How is climate influencing and shaping forests and reforestation?

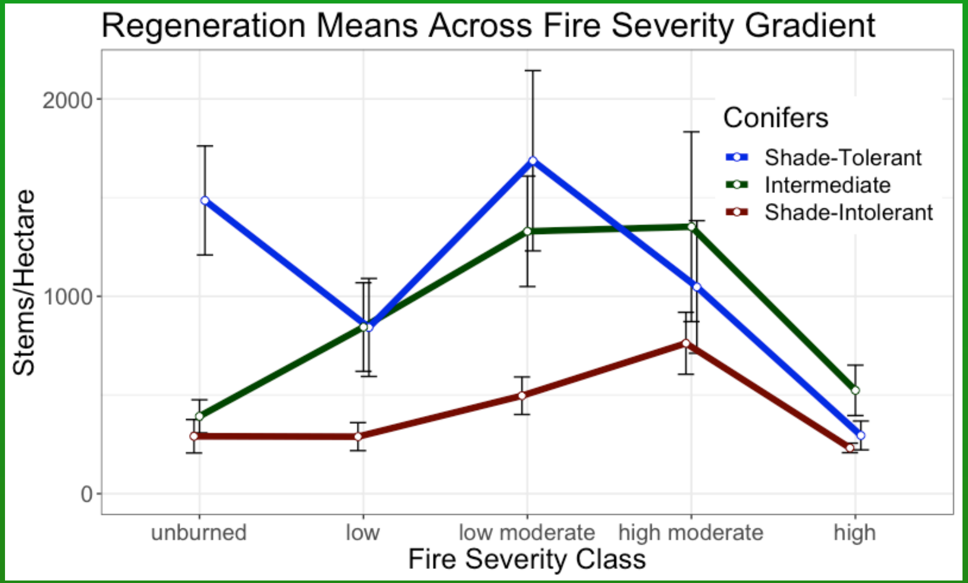
What does the future hold?

California's 4th climate change assessment (Sierra Nevada Region)

By the end of the 21st century:

- Warmer temperatures
  - Average increase of 6-9 °F
  - Enough to raise rain-snow transition zone by 1,500-3,000 feet
- Increase in precipitation extremes
  - more drought and more deluge
- Significant decline in snowpack
  - Likely eradication of snowpack below ~6,000 feet elevation
  - Reduction by more than 60% across nearly all of the range
- Drying of soils ~15-40% below historical norms
- More wildfire and drought, and lower carbon storage

Insights from Post-fire Natural Regeneration



Ecosphere 2016

14 fires on 10 National Forests

What drives or constrains natural regeneration?

1. Fire Severity — seed tree mortality
2. Distance to seed source —increases with high severity
3. Topographic context — slope, aspect, slope position (solar radiation)
4. Precipitation — germination cues, surviving dry summers
5. Shrubs — competition and/or facilitation, impacts on water availability

Synchrony between seed production, seed arrival, precipitation and microclimate

Potential Climate Change Effects

I. **Altered fire regimes**

A. Magnitude — Increase area burned by high severity fire

Seed bank is reduced

Decrease in seed arrival through seed mortality, seed tree mortality and increased distance to surviving seed sources.

