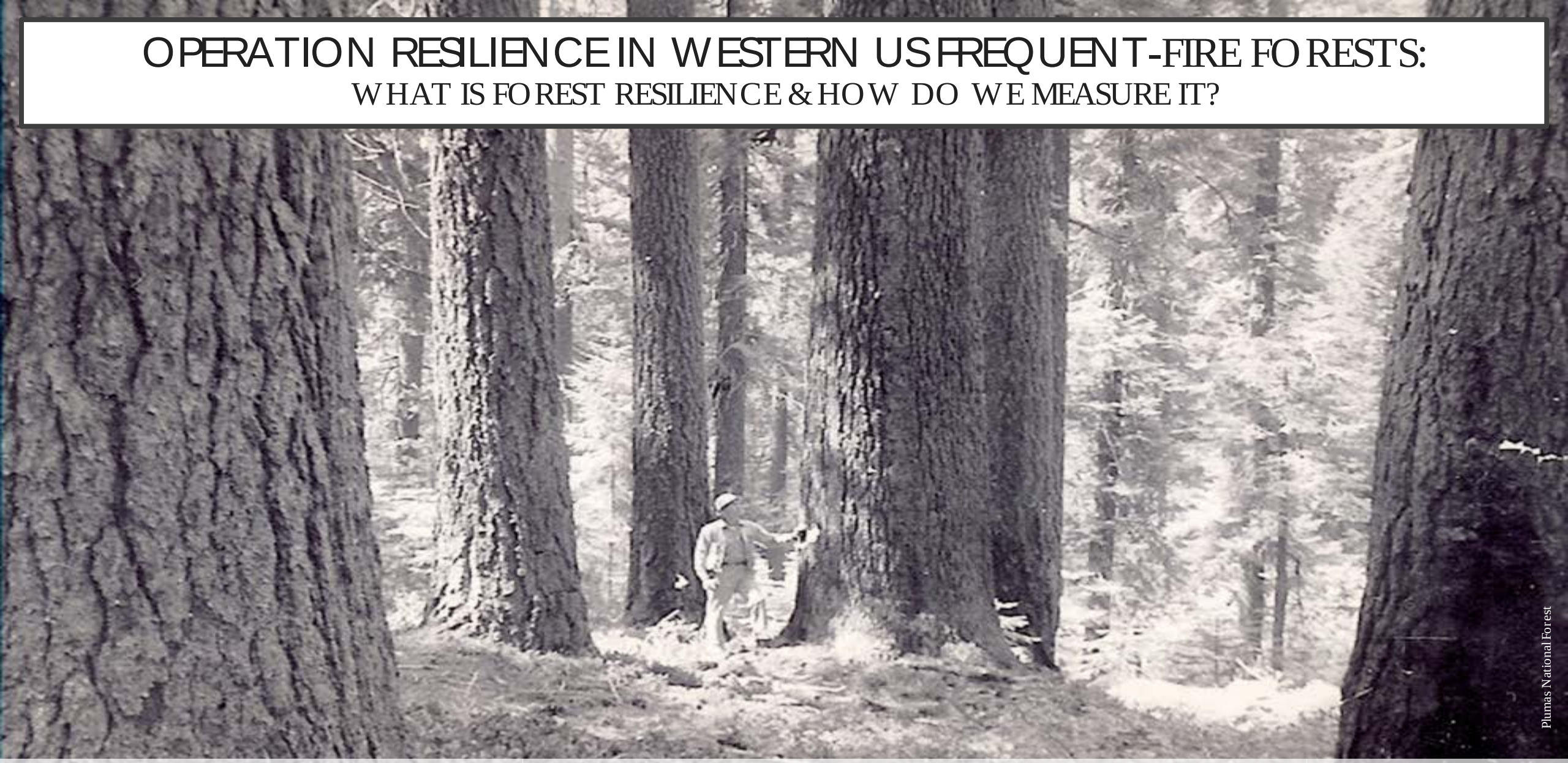
# OPERATION RESILIENCE IN WESTERN US FREQUENT-FIRE FORESTS:

