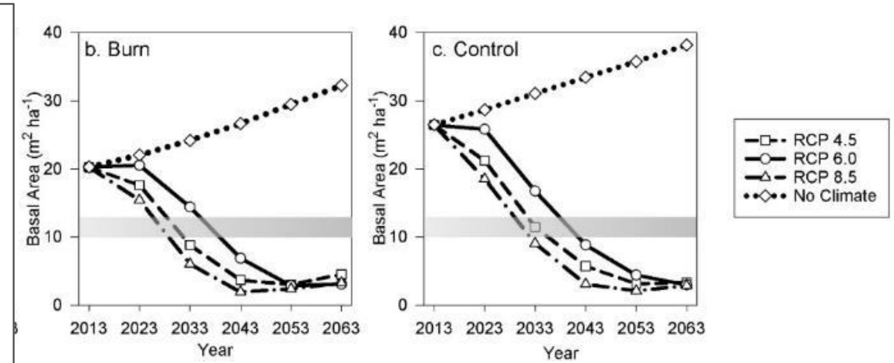
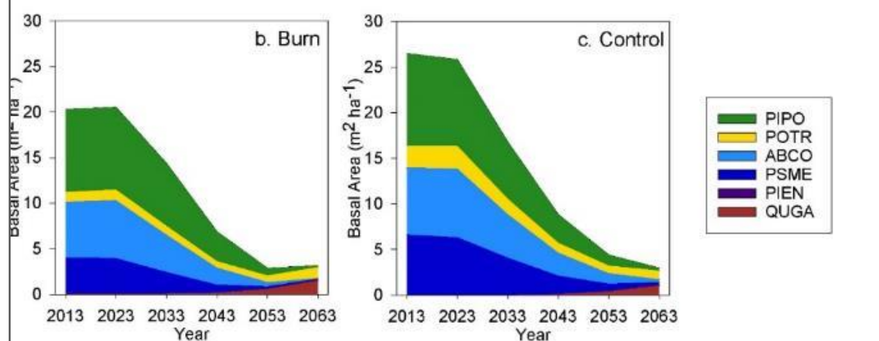


Fig. 4. Repeat photos taken from alternative restoration treatments before treatment (2003) and 5 years after treatment (2013).



a^{-1}) by RCP (Representative Concentration Pathways) climate scenario (4.5, 6.0, 8.5 and No Climate) and the natural range
ea (10–13 m^2 ha^{-1}; Fulé et al., 2009) for the three treatments implemented in 2009 (thin/burn, burn, and control).



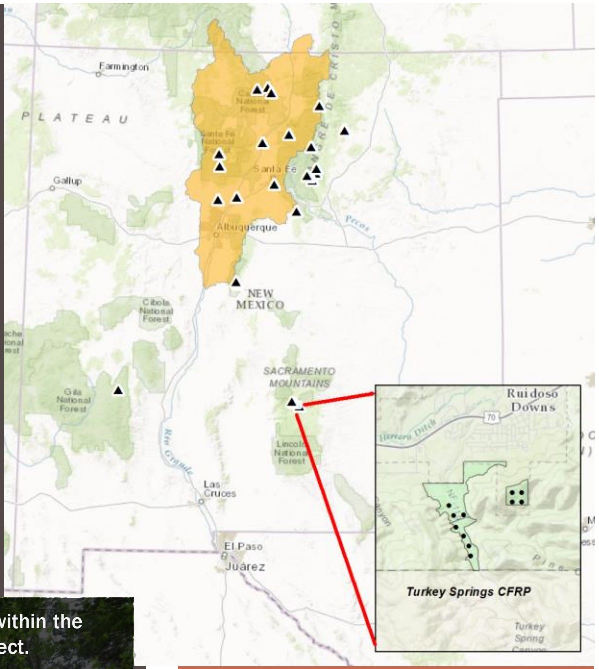
for the RCP (Representative Concentration Pathways) 6.0 climate scenario. Species in each stacked area are listed in legend.
ow to note are: PICO, JUCO, and ABLA.

Stoddard, M.T., Sánchez Meador, A.J., Fulé, P.Z., and J.E. Korb. 2015. 5-year post-restoration treatment conditions and simulated forest trajectories under alternative climate scenarios in a southwestern warm/dry mixed-conifer forest. Forest Ecology and Management 356: 253-261.

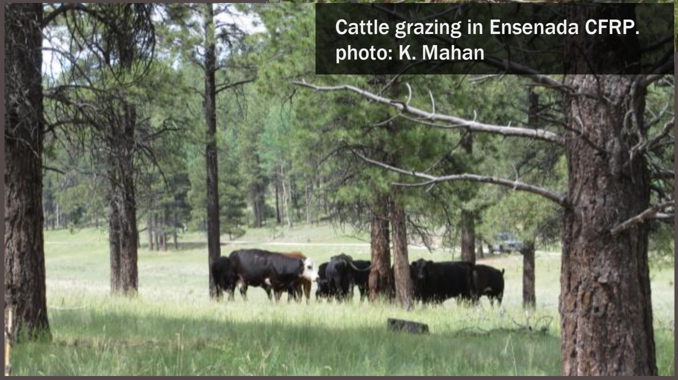
Fact Sheet: Five-Year Post-Restoration Conditions and Simulated Climate Change Trajectories in a Warm/Dry Mixed-Conifer Forest, Southwestern Colorado, USA. Stoddard, M.T. 2016. Ecological Restoration Institute, Northern Arizona University. 2 p.

FUTURE DIRECTIONS

- Collaborative Forest Restoration
- Rio Grand Water Fund
- San Juan-Rio Chama Watershed Project
- Post fire recovery
- Piñon-Juniper
- Grazing
- Etc.



Mixed conifer treatment within the San Juan-Rio Chama project. photo: K. Mahan



Cattle grazing in Ensenada CFRP. photo: K. Mahan

Moon mountain fire. photo: K. Mahan