B. Temporal — Fires burn more frequently & earlier in season

Killing saplings before reaching reproductive age

Cones do not reach maturity before fire

II. **Altered precipitation patterns**

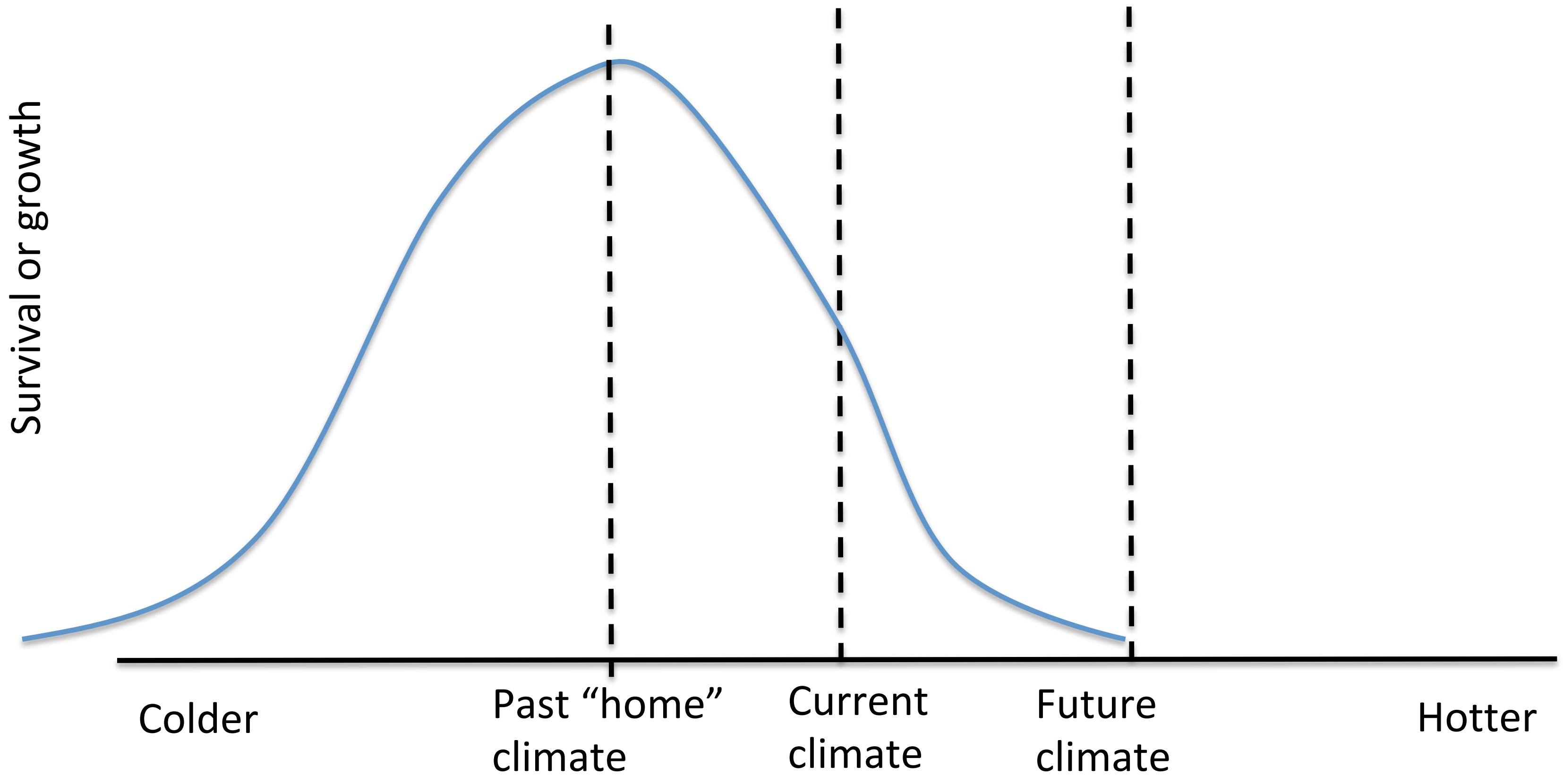
More drought stresses throughout life-phase of conifer

Breaking the synchrony between seed production, arrival, germination and establishment.

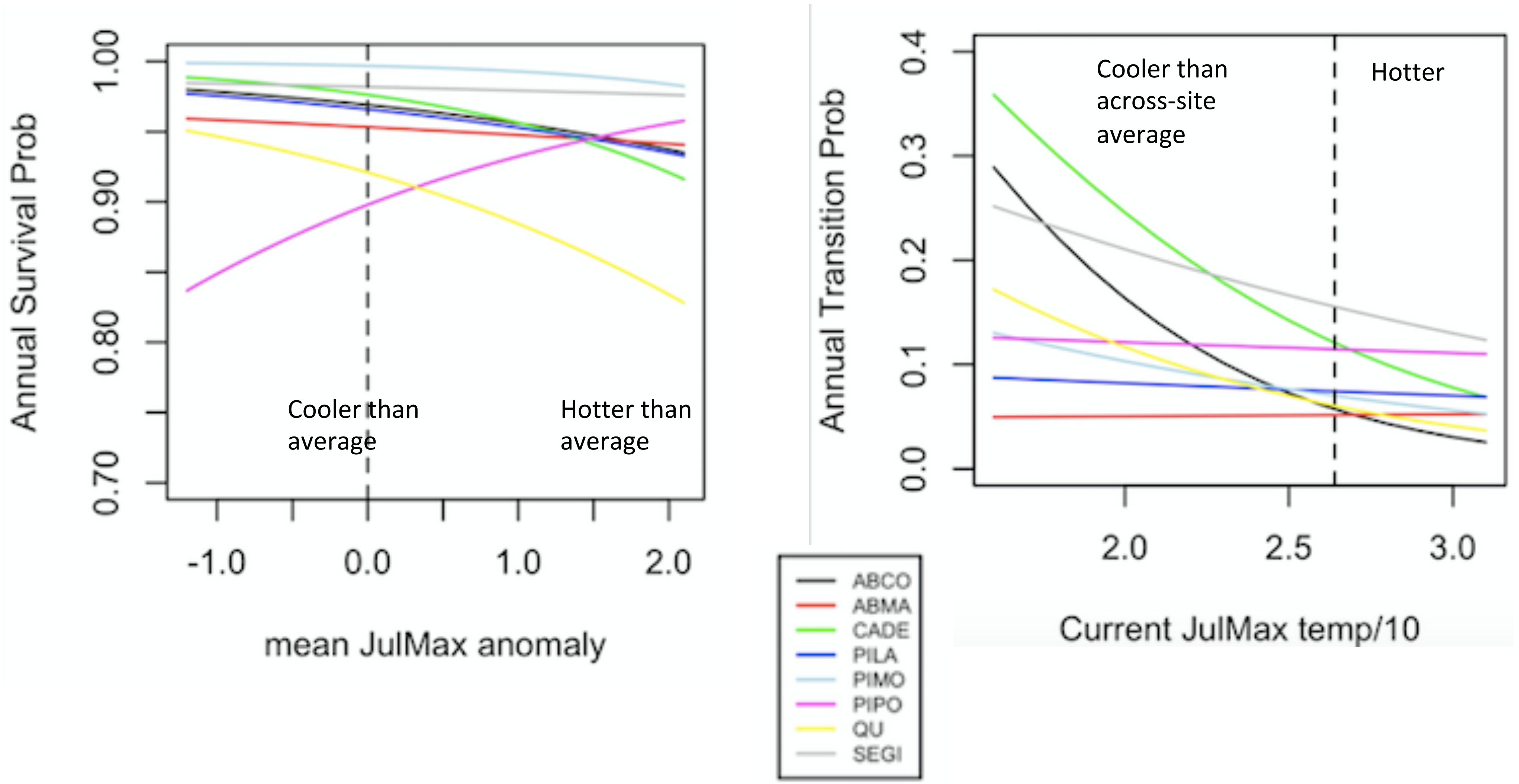
Environmental drivers and constraints for forest establishment and persistence