## WHAT IS FOREST RESILIENCE & HOW DO WE MEASURE IT?



Plumas National Forest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# DISCUSSION ROADMAP:

1

Malcolm North: Framework for resiliency

2

Brandon Collins: Background on historical data

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Ryan Tompkins: Relative SDI and resiliency

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Rob York: Management implications

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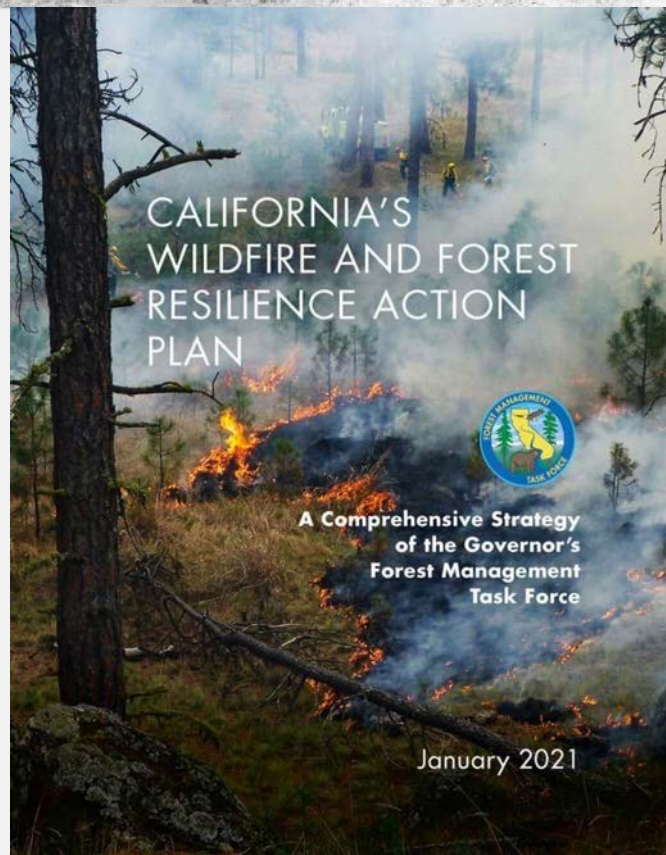
Alexis Bernal: Resiliency and the future

# FOREST RESILIENCE AND ITS "BAGGAGE"

- Treatments use to be designed to restore pre-European conditions
- But changing climate and disturbance regimes ⇒ emphasize on resilience (2012 USFS Forest Planning Rule, CA Task Force)
- Resilience definitions lack precision: "a [malleable] term that facilitates communication across disciplinary borders by creating shared vocabulary… (bridging) the gap between science and policy" (Brand and Jax 2007)

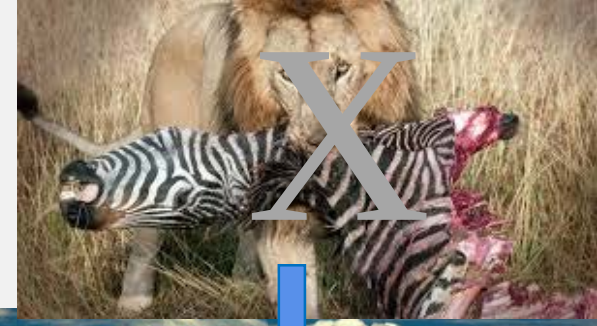


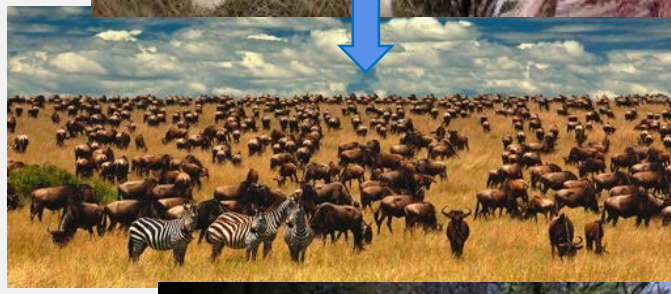

# DIFFERENCE BETWEEN RESISTANCE AND RESILIENCE

Resistance, a **measure of persistence**, focuses on minimizing change to a **specific stress**: ex. fuels reduction

