Adaptive Management in Colorado

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Colorado State Forest Service
July 30, 2024

COLORADO STATE FOREST SERVICE
COLORADO STATE UNIVERSITY

Outline

- What are the major challenges in adaptive management?
- Forest types in Colorado and complexities of management
- CSFS Science and Data - tracking treatments and FRWRM monitoring, long-term research collaborations, carbon, forest inventory and analysis, beetles & pollinators
- Discussion

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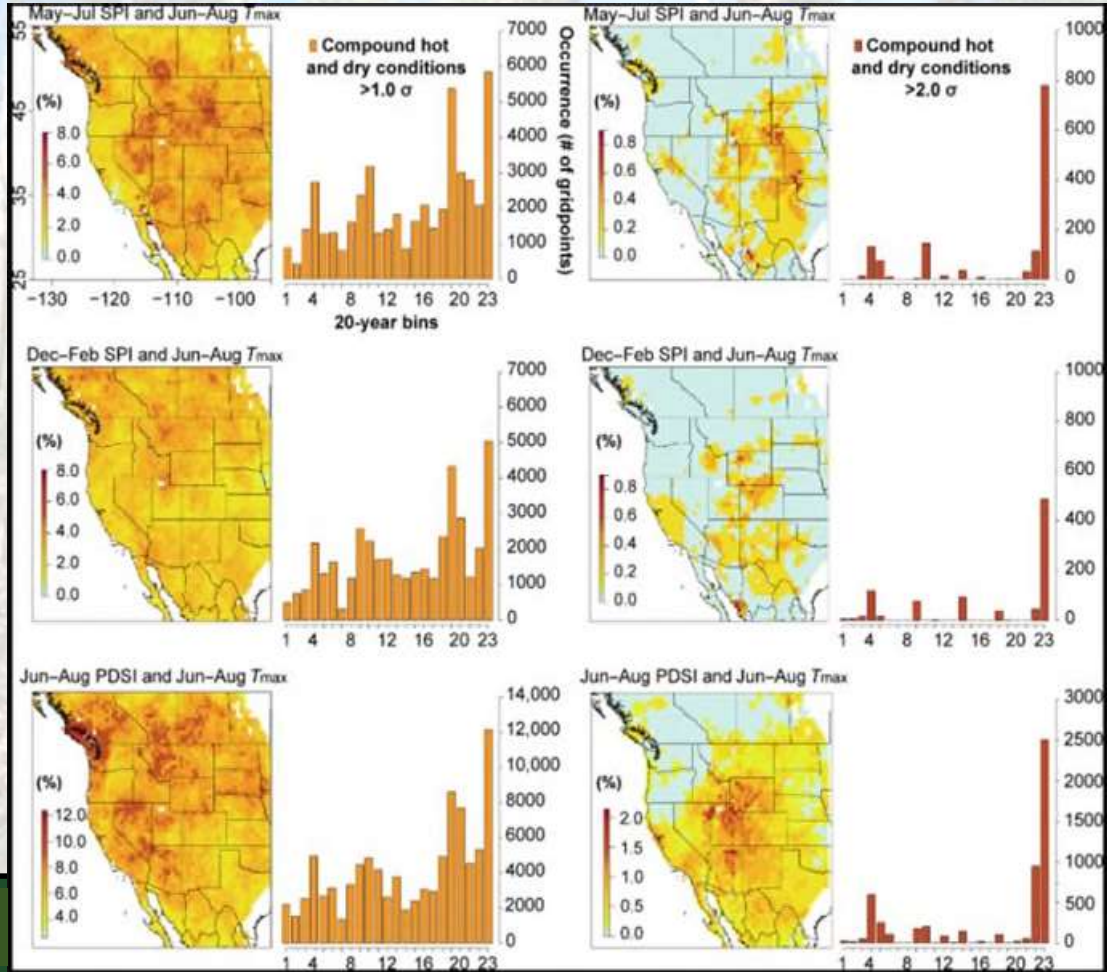
Colorado State University
Warner College of Natural Resources

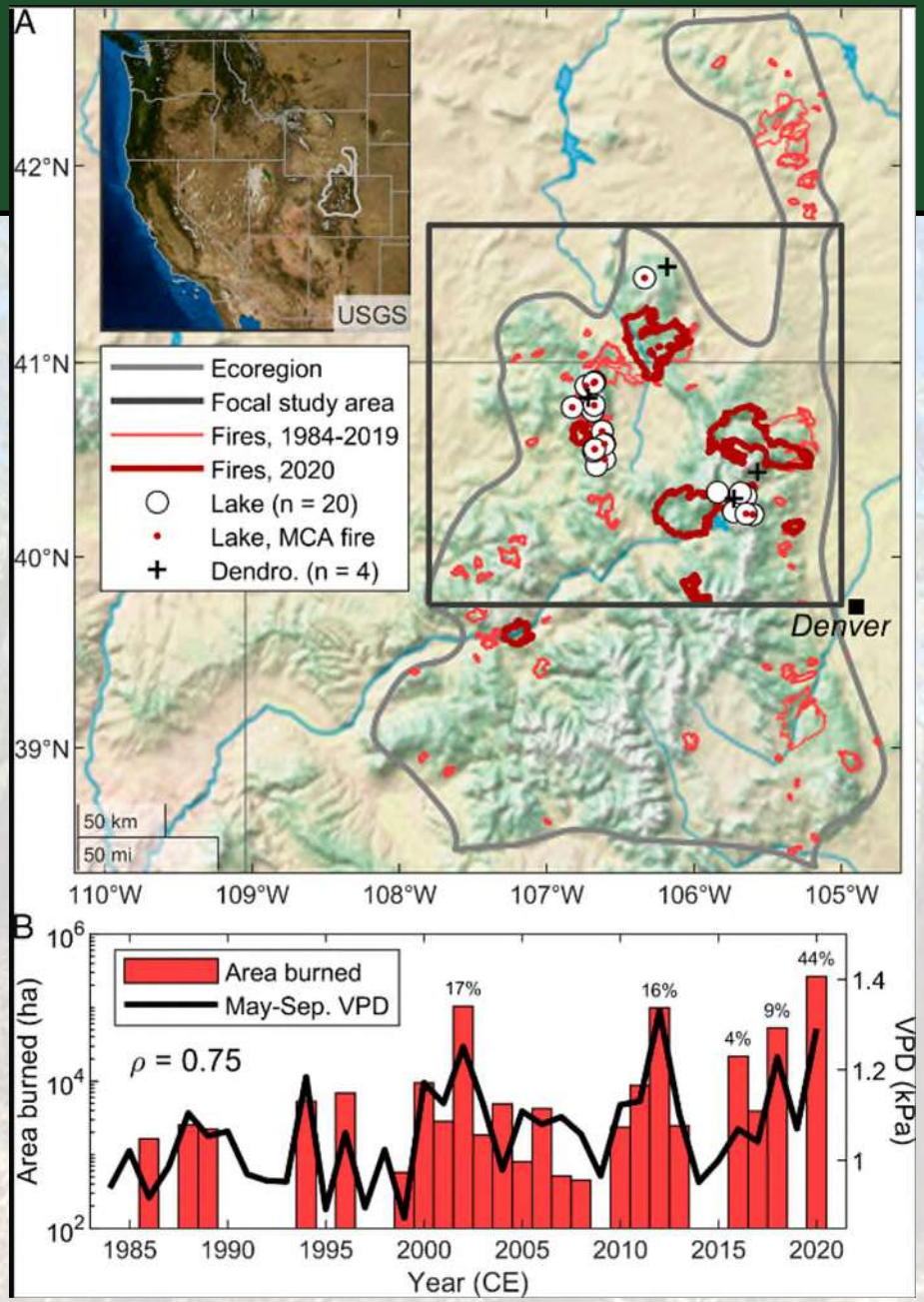
COLORADO
Department of Natural Resources

What are the biggest challenges?

- Increasing heat, aridification - unprecedented since at least 16th century
- Decreasing fuel moisture content; increases likelihood of wildfire ignition, spread in systems not fuel-limited; in high-wind conditions can increase intensity and severity
- Add fine fuels from I&D
  - altering fuels arrangements
- Wildfires have shaped forested systems in Colorado for millennia, but interactions among climate, fire, and society are rapidly transforming these systems
- How to protect values at risk, such as homes, water and infrastructure, culture and recreation, while promoting resilience and adaptation in each unique forest type is what keeps many practitioners up at night



King et al. 2024 Science Advances



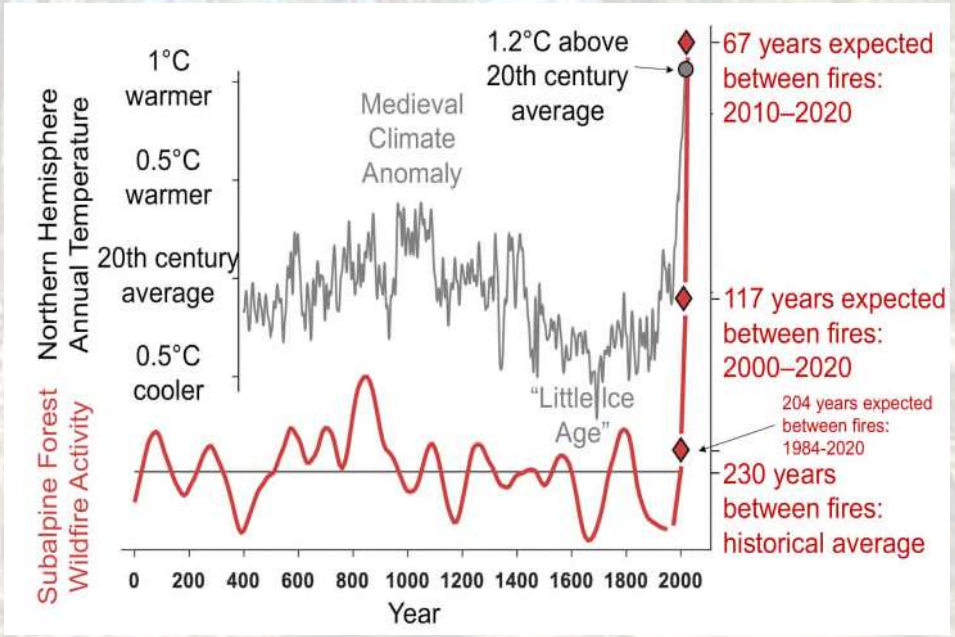
RESEARCH ARTICLE | BIOLOGICAL SCIENCES

Rocky Mountain subalpine forests now burning more than any time in recent millennia

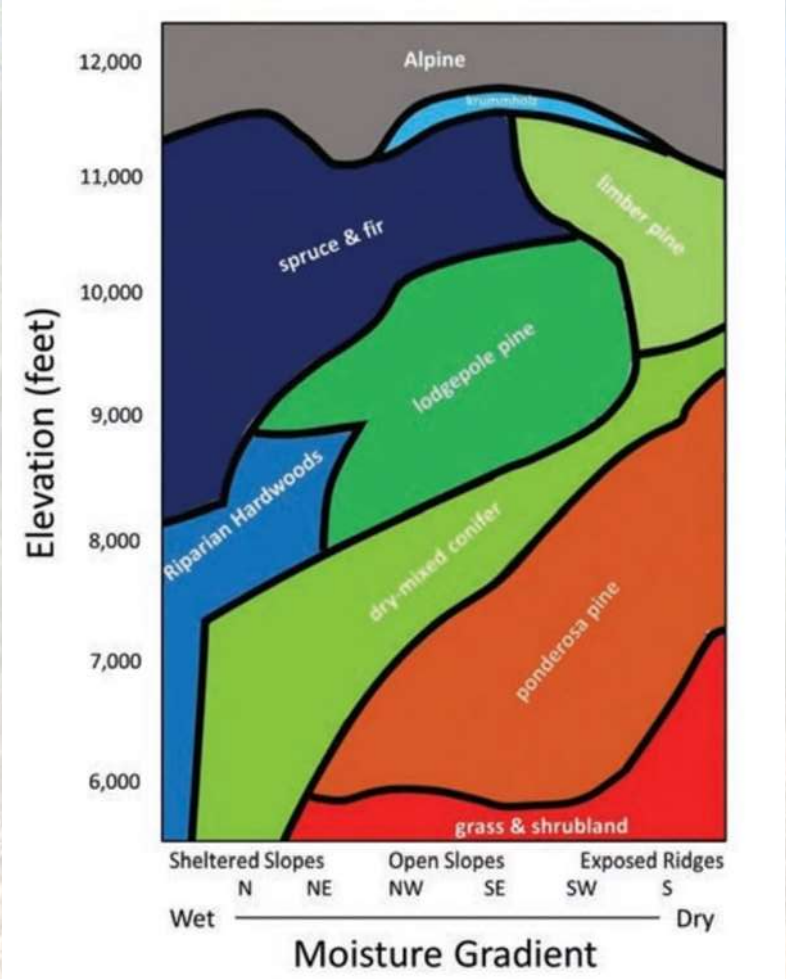
Philip E. Higuera, Bryan N. Shuman, and Kyra D. Wolf Authors Info & Affiliations