Emily Moran, UC Merced, emoran5@ucmerced.edu

Rapidly shifting climates could lead to maladaptation, declines in tree fitness, and ecosystem function



For instance, growth and survival of most Sierra Nevada tree seedlings reduced by hotter summers



(Model fitted to 1999-2008 observational data from 22 plots in SEKI and Yosemite)

To manage forests in the future, and know when to intervene, we need to know:

- Do seeds disperse far enough to reliably colonize newly suitable areas?
  - Can include warming areas, burns
- How will interactions with existing vegetation affect establishment of colonizing juveniles?
  - Competitive or facilitative?
- Could existing genetic variation in tree populations enable evolutionary adaptation?
  - If yes, less intervention needed
- If natural responses are insufficient, how might we select seed sources for assisted migration/gene flow?

Answers so far…

- Dispersal and colonization?
  - Max spread rates of 100 m/yr likely for trees
  - Sufficient for many elevation shifts, insufficient for most latitudinal
- Establishment limitation?
  - Competitive interactions, especially with adult trees, can slow spread
  - In harsh conditions moderate shading can facilitate seedling survival
- Evolutionary adaptation?
  - Probably to some extent, but lags will likely persist
  - Importance for prediction reliability still unclear
- Selecting seed sources
  - In widespread species, variation in climate responses exists
  - Comparing past to predicted future conditions, use of genetic markers, may help

How is Climate Influencing & Shaping Forests and Reforestation?

Increasing frequency and severity of wildfire and drought

Reforestation ➡ build resilience in young stands as early as possible

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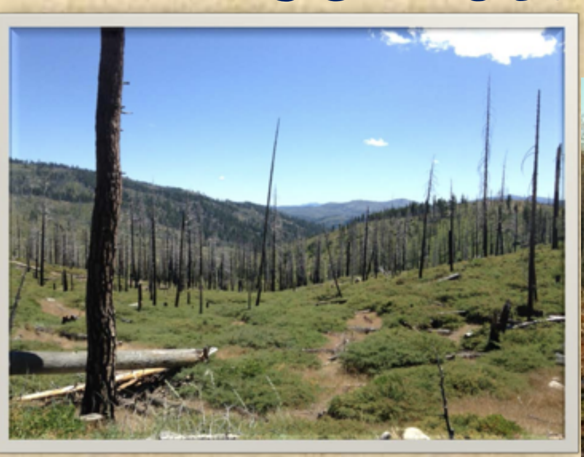
Current Reforestation Practices in the Sierra Nevada: sometimes termed "Pines in Lines"



Objectives:

- Bypass uncertain natural seeding & vulnerable seedling stage
- Crowns soon interlock shading out aggressive shrubs (i.e., manzanita ceanothus)
- Rapid initial height and diameter growth for ≈ 15-25 yrs
- Commercial thin to adjust stand density and accelerate large tree development