Resilience, a **measure of adaptability**, focuses on retaining an ecosystem's essential structure and composition to a **range of stresses**

# MORE PRECISE, MEASURABLE DEFINITION OF RESILIENCE IS POSSIBLE USING ECOLOGICAL CONCEPTS AND CONTEXT







Fire is similar to herbivory: consumers control ecosystem biomass and species composition

When predators are scarce (no lions) ⇒ little plant competition because herbivores proliferate, limiting plant growth more than resources

In the absence of suppression (scarce firefighters), fire proliferates, limiting tree density more than resource availability (i.e., water, light, and nutrients) ⇒ significantly reducing competition

Forest appears ‘understocked’

Early CA survey “Suppression of the young growth has always been one of the serious results of fires…The land does not carry more than 35 percent of the quantity of timber it is capable of supporting” (Leiberg 1902)

Many studies have shown that vigorous growth (ex., large growth rings) increases a tree's defenses to multiple stressors (i.e., beetles, fire, drought, etc.)

What has happened in modern forests?

In fire's absence, live tree density and biomass accumulate ⇒ competition for growth resources ⇒ reduced tree vigor

Historically, frequent-fire forests have been long-lived because they were adapted to stress pulses (i.e., fire, beetle outbreaks) but modern forests are exposed to a long-term 'press', competition, that compromises tree vigor

HYPOTHESIS

FOR RESILIENCE, TREATMENTS NEED TO RESTORE TREE VIGOR BY CREATING THE VERY LOW DENSITIES CHARACTERIZED BY LITTLE RESOURCE COMPETITION THAT SUSTAINED FREQUENT-FIRE FORESTS

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Form 321 a. ✓

UNITED STATES DEPARTMENT OF AGRICULTURE,
FOREST SERVICE.

"Forty" Estimate Sheet.