Edited by Michael E. Mann, Pennsylvania State University, University Park, PA, and approved April 28, 2021 (received for review February 24, 2021)

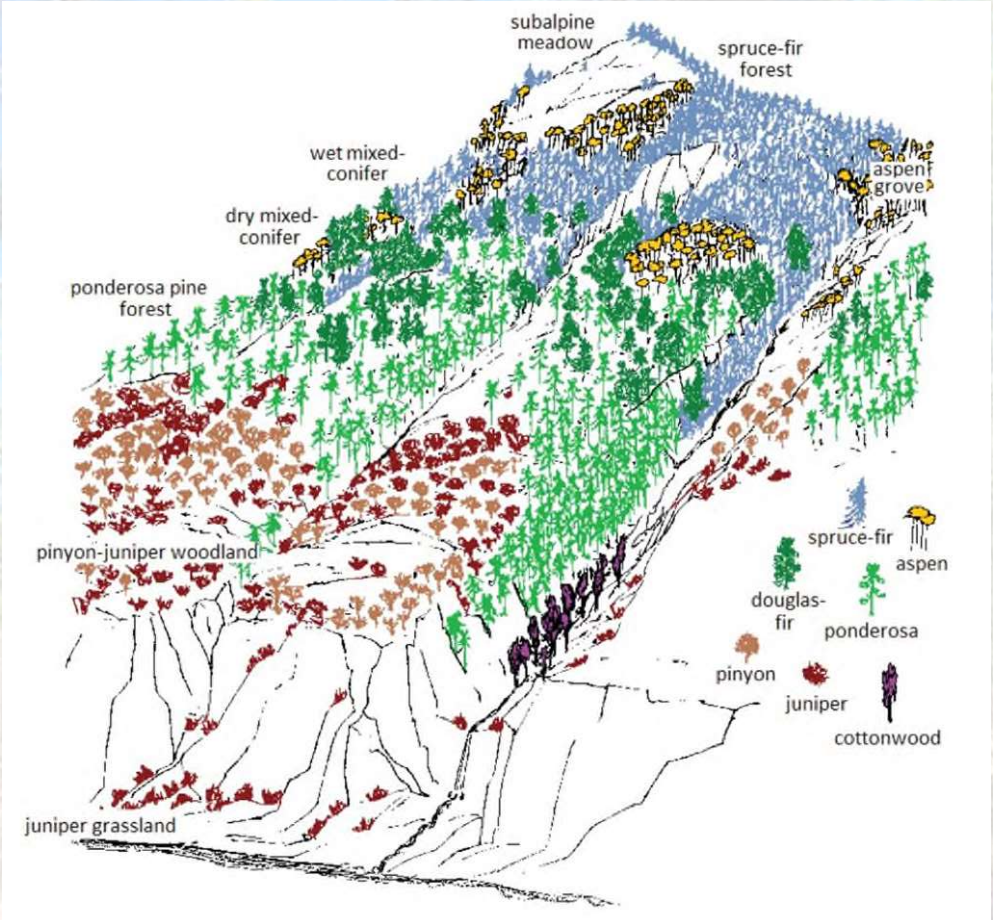
June 14, 2021 | 118 (25) e2103135118 | https://doi.org/10.1073/pnas.2103135118



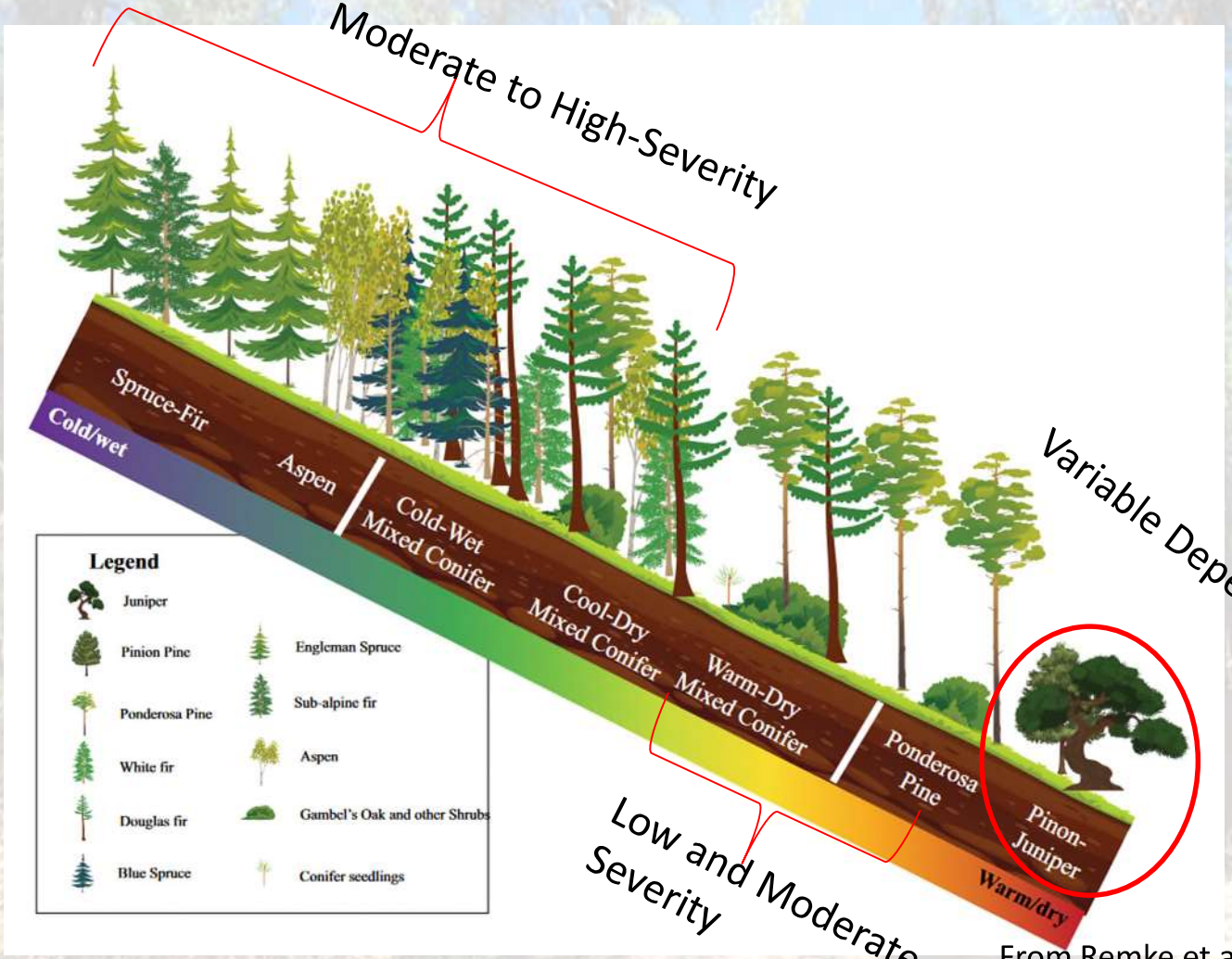
Forest Types in Colorado



From: Addington et al 2018



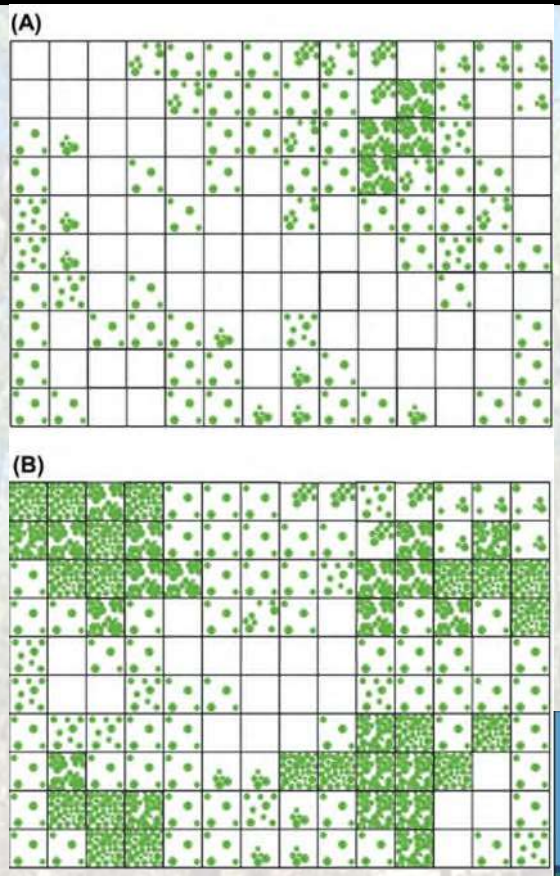
Mixed Conifer Forests



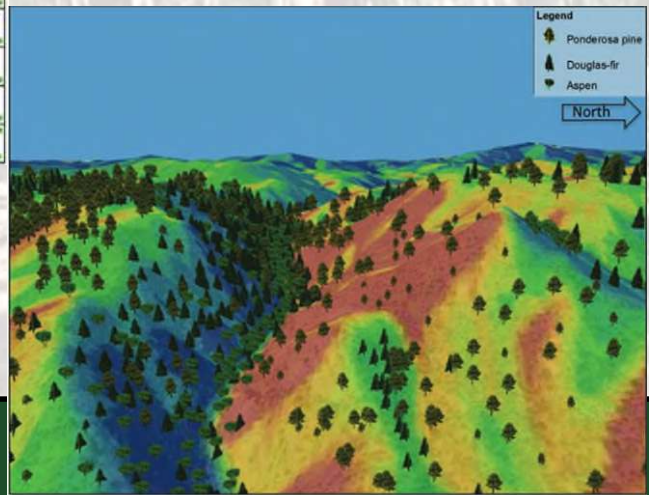
From Remke et al. 2021

Lower Montane

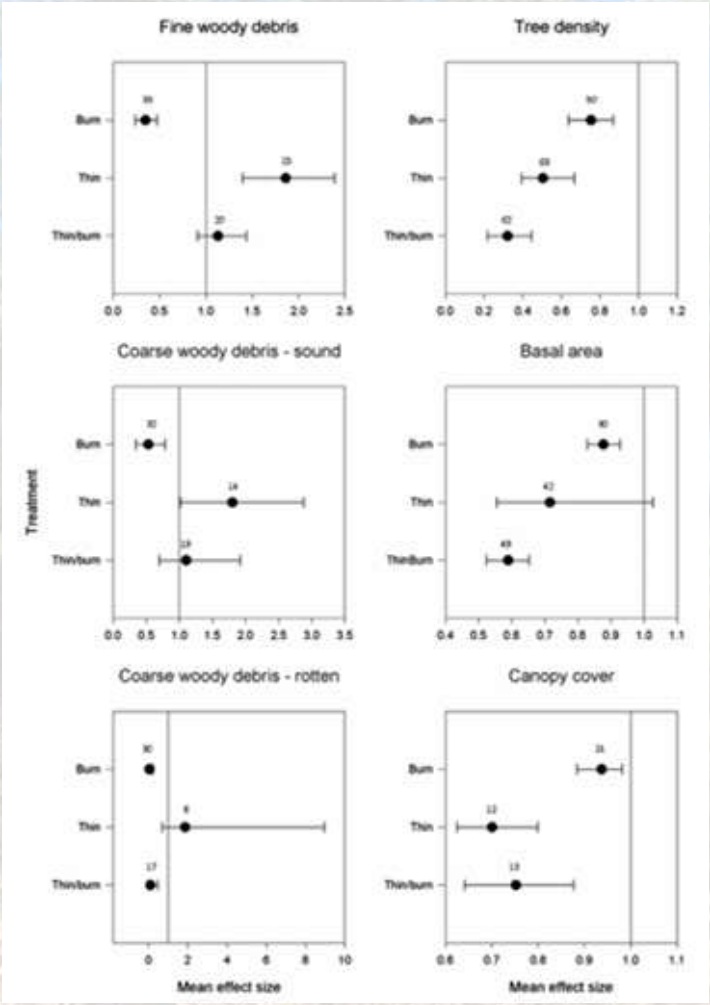
- Ponderosa pine and dry mixed-conifer
- Frequent (10-40 years) fire
  - Varying severity
- Variable horizontal and vertical spatial configuration
  - Productivity
  - Species assemblage