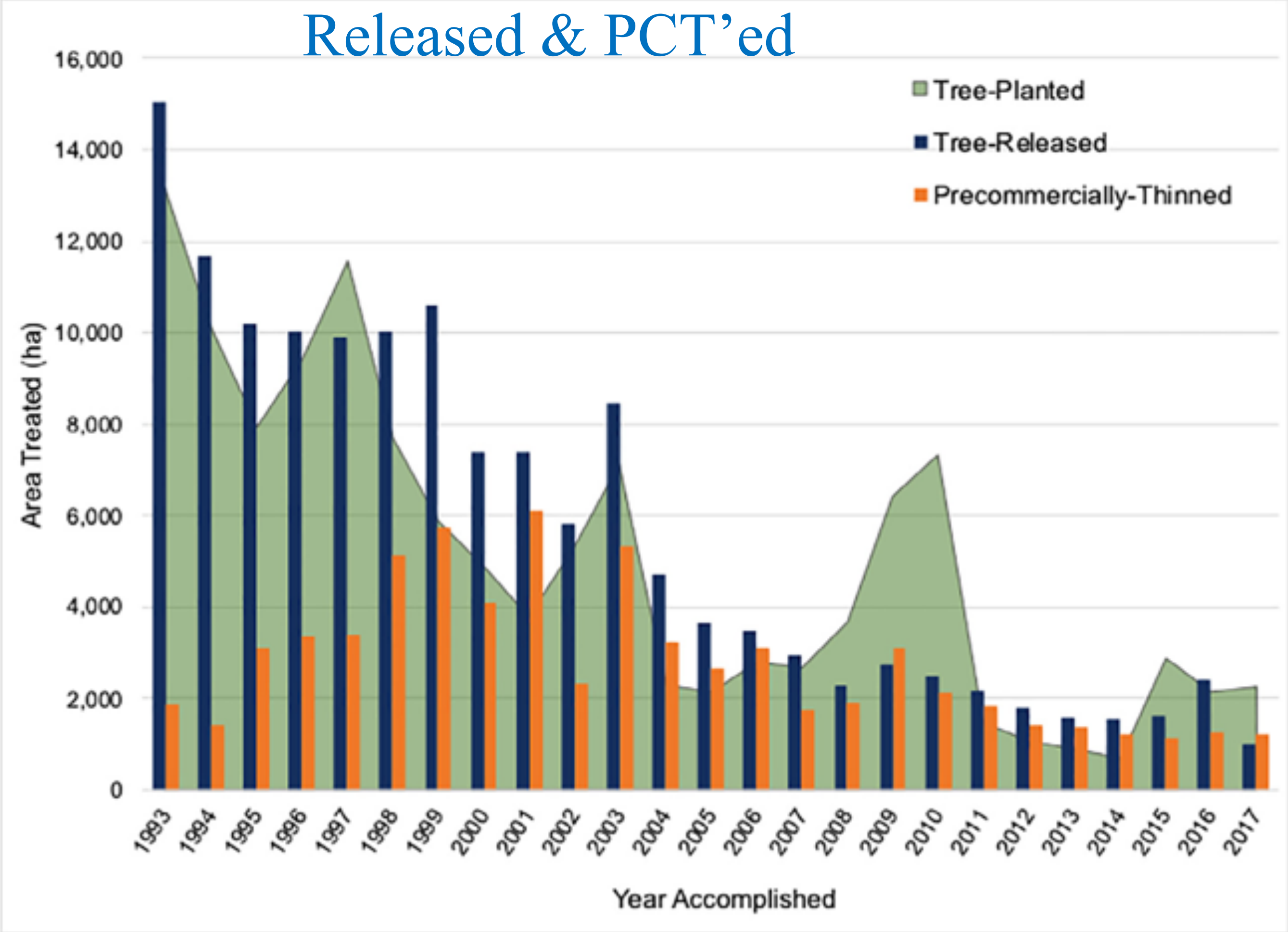
Problems with 'pines in lines' reforestation

- Method is heavily dependent on costly 'course correction':
- Reduce shrubs with manual herbicide or labor intensive grubbing
- PCT often needed to reduce density, change composition, and spatial pattern

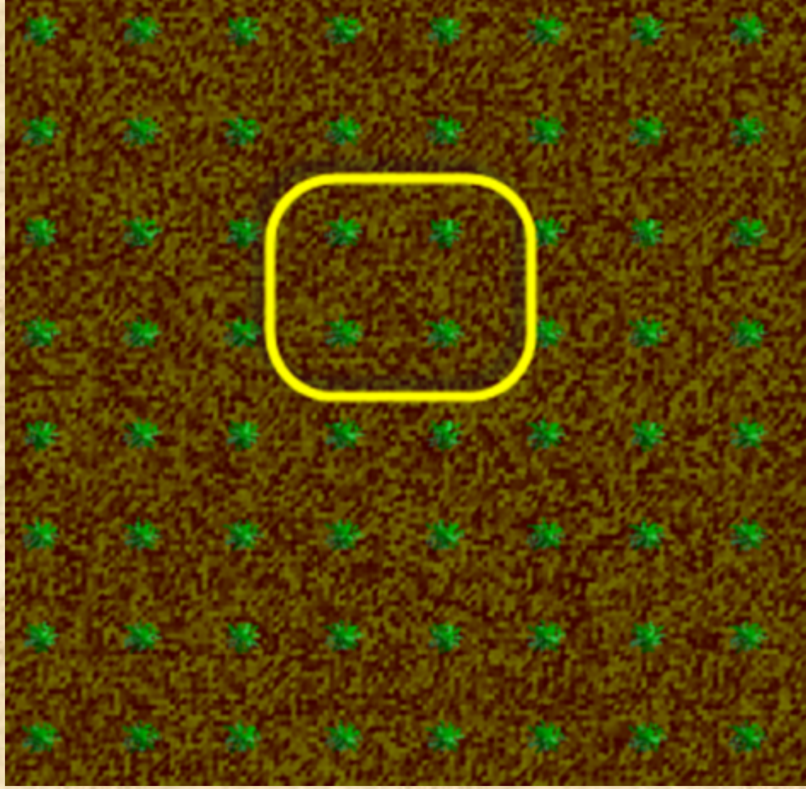
USFS Regions 1-6:
40% decline in acreage released