Tp. 1 S, R. 20 E, MD M. Sec. 19, Forty 3 NE¼NW Course Due N Slope SW

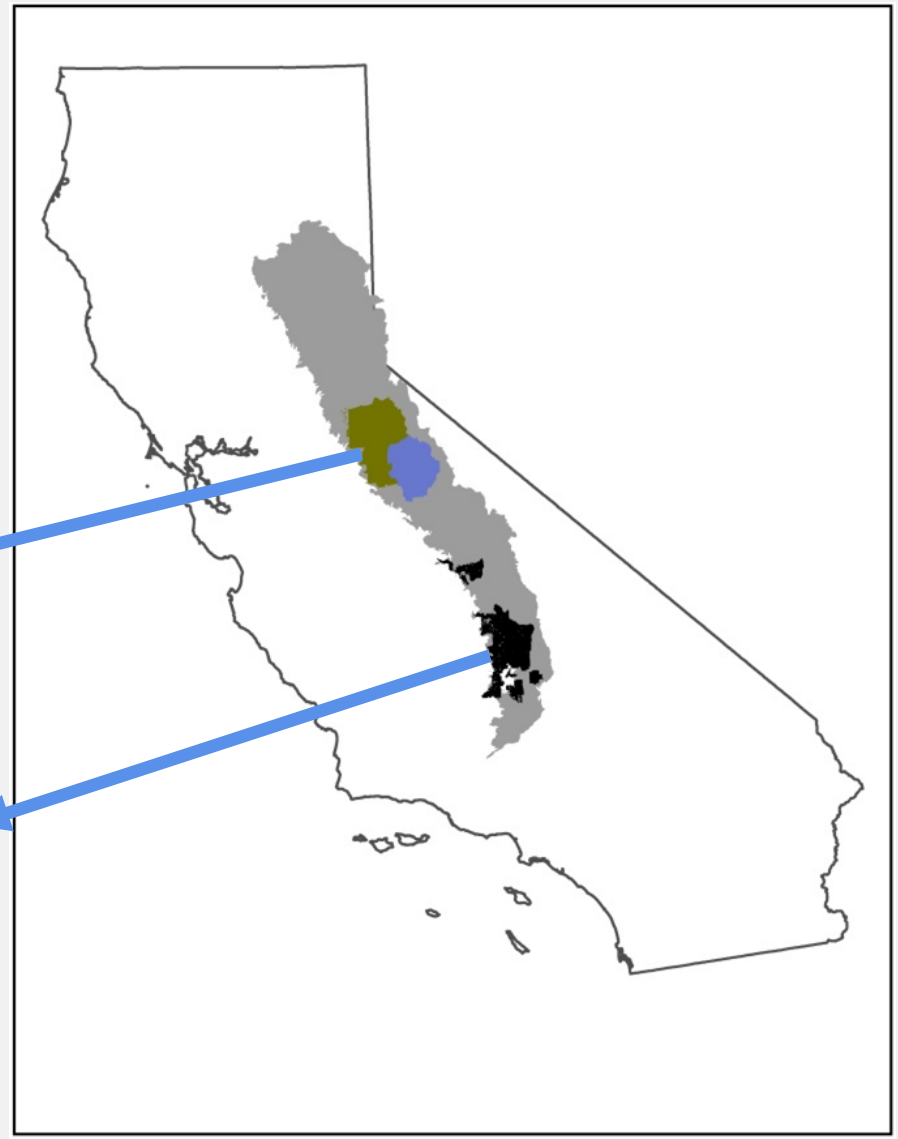
Sheet Number 243 Series, Date 7-8, 1911

Examiners { Estimator E H Coulson
Compassman J R Berry

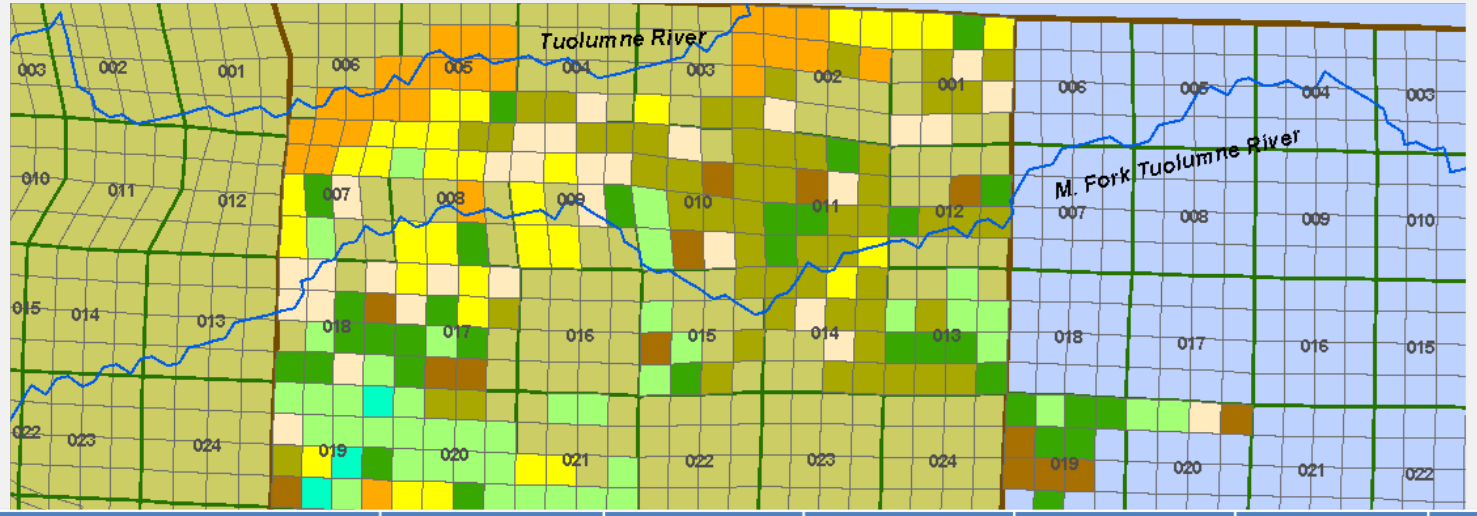
| D. B. H. | YP Species | | | | SP Species | | | | WF Species | | | | IC Species | | | | Miscellaneous Green; Dead (All Species) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ins. | 1 | 2 Number | 3 of logs | 4 | 1 | 2 Number | 3 of logs | 4 | 1 | 2 Number | 3 of logs | 4 | 1 | 2 Number | 3 of logs | 4 | YP | SP Number | WF of logs | IC |
| Poles | ☒ | | | | | | | | | | | | | | | | buddings | | | |
| 12 | | | | | | | | | | | | | | | | | 15 | | | 20 |
| 14 | | | | ✓ | | | | | | | | | | | ✓ | | saplings | | | |
| 16 | | | ✓ | | | | | | | | | | | | | | 10 | | | 8 |
| 18 | | | | | | | | | | | | | | | | | dead | | | |
| | 4 | 5 Number | 6 of logs | 7 | 4 | 5 Number | 6 of logs | 7 | 4 | 5 Number | 6 of logs | 7 | 3 | 4 Number | 5 of logs | 6 | 4 | Number | of logs | 3 |
| 20 | ✓ | ✓ | | | | | | | | | | | | | | | | | | |
| 22 | | ✓ | | | | | | | | | | | | | | | | | | |
| 24 | ✓ | ✓ | | | | | | | | | | | ✓ | | | | | | | |
| 26 | | ✓ | ✓ | ✓ | | | | | | | | | | | | | | | | |
| 28 | | | ✓ | ✓ | | | | | | | | | | | | | | | | |
| 30 | | | ✓ | ✓ | | | | | | | | | | | | | | | | |
| 32 | | | ✓ | | | | | | | | | | ✓ | | | | | | | |
| 34 | | | ✓ | ✓ | | | | | | | | | | | | | | | | |
| 36 | | | | ✓ | | | | | | | | | | ✓ | | | | | | |