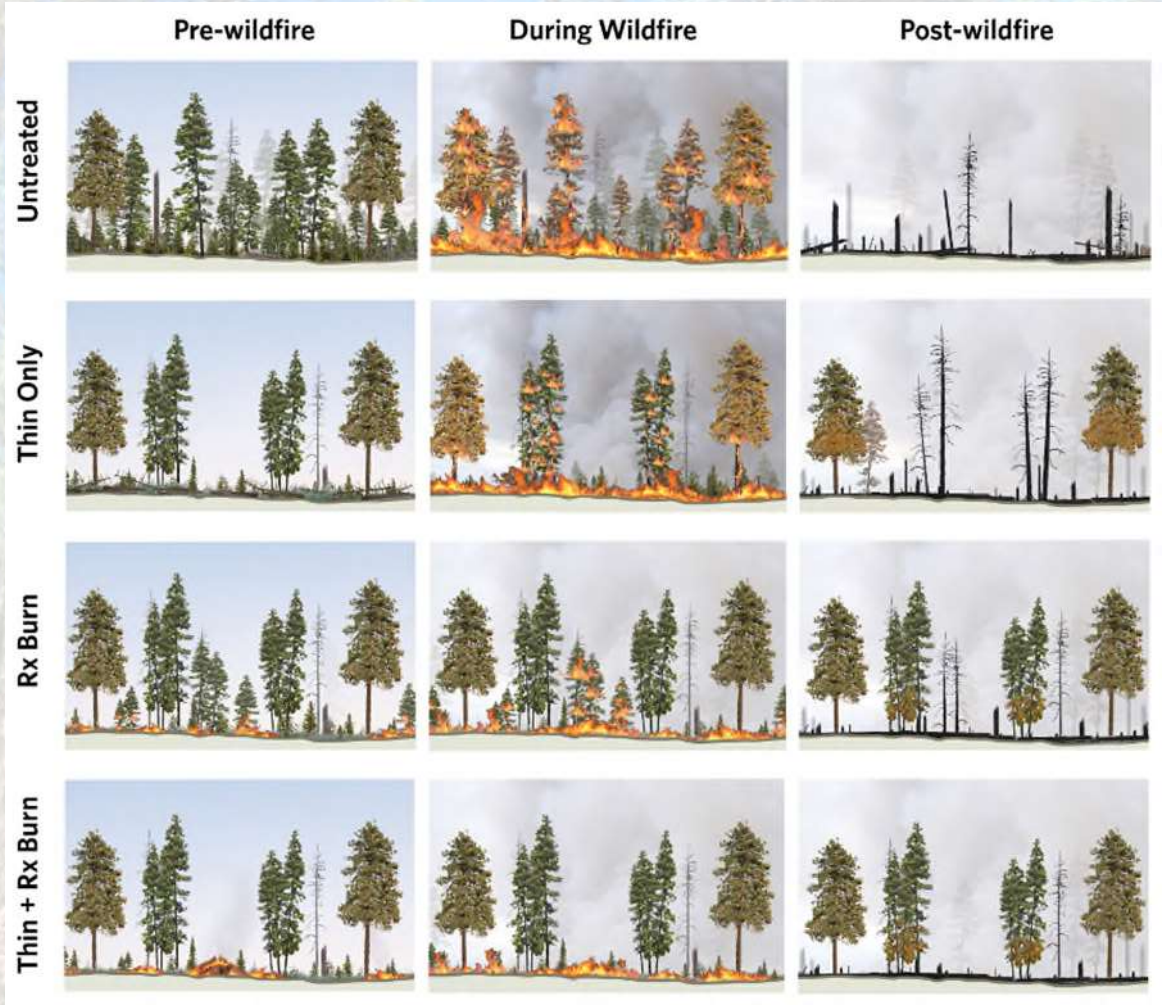
From: Addington et al. 2018



Lower Montane: Management



From: Fule et al. 2012



From: Davis et al. 2024

Upper Montane

- Cool/Dry and Cold/Wet
- Includes lodgepole pine forests
- Increasing shade tolerant species composition
- Fire return interval varies on the scale of decades to centuries
  - Higher-severity trend

Subalpine Forests

- Fire return intervals long (centuries)
- Short growing seasons and reliance on snowpack
- Insect and Disease issues
  - Defoliators
  - Root disease
  - Bark beetles

What is treatment effectiveness?

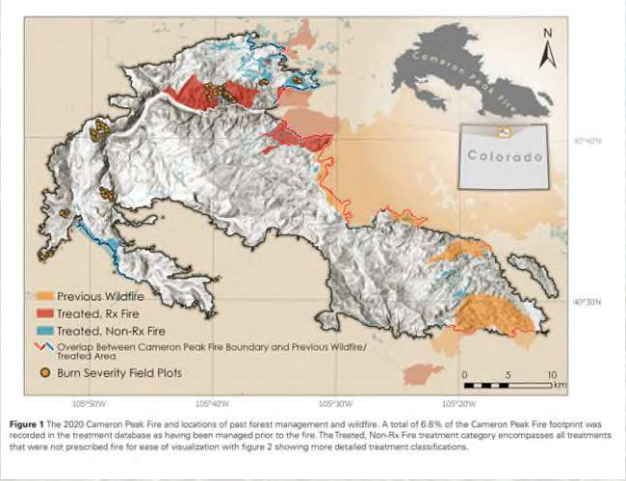


Figure 1 The 2020 Cameron Peak Fire and locations of past forest management and wildfire. A total of 6.8% of the Cameron Peak Fire footprint was recorded in the treatment database as having been managed prior to the fire. The Treated, Non-Rx Fire treatment category encompasses all treatments that were not prescribed fire for ease of visualization with figure 2 showing more detailed treatment classifications.

Vorster et al. 2023 Journal of Forestry

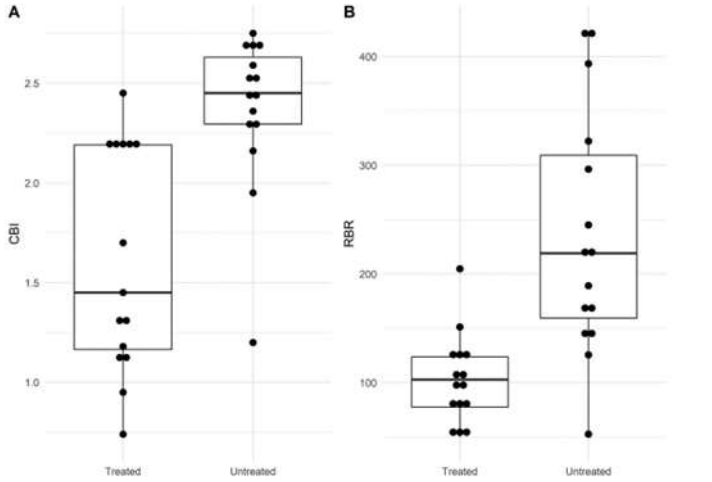


Figure 5 Field measured burn severity as measured by (A) the CBI and (B) remotely sensed burn severity as measured by the RBR. Values are shown for the thirty field plot locations across three focal treated and untreated pairings of the Cameron Peak Fire.

Table 3. Ecological metrics of treatment effects on wildfire, their definition, and common measures used to evaluate the impact of treatment, and citations that use these metrics in empirical studies.

Metric	Definition	Data sources	Evaluation measurements	Citations
Ecological indicators				
Soils conditions and processes	Treatment reduced soil burn severity and related impacts to soil function (e.g., water infiltration, nutrient retention, etc.)	Remote sensing and field observations of soil burn severity Biogeochemical properties Erosion Soil function Microbiome impacts	Remotely sensed burn severity Organic matter and surface fuel consumption Soil structure Soil nitrogen and carbon concentration Runoff chemistry Microbial biomass and composition Infiltration Evidence of rilling Headcutting Mass of soil eroded and accumulated	Choromanska and DeLuca (2001) Homann et al. (2011) Fultz et al. (2016)
Watershed and water impacts	Treatments altered impacts to water resources	Impacts on water quality, erosion events, hydrology, debris flows, and disruption to water supply Hillslope, stream channel, and floodplain geomorphology Riparian and wetland habitat condition	Stream channel change Streamflow amount, timing, and fluctuation Water chemistry (N, P, and metals) Sediment transport Vegetation recovery Remotely sensed burn severity of watersheds Evidence of rilling Headcutting	Jones et al. (2017) Salis et al. (2019)
Tree survival	Treatment increased tree survival	Forest inventory Remote sensing	Live trees/area Forest demographics Remotely sensed burn severity and live tree canopy	Shive et al. (2013) Agee and Skinner (2005) Stephens et al. (2012) Waltz et al. (2014) Prichard et al. (2010) Ritchie et al. (2007) Weatherspoon and Skinner (1995)
Vegetation consumption and response	Treatment impacted the amount of vegetation material consumed and its response	Remote sensing Field observations	Remotely sensed burn severity and vegetation recovery Vegetation consumption and recovery Charring Cone consumption Scorching Vegetation cover, richness, and composition	Prichard and Kennedy (2014) Springer et al. (2018) Stevens-Rumann et al. (2016)
Forest response	Treatments altered forest response or resilience	Proximity to viable seed Regeneration surveys	Distance to nearest seed source Fire severity patch metrics (size, density, shape, core) Cone consumption Seedling, sapling and sprout stems/area Cones/tree Refugia	Tubbesing et al. (2019) Roccaforte et al. (2018) Waltz et al. (2014)
Wildlife habitat	Treatment influenced how wildfire changes wildlife habitat	Wildlife census Habitat survey	Habitat suitability: food, shelter, water, space Survivorship and population connectivity	Stevens-Rumann et al. (2013)
Spatial patterns and heterogeneity	Treatments increase post-fire heterogeneity or result in landscape ecology conditions that increase resilience	Remote sensing Field observations	Patch metrics of fire severity, forest, openings, etc. (size, density, shape, core) Forest demographics Remotely sensed burn severity and vegetation recovery/structure Canopy cover and openness Snow accumulation patterns Spatial heterogeneity/homogeneity	Shive et al. (2013) Waltz et al. (2014)
Carbon storage	Treatments impacted wildfire emissions and carbon storage following wildfire	Carbon stock inventory and allocation into each pool Postfire growth rates Soil carbon loss from organic matter consumption or post-fire erosion	Biomass consumption Soil carbon Carbon stocks and their allocation into live and dead and above and belowground pools	Finkral and Evans (2008) North and Hurteau (2011) Zhang et al. (2023)