USFS All Regions:
Budgets stagnant to shrinking, yet from 2000 to 2018, fire suppression costs have increased >250% (in $2017)

Declining Acres of Sierra Nevada NF Ownership Planted, Released & PCT'ed



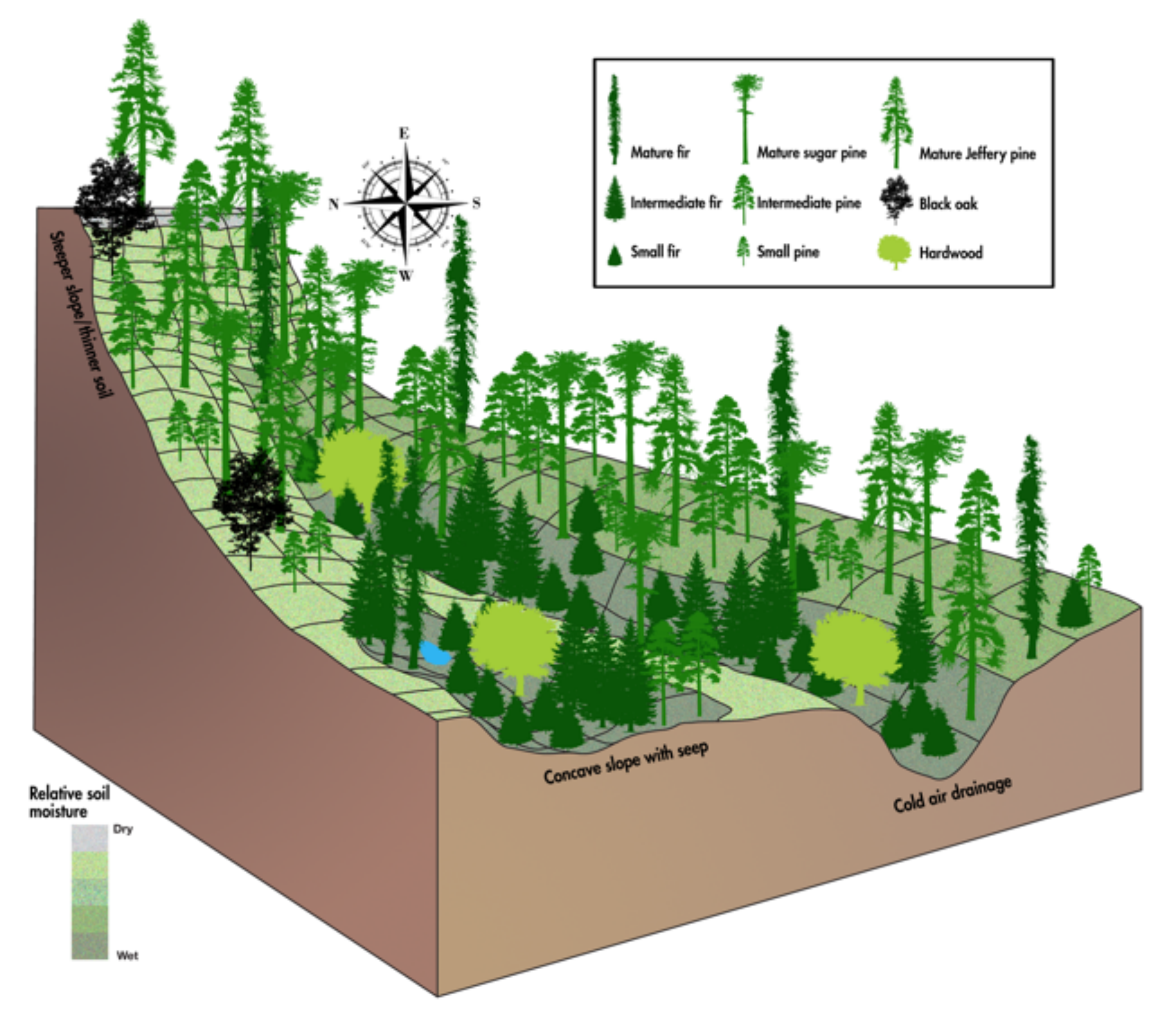
High density of 'pines in lines' is not resilient to drought mortality, and when burned can lead to 100% incineration