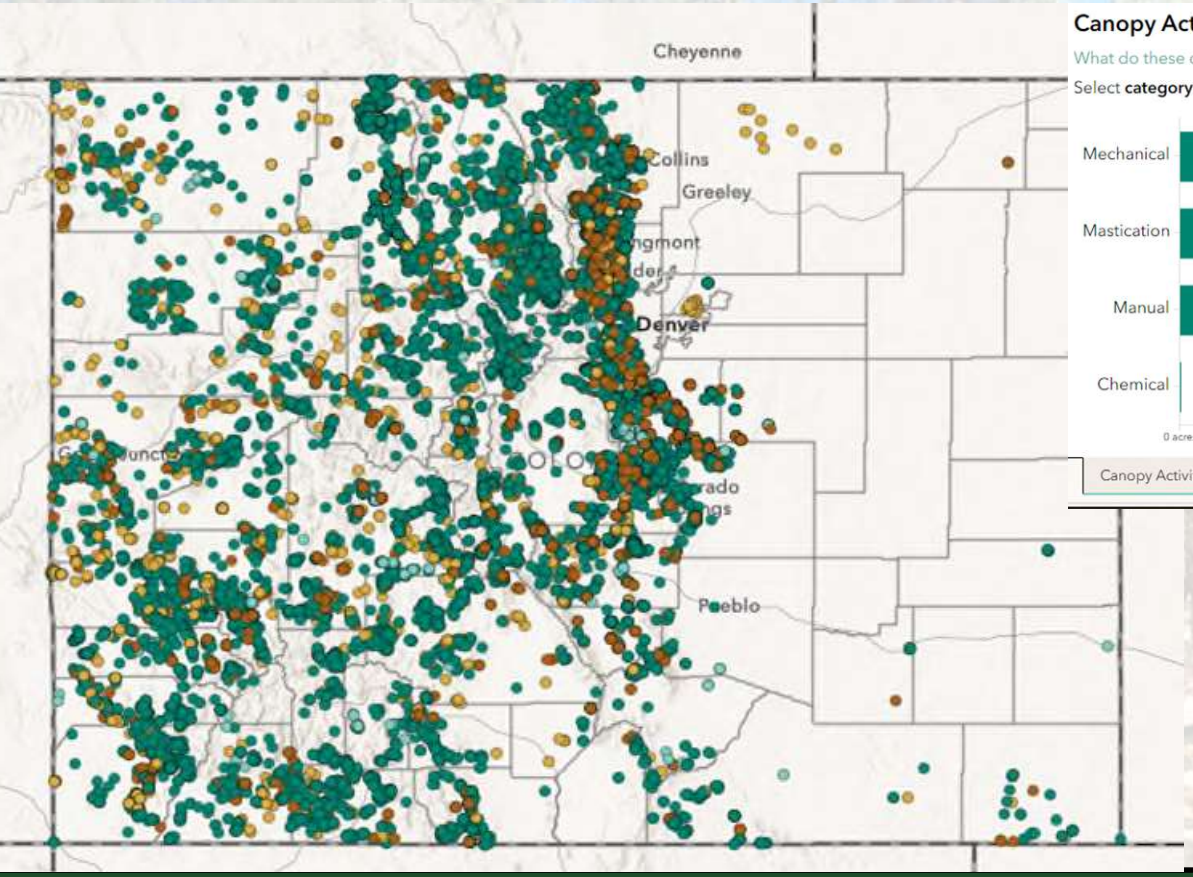
Forest Tracker

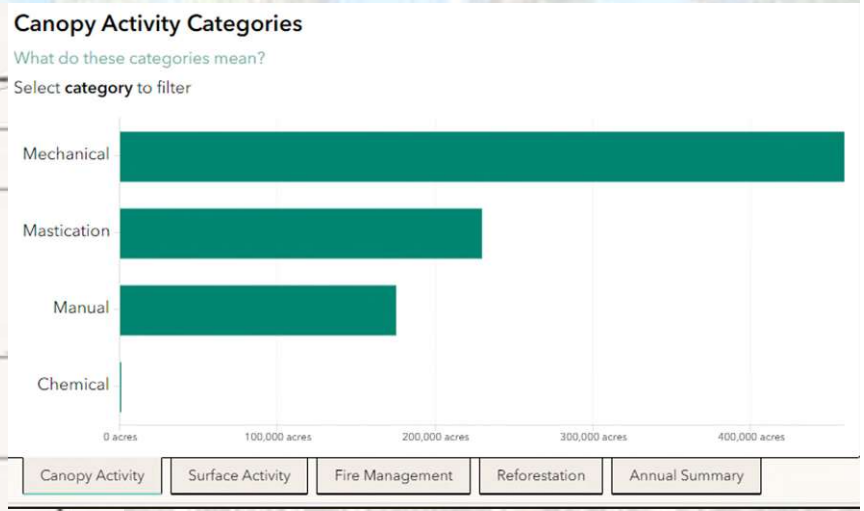
COLORADO FOREST RESTORATION INSTITUTE

Home | Learn More | Launch Data Viewer | Download Data

Colorado Forest Tracker (BETA)

Land Ownership: All Landowners | County: All Counties | Forest Type: All Types | Management Type: All Types | Date Completed: All Dates





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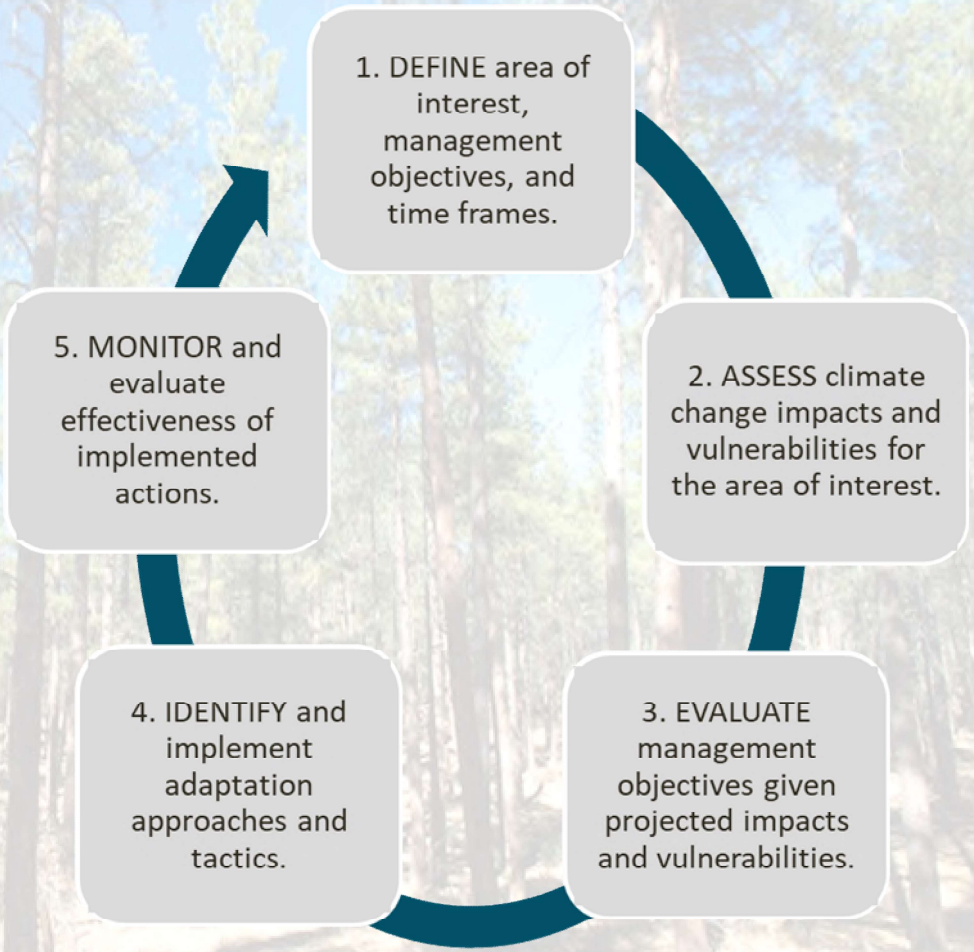
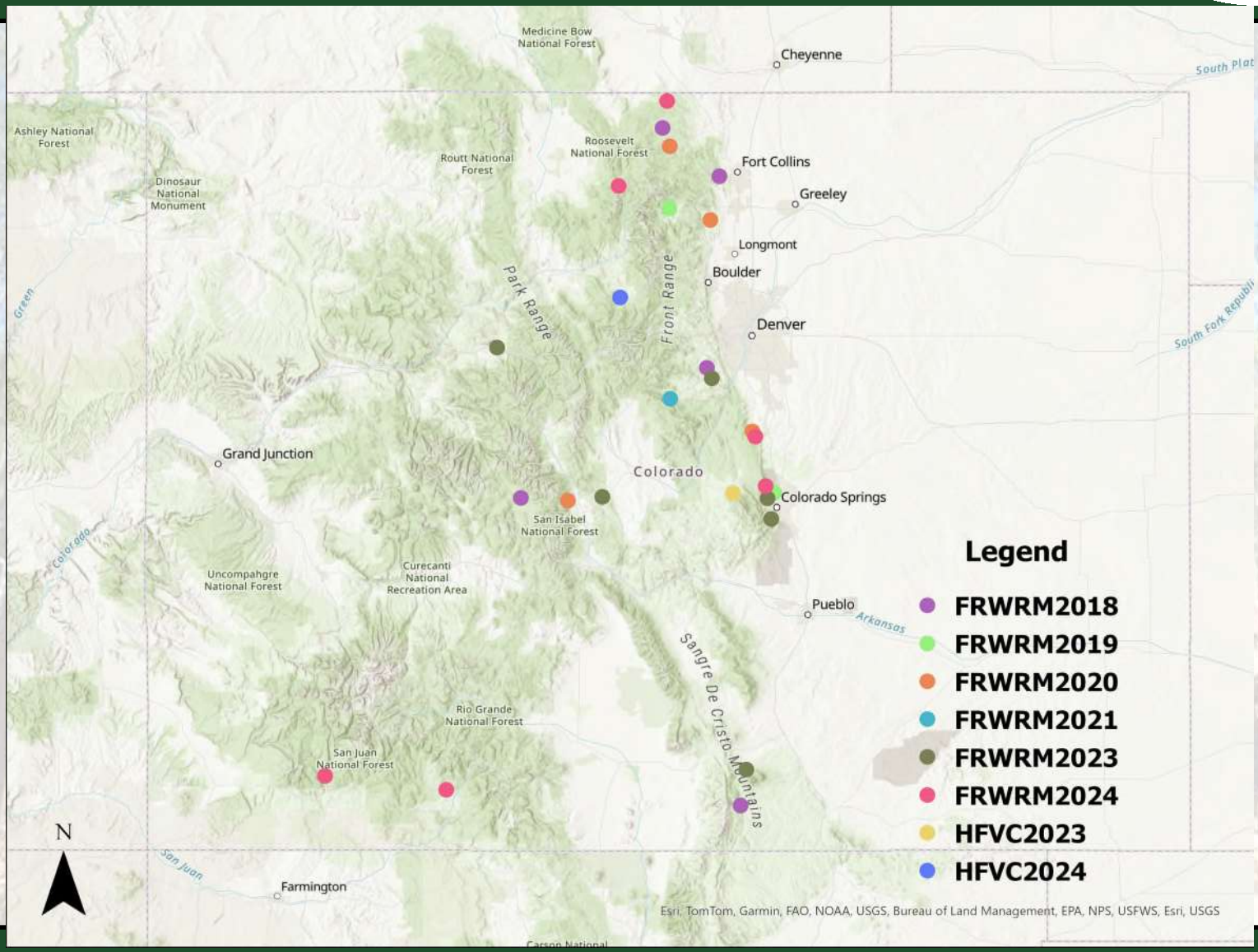
Monitoring Forest Treatments

- CSFS established a monitoring program in late 2022
  - FRWRM, HFVC
  - Major goals:
    - Assess treatment outcomes
    - Characterize treatment types
    - Carbon accounting



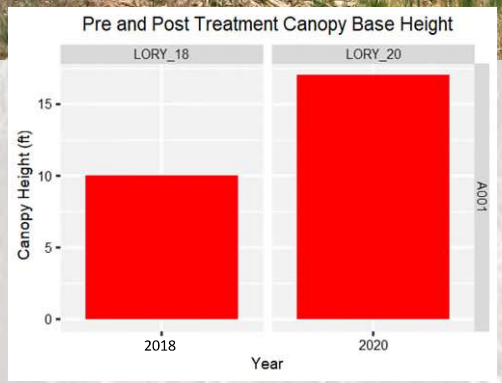
Swanston et al. 2016; Janowiak et al 2014; Nagel et al. 2017

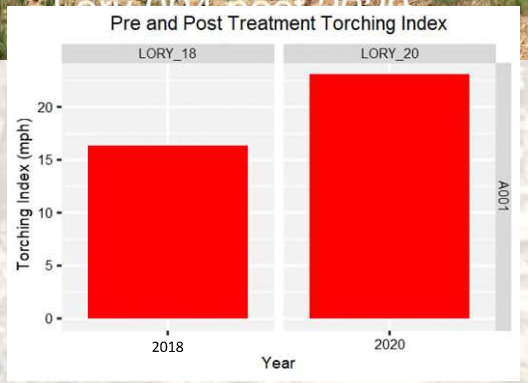
CSFS Monitoring

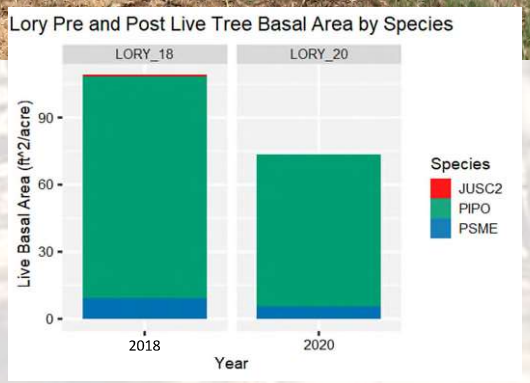


Lory FRWRM

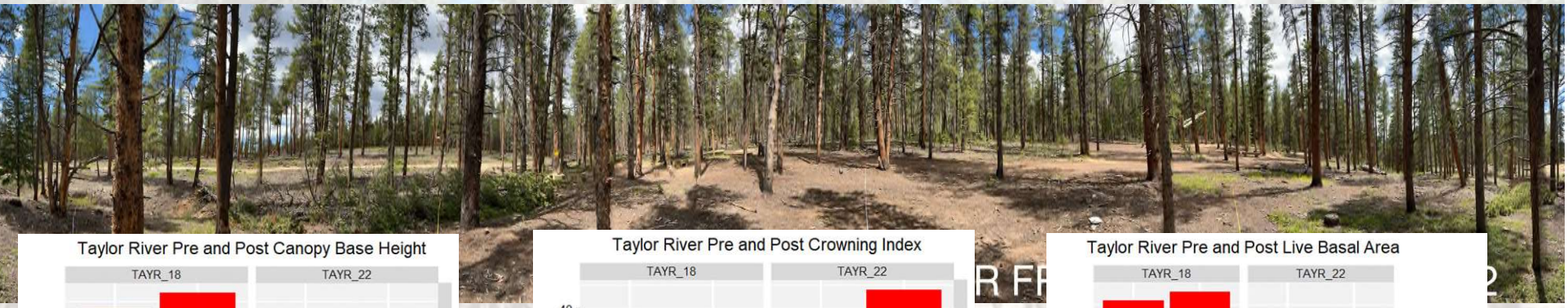

Lory 004 pre treat
2018

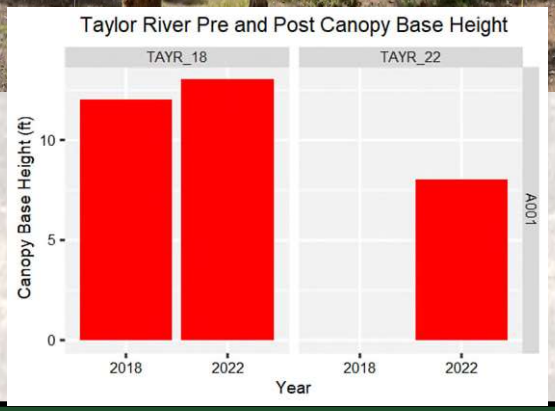

Pre and Post Treatment Canopy Base Height
LORY_18
LORY_20
Canopy Height (ft)
15
10
5
0
2018
2020
Year
A001

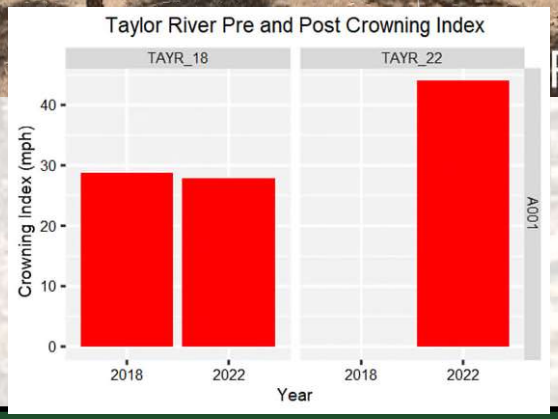

Pre and Post Treatment Torching Index
LORY_18
LORY_20
Torching Index (mph)
20
15
10
5
0
2018
2020
Year
A001

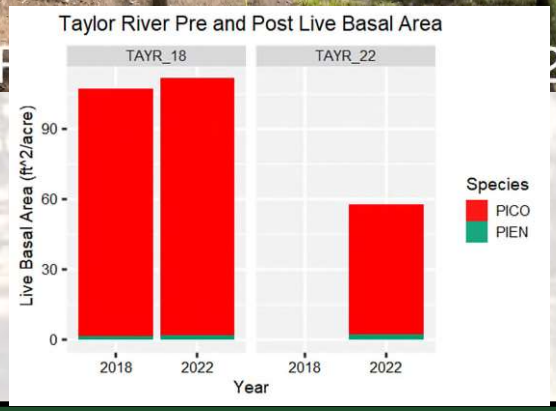

Lory Pre and Post Live Tree Basal Area by Species
LORY_18
LORY_20
Live Basal Area (ft^2/acre)
90
60
30
0
2018
2020
Year
Species
JUSC2
PIPO
PSME

Taylor River FRWRM

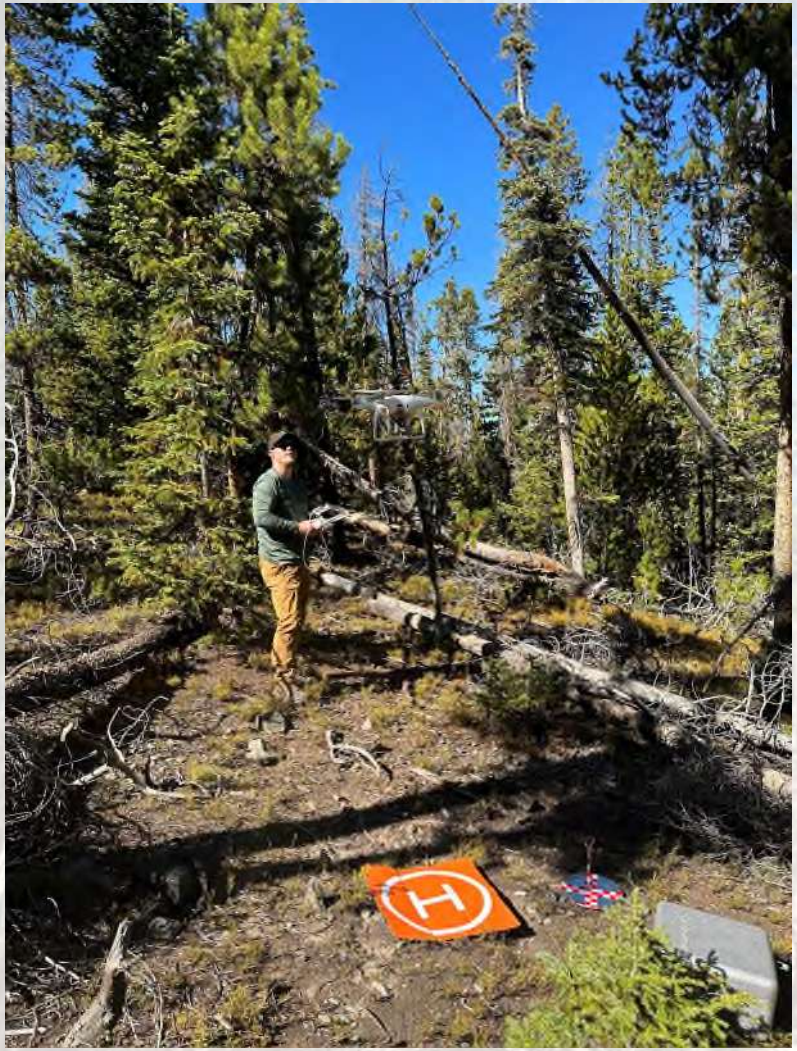








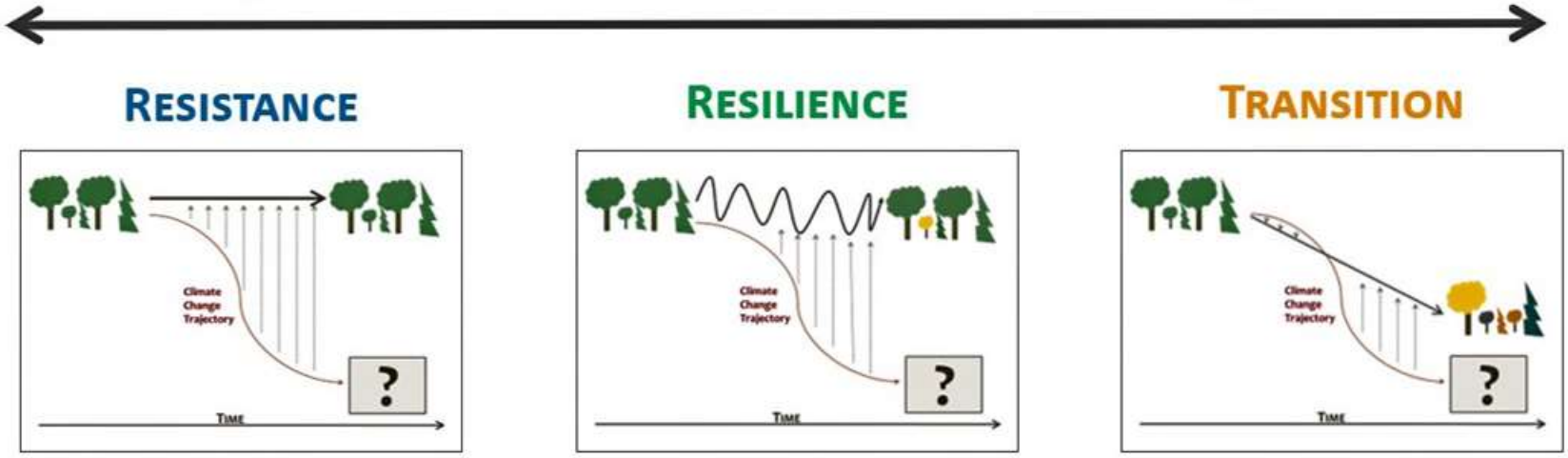
Monitoring Technologies



RRT: A Framework for Climate Adaptation

Manage for Persistence
Ecosystems are still recognizable as being the same system (character)

Manage for Change
Ecosystems have fundamentally changed to something different



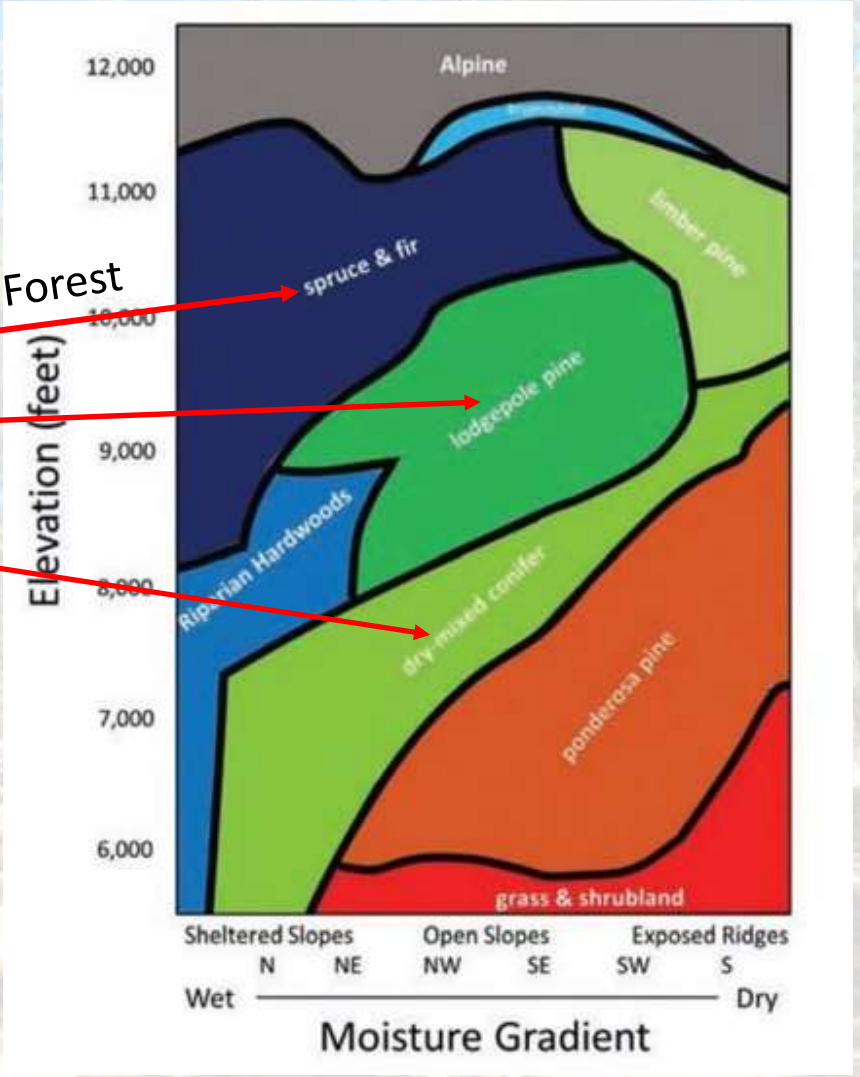
Millar et al. 2007, Swanston et al. 2016, Nagel et al. 2017