- While good for maximizing tree growth, regular spacing lacks a gradient of densities and has a narrower range of microclimates, habitats, and stress resilience

Two important research findings suggest tree location, local density and spatial pattern have and should vary with edaphic and abiotic conditions

1) In forests with restored fire regimes, local density, composition, and structure are **congruent with how topography influences water availability and fire intensity**



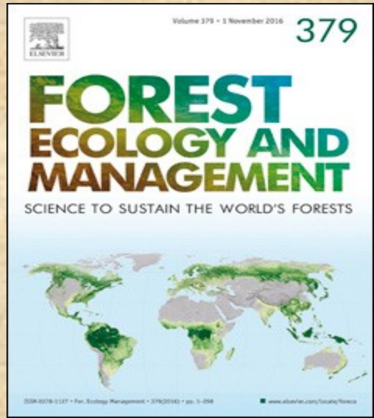
2) A recent meta-analysis found frequent fire forests consistently have a spatial pattern of individual trees, clumps of trees and openings (ICO)—a pattern that made historical forests more resilient

ICO pattern in fire-restored forest, Yosemite

Reforestation For Resilience:
3 main objectives

1) Divide reforestation area into zones by potential seeding and access/costs
2) Composition, density, and pattern should vary and be aligned with local ecosystems conditions
3) Build young forest resilience with use of early, frequent prescribed fire

North, M.P., J.T. Stevens, D.F. Greene, M. Coppoletta, E.E. Knapp, A.M. Latimer, C.M. Restaino, R.E. Tompkins, K.R. Welch, R.A. York, D.J.N. Young, J.N. Axelson, T.N. Buckley, B.L. Estes, R.N. Hager, J.W. Long, M.D. Meyer, S.M. Ostoja, H.D. Safford, K.L. Shive, C.L. Tubbesing, H. Vice, D. Walsh, C.M. Werner, and P. Wyrsch. 2019. **Tamm Review: Reforestation for resilience in dry western U.S. forests.** Forest Ecology and Management 432: 209-224.