ASCC in Colorado

State Forest

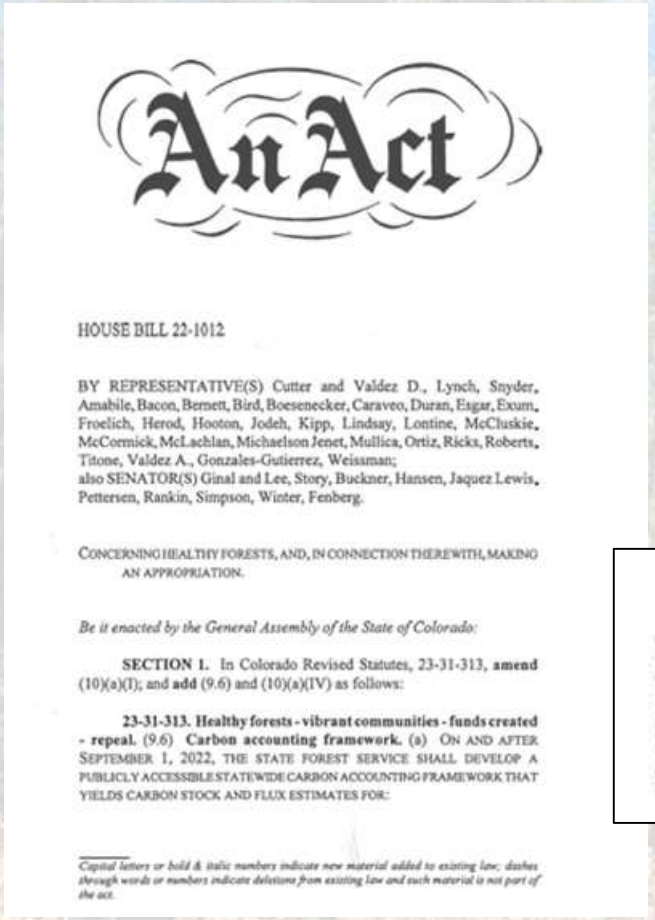
Taylor Park

San Juan



https://adaptivesilviculture.org/

Statewide Forest Carbon Inventory



An Act

HOUSE BILL 22-1012

BY REPRESENTATIVE(S) Cutter and Valdez D., Lynch, Snyder, Amabile, Bacon, Bernett, Bird, Boesenecker, Caraveo, Duran, Esgar, Exum, Froelich, Herod, Hooton, Jodeh, Kipp, Lindsay, Lontine, McCluskie, McCormick, McLachlan, Michaelson Jenet, Mullica, Ortiz, Ricks, Roberts, Titone, Valdez A., Gonzales-Gutierrez, Weissman;
also SENATOR(S) Ginal and Lee, Story, Buckner, Hansen, Jaquez Lewis, Pettersen, Rankin, Simpson, Winter, Fenberg.

CONCERNING HEALTHY FORESTS, AND, IN CONNECTION THEREWITH, MAKING AN APPROPRIATION.

Be it enacted by the General Assembly of the State of Colorado:

SECTION 1. In Colorado Revised Statutes, 23-31-313, **amend** (10)(a)(I); and **add** (9.6) and (10)(a)(IV) as follows:

23-31-313. Healthy forests - vibrant communities - funds created - repeal. (9.6) **Carbon accounting framework.** (a) ON AND AFTER SEPTEMBER 1, 2022, THE STATE FOREST SERVICE SHALL DEVELOP A PUBLICLY ACCESSIBLE STATEWIDE CARBON ACCOUNTING FRAMEWORK THAT YIELDS CARBON STOCK AND FLUX ESTIMATES FOR:

Capital letters or bold & italic numbers indicate new material added to existing law; dashes through words or numbers indicate deletions from existing law and such material is not part of the act.

Colorado House Bill 22-1012

Wildfire Mitigation And Recovery

- Use USDA's USFS Forest Inventory and Analysis program data
- Develop tabular data of carbon flux and stock estimates
- Across all forest types, ownerships, and carbon pools

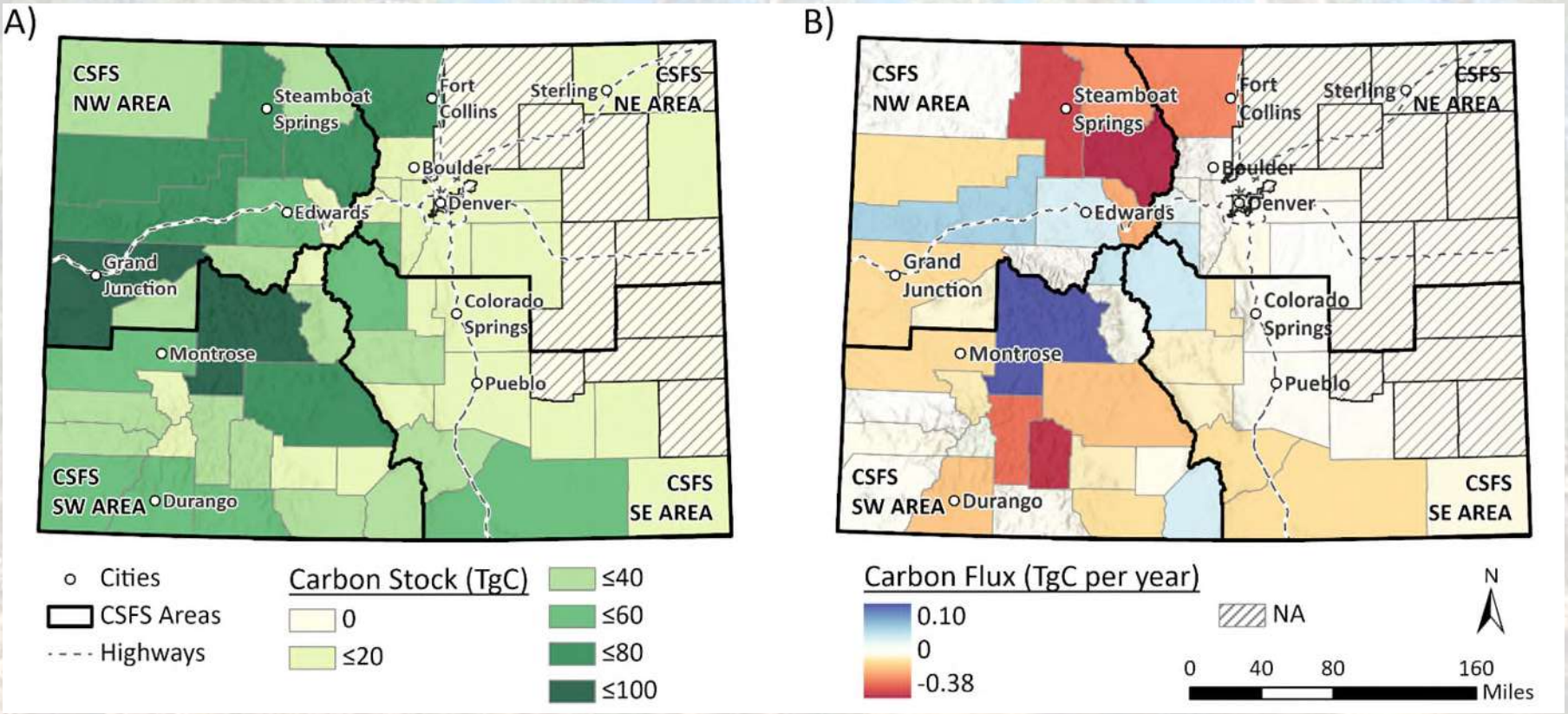
(I) "CARBON ACCOUNTING FRAMEWORK" MEANS A MODEL THAT USES DATA FROM THE FOREST INVENTORY AND ANALYSIS PROGRAM OF THE UNITED STATES DEPARTMENT OF AGRICULTURE'S FOREST SERVICE TO DEVELOP TABULAR DATA OF CARBON FLUX AND STOCK ESTIMATES FOR ALL FOREST TYPES AND WOOD PRODUCTS IN THE STATE OF COLORADO.

USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

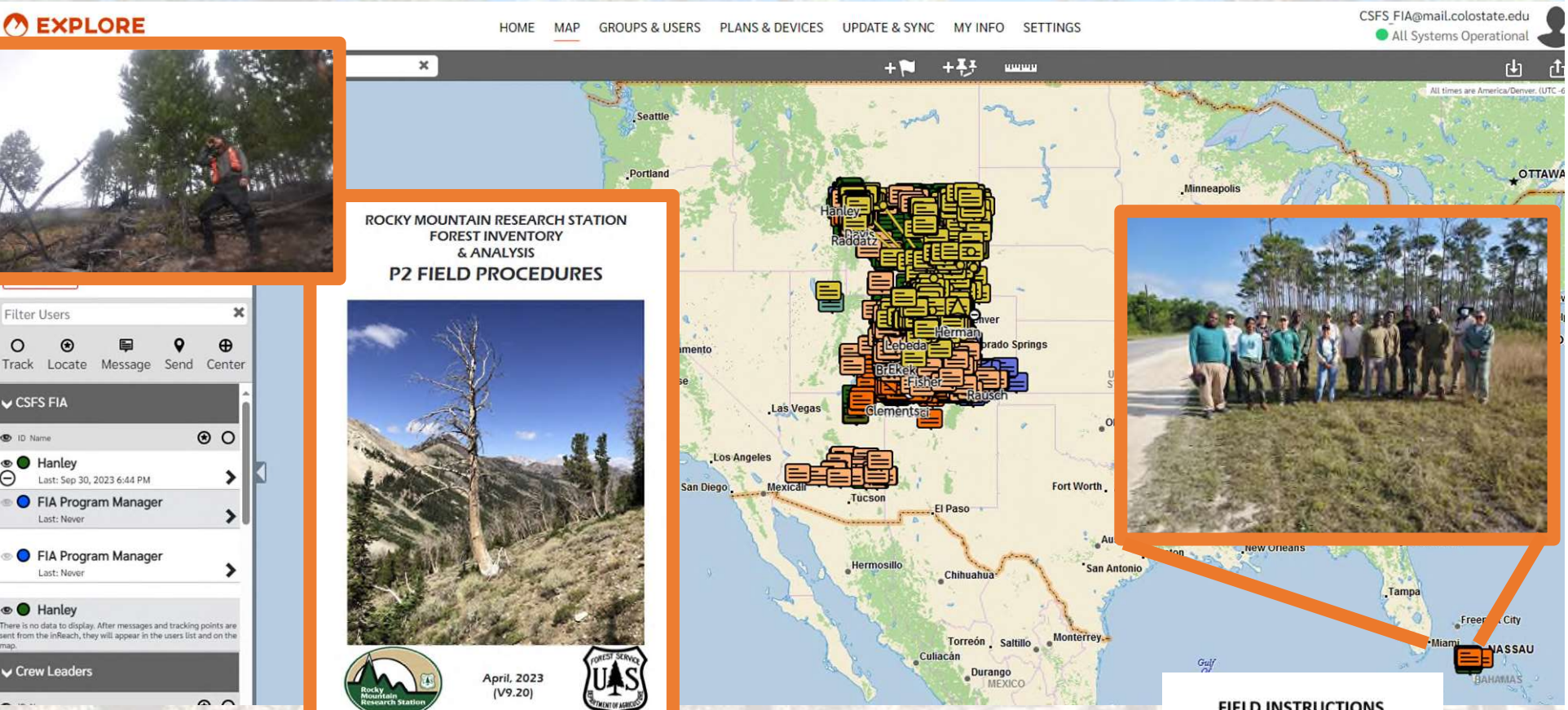
NATURAL RESOURCE ECOLOGY LABORATORY

County & Regional Differences

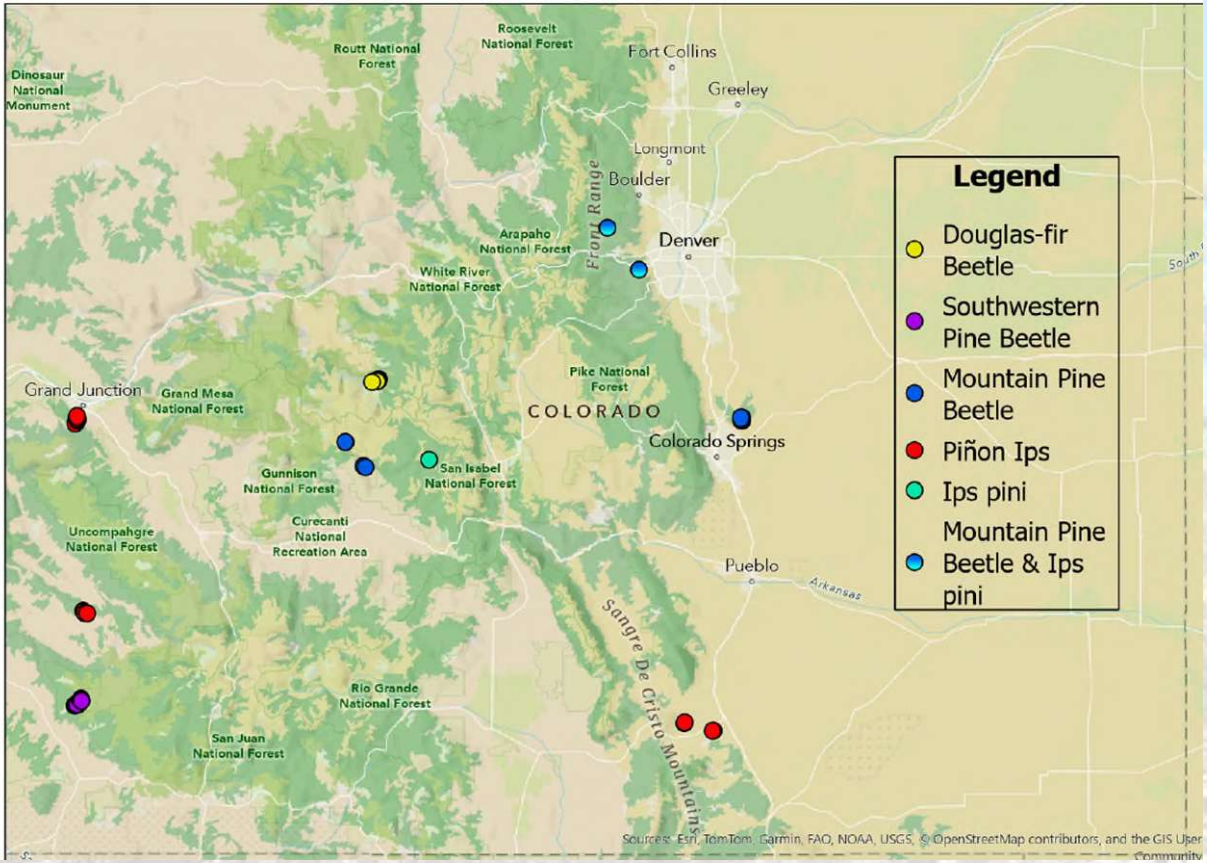
A) Carbon stock of Colorado counties for forested lands from FIA plots measured between 2010 and 2019. B) The average annual net flux is shown for Colorado's forest lands remaining forested for plots measured between 2002- 2009 and 2012 – 2019.



CSFS FIA Program Geography
2001 - 2023

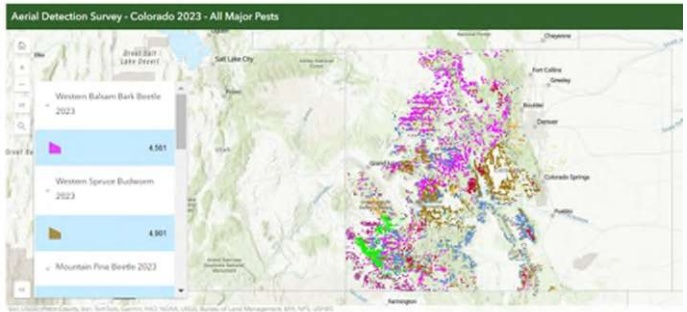


Forest Health Monitoring



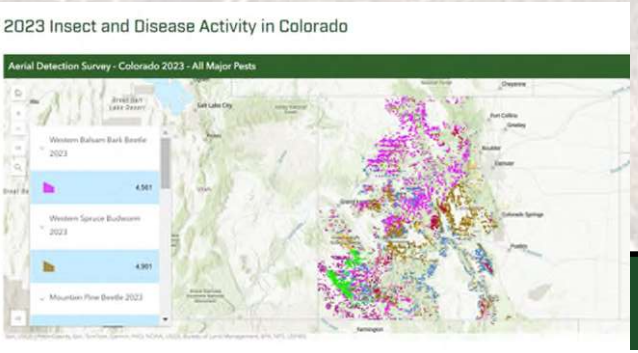
- In 2023, 3 new staff using BIL; 145 landowners
- 51,850 semiochemical packets across CO
- 86 traps for 5 spp. of bark beetle deployed
- New research protocol, FMPs & pollinators, response to “Colorado Native Pollinating Insects Health Study”; collaborators
- Established 16 plots this year for monitoring.

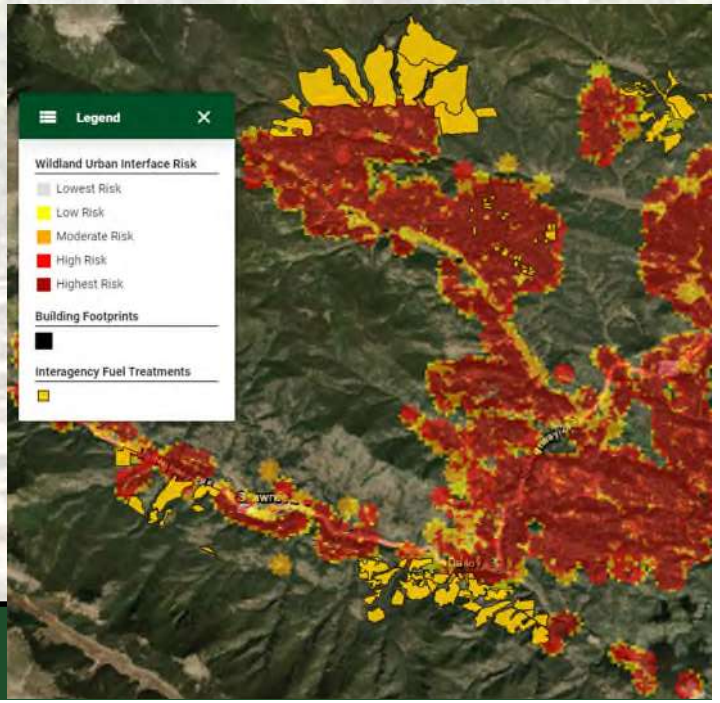
2023 Insect and Disease Activity in Colorado



Continuous investments in monitoring

- Forest Tracker
  - Data cleaning, web apps, remote sensing
- FRWRM treatment monitoring
  - Provide guidance to technical advisory panel and FRWRM administrators
  - Prescription development (ongoing)
- Carbon
- FIA - USDA RMRS
- Insect and disease
  - Info on timing
  - Pollinators





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References

- Rothermal 1972. A mathematical model for predicting fire spread in wildland fuels. Res. Pap. INT-115. Ogden, UT: U.S. Department of Agriculture, Intermountain Forest and Range Experiment Station. 40 p.
- Higuera et al. 2021. Rocky Mountain subalpine forests now burning more than any time in recent millennia. PNAS 118 (25)
- Overpeck and Udall 2020. Climate change and the aridification of North America, Proceedings of the National Academy of Sciences. DOI: 10.1073/pnas.2006323117 , www.pnas.org/content/early/2020/05/15/2006323117
- Davis, K. T., Peeler, J., Fargione, J., Haugo, R. D., Metlen, K. L., Robles, M. D., & Woolley, T. (2024). Tamm review: A meta-analysis of thinning, prescribed fire, and wildfire effects on subsequent wildfire severity in conifer dominated forests of the Western US. *Forest Ecology and Management*, *561*, 121885. https://doi.org/10.1016/j.foreco.2024.121885
- Addington, R. N., Aplet, G. H., Battaglia, M. A., Briggs, J. S., Brown, P. M., Cheng, A. S., Dickinson, Y., Feinstein, J. A., Pelz, K. A., Regan, C. M., Thinnes, J., Truex, R., Fornwalt, P. J., Gannon, B., Julian, C. W., Underhill, J. L., & Wolk, B. (2018). *Principles and practices for the restoration of ponderosa pine and dry mixed-conifer forests of the Colorado Front Range* (RMRS-GTR-373; p. RMRS-GTR-373). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://doi.org/10.2737/RMRS-GTR-373
- King, K.E. et al. 2024. Increasing prevalence of hot drought across western North America since the 16th century. Science Advances Vol 10, Issue 4 DOI: https://doi.org/10.1126/sciadv.adj4289
- Fulé, P. Z., Crouse, J. E., Roccaforte, J. P., & Kalies, E. L. (2012). Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine-dominated forests help restore natural fire behavior? *Forest Ecology and Management*, *269*, 68–81. https://doi.org/10.1016/j.foreco.2011.12.025
- Hood, S. M., Crotteau, J. S., & Cleveland, C. C. (2024). Long-term efficacy of fuel reduction and restoration treatments in Northern Rockies dry forests. *Ecological Applications*, *34*(2), e2940. https://doi.org/10.1002/eap.2940
- Millar, C. I., Stephenson, N. L., & Stephens, S. L. (2007). CLIMATE CHANGE AND FORESTS OF THE FUTURE: MANAGING IN THE FACE OF UNCERTAINTY. *Ecological Applications*, *17*(8), 2145–2151. https://doi.org/10.1890/06-1715.1
- Nagel, L. M., Palik, B. J., Battaglia, M. A., D'Amato, A. W., Guldin, J. M., Swanston, C. W., Janowiak, M. K., Powers, M. P., Joyce, L. A., Millar, C. I., Peterson, D. L., Ganio, L. M., Kirschbaum, C., & Roske, M. R. (2017). Adaptive Silviculture for Climate Change: A National Experiment in Manager-Scientist Partnerships to Apply an Adaptation Framework. *Journal of Forestry*, *115*(3), 167–178. https://doi.org/10.5849/jof.16-039

Thank you!