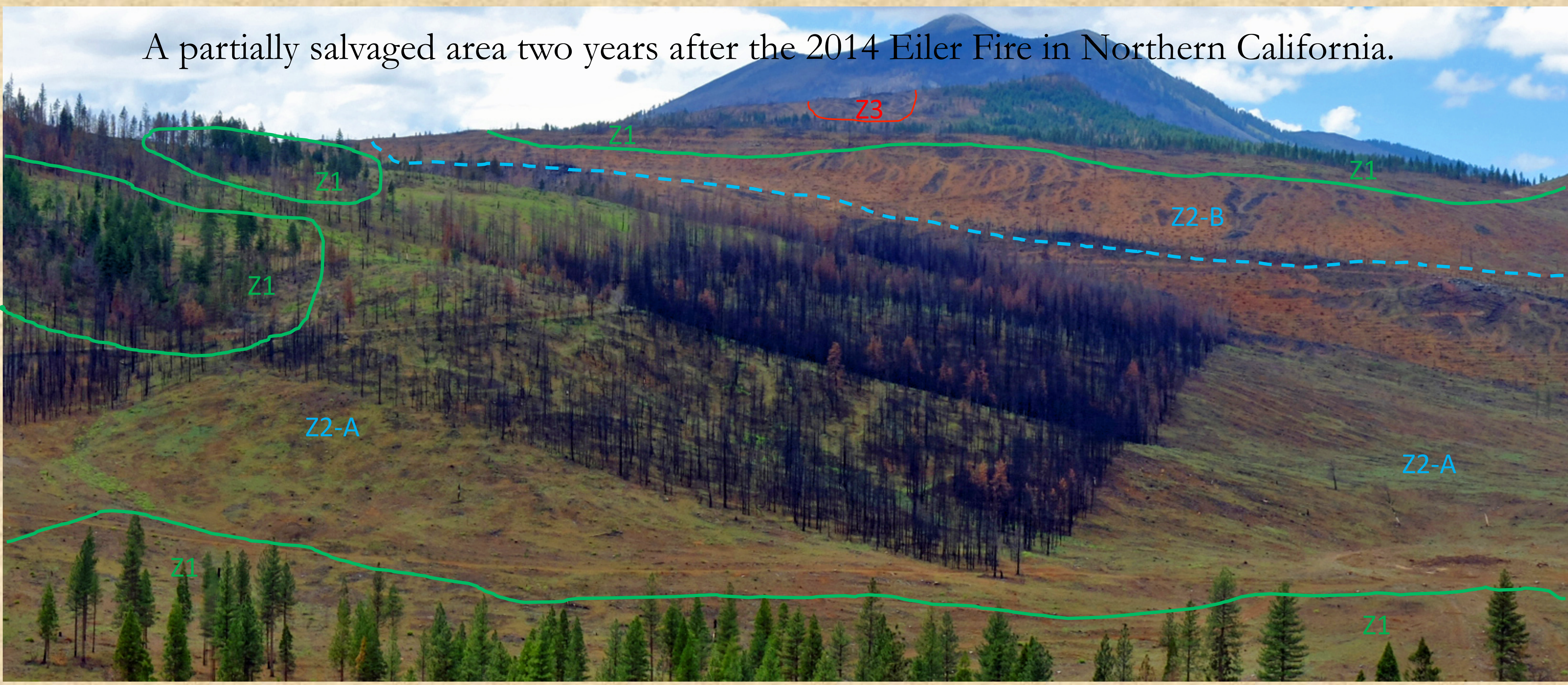


#1) Zones With Different Strategies

Z1: Interplant as needed within seed dispersal distance of green trees

Z2: Cluster/regular planting in accessible (for salvage and planting) areas beyond seed dispersal

Z3: Plant founder stands in remote, inaccessible areas with cost and safety challenges



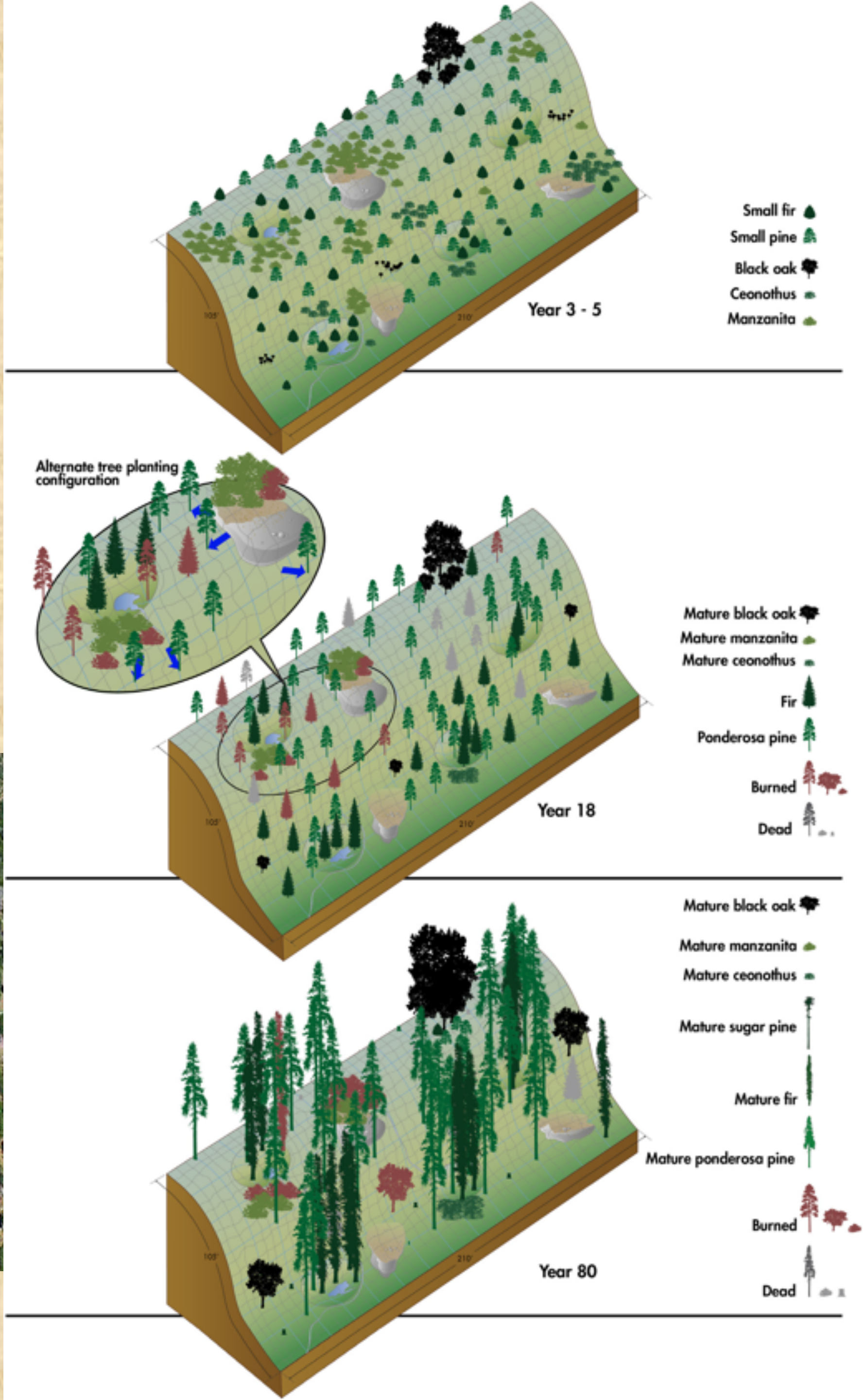
#2 Proposed Planting:

Schematic of the initial planting and subsequent stand development for a 0.5 ac (105 X 210ft) slope of forest.

Clusters of seedlings planted where there is more water (concavities), species varies with local projected fire intensity and low density of regularly spaced seedlings planted between clusters.

'Martir' Baja forest structure resilient to drought and fire

Spatial Pattern in the Beaver Creek Pinery

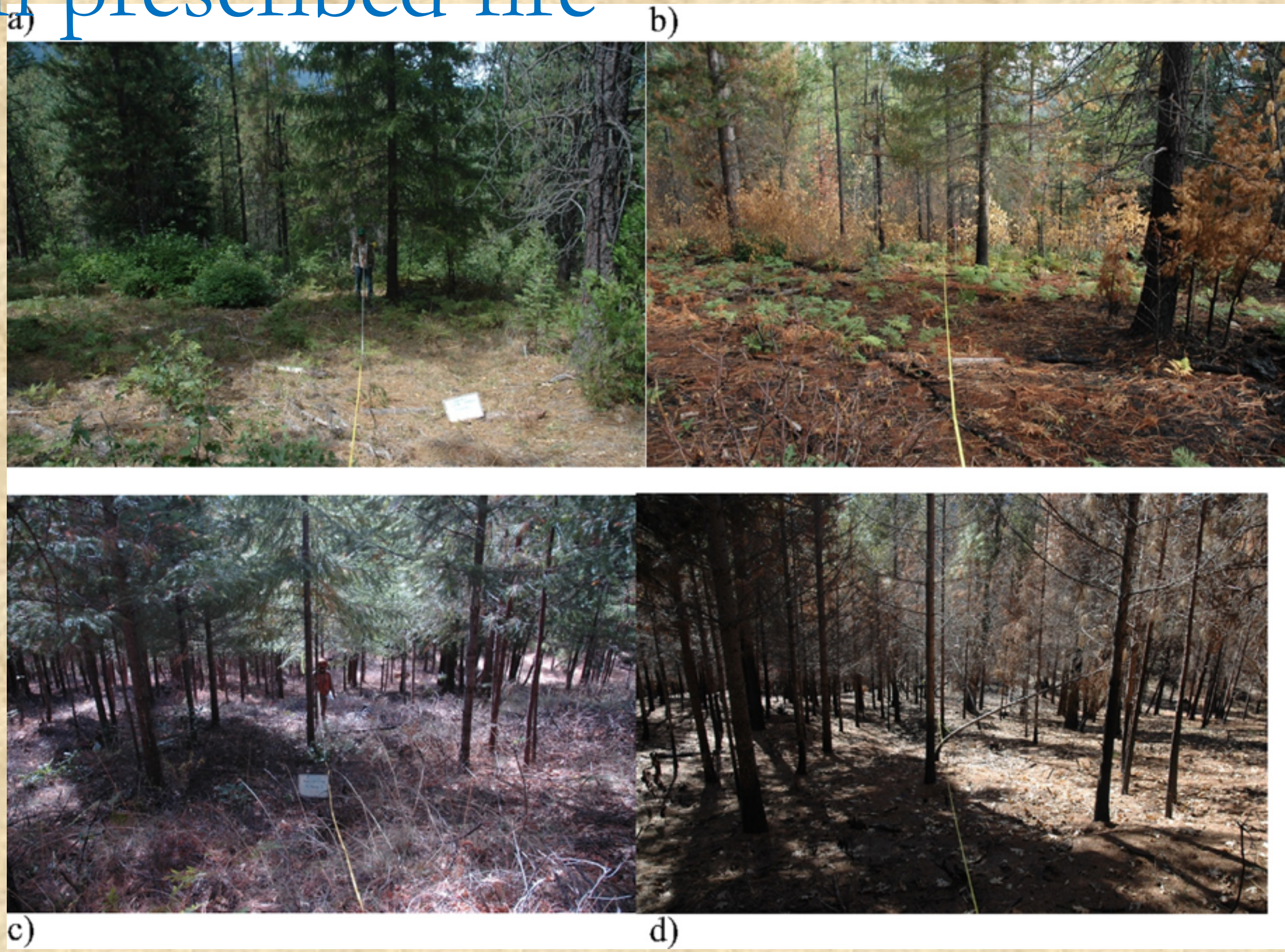


#3: Build early resilience and genetic selection for fire tolerance with prescribed fire

Before and after examples of young stand Rx burns on the Shasta-Trinity National Forest.

The upper pair, a) and b), show a mixed-conifer plantation that was spring burned 33 years after planting. Surface fuels were reduced, as was density by killing smaller trees.

The lower pair, c) and d), showing how the burn in a 25 yr old stand acted like a cost effective pre-commercial thin reducing natural recruitment density.



Reforestation practices can become more resilient using early fire and by increasing variability in resource competition, fuel loads, and wildlife habitat

QUESTIONS AND DISCUSSION