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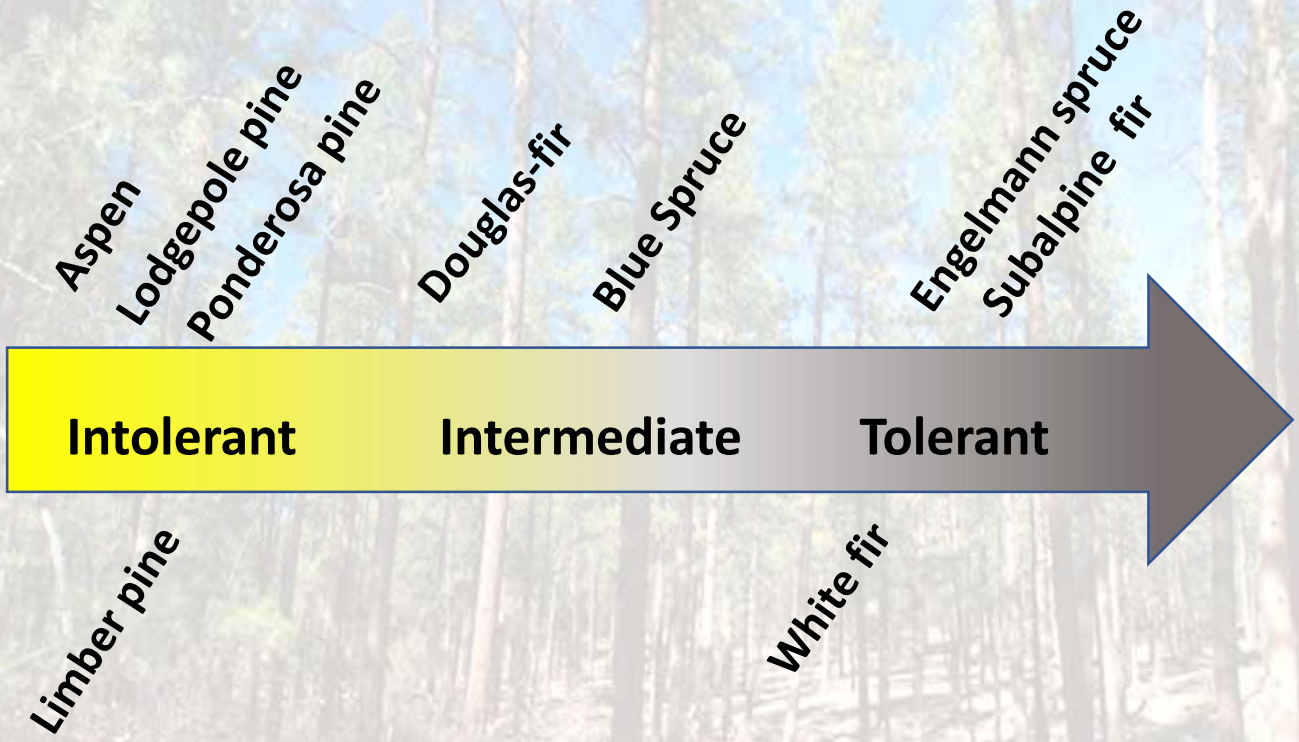
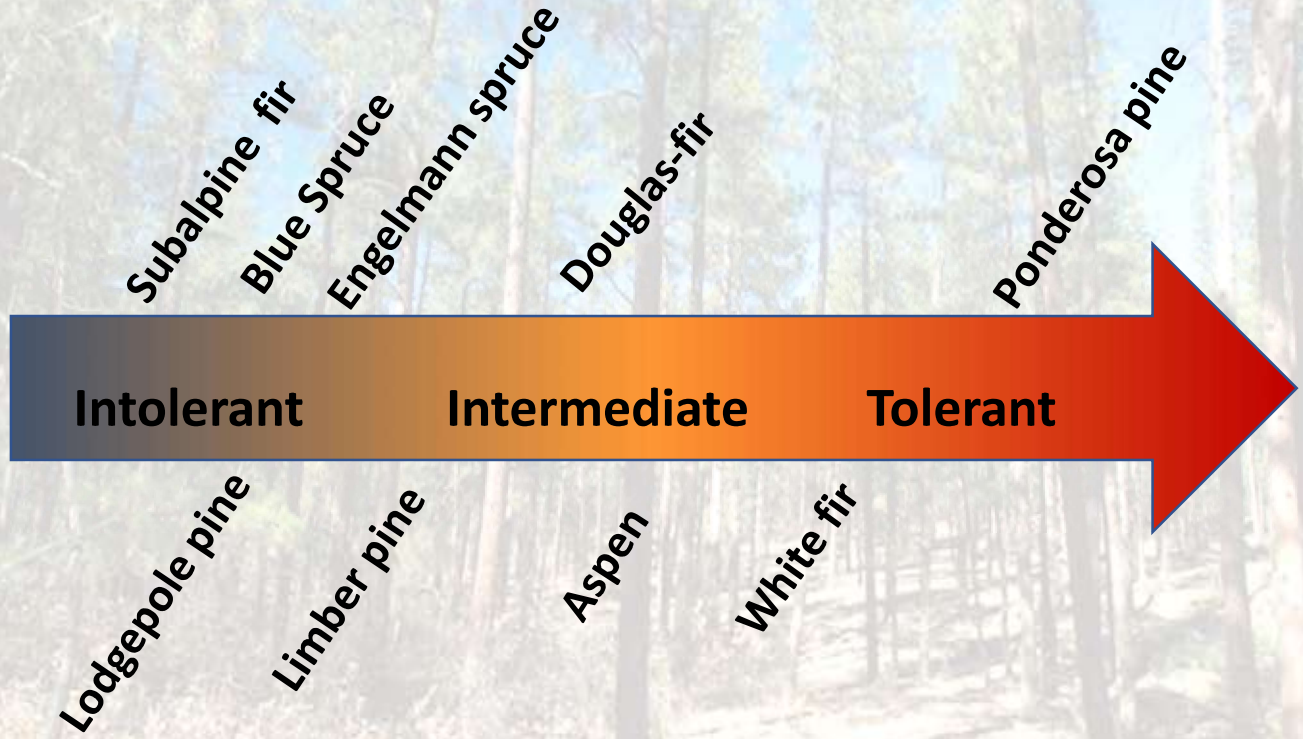
Shade tolerance

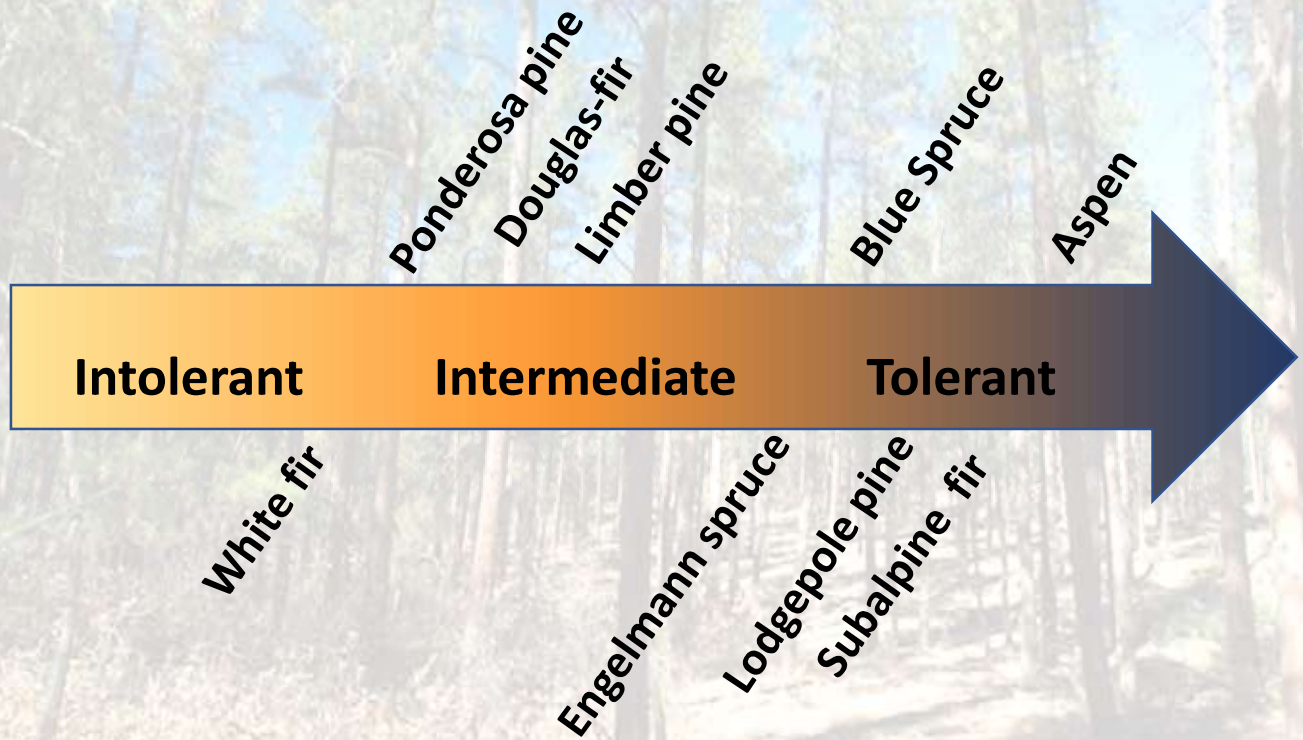


Niinemets, U., Vallardes, F., 2006. Tolerance to shade, drought, and waterlogging of temperate Northern Hemisphere trees and shrubs. Ecol. Monogr. 76, 521–547 (Ecological Archives M076-020-A1).

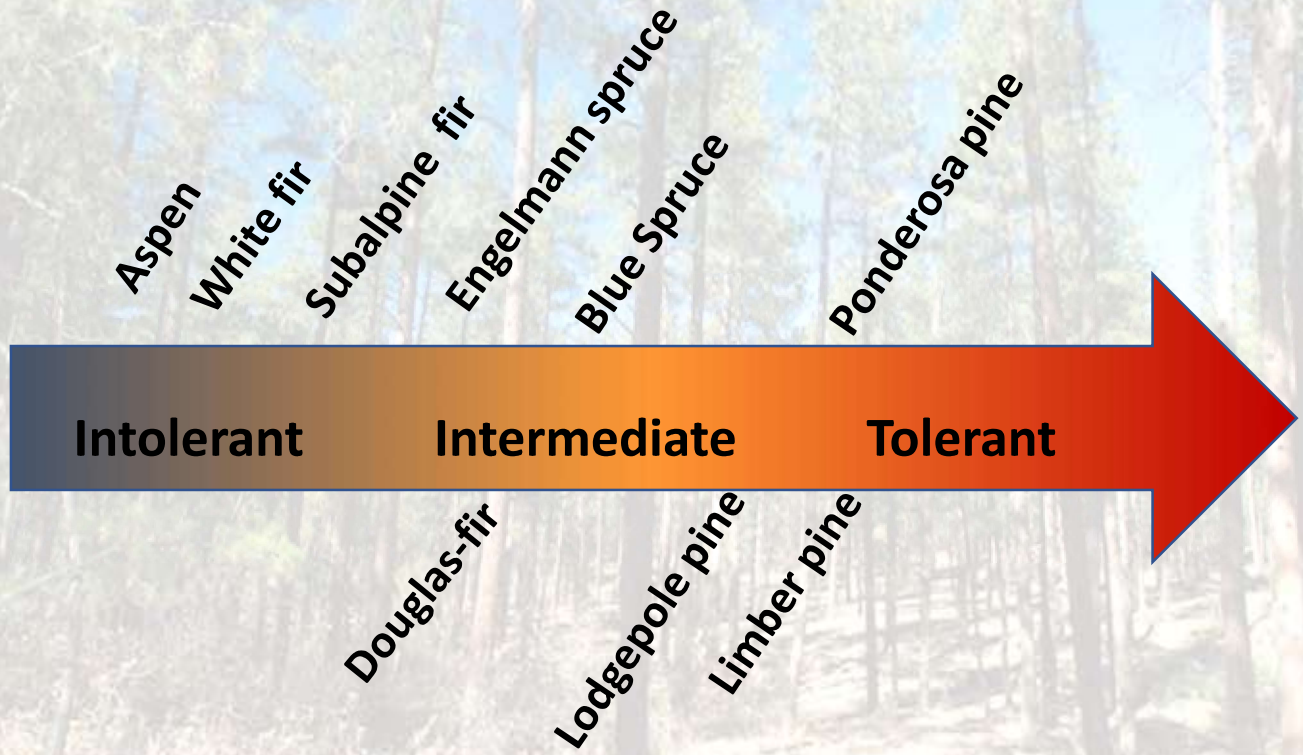
Heat tolerance



Cold tolerance



Drought tolerance



Niinemets, U., Vallardes, F., 2006. Tolerance to shade, drought, and waterlogging of temperate Northern Hemisphere trees and shrubs. Ecol. Monogr. 76, 521–547 (Ecological Archives M076-020-A1).