| Total count | Stanislaus NF & Yosemite NP | Sequoia (Kern) NF Greenhorn Mts. |
|---|---|---|
| Transects | 294 | 378 |
| Trees | 20,700 | 18,052 |
| Survey area (ac)* | 41,496 | 28,405 |

*no prior timber harvesting, ~3% sample of total area



# STF-YOSE – FOREST STRUCTURE AND COMPOSITION

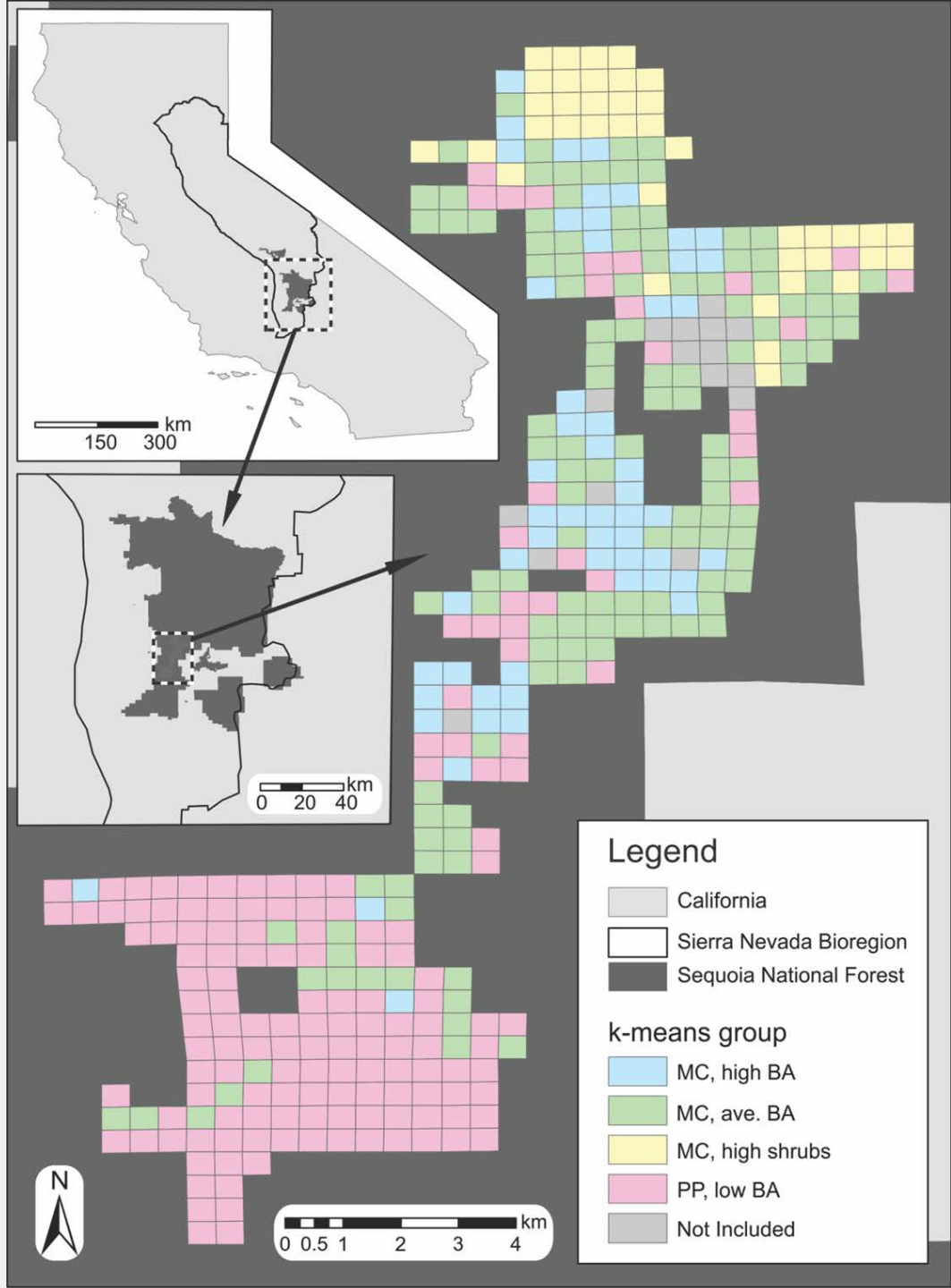



| Vegetation group | No. (transects) | CHFO (% cover) | Shrub (% cover) | Total BA ($ft^2\ ac^{-1}$) | Trees > 6" ($ac^{-1}$) | Canopy cov. (%) |
|---|---|---|---|---|---|---|
| Shrub | 27 | 2 | 84 | 0 | 0 | 0 |
| Low BA, high shrub | 48 | 25 | 54 | 35 | 10 | 9 |
| Low BA, high small trees | 31 | 32 | 22 | 43 | 20 | 12 |
| PIPO, low BA, high CHFO | 44 | 80 | 11 | 60 | 15 | 16 |
| PIPO, high BA, mod CHFO | 41 | 55 | 21 | 94 | 29 | 24 |
| PIPO-CADE, low CHFO | 60 | 18 | 17 | 73 | 19 | 17 |
| Mixed-con., high lg. trees | 24 | 43 | 25 | 132 | 29 | 28 |
| PSME-PILA | 16 | 26 | 36 | 82 | 18 | 20 |
| AB sp., high large trees | 3 | 0 | 22 | 129 | 32 | 20 |

Collins et al 2015, *Ecol. Appl.*

# KERN – FOREST STRUCTURE AND COMPOSITION

| Vegetation group | No. (trans.) | CHFO (%cover) | Shrub (%cover) | BA ($ft^2\ ac^{-1}$) | Trees *($ac^{-1}$) | Can. cov. (%) |
|---|---|---|---|---|---|---|
| MC, high BA | 55 | 0 | 20 | 182 | 40 | 25 |
| MC, ave. BA | 127 | 5 | 26 | 107 | 24 | |
| MC, shrubs | 39 | 62 | 76 | 122 | 38 | |
| PP, low BA | 157 | 1 | 14 | 49 | 10 | 12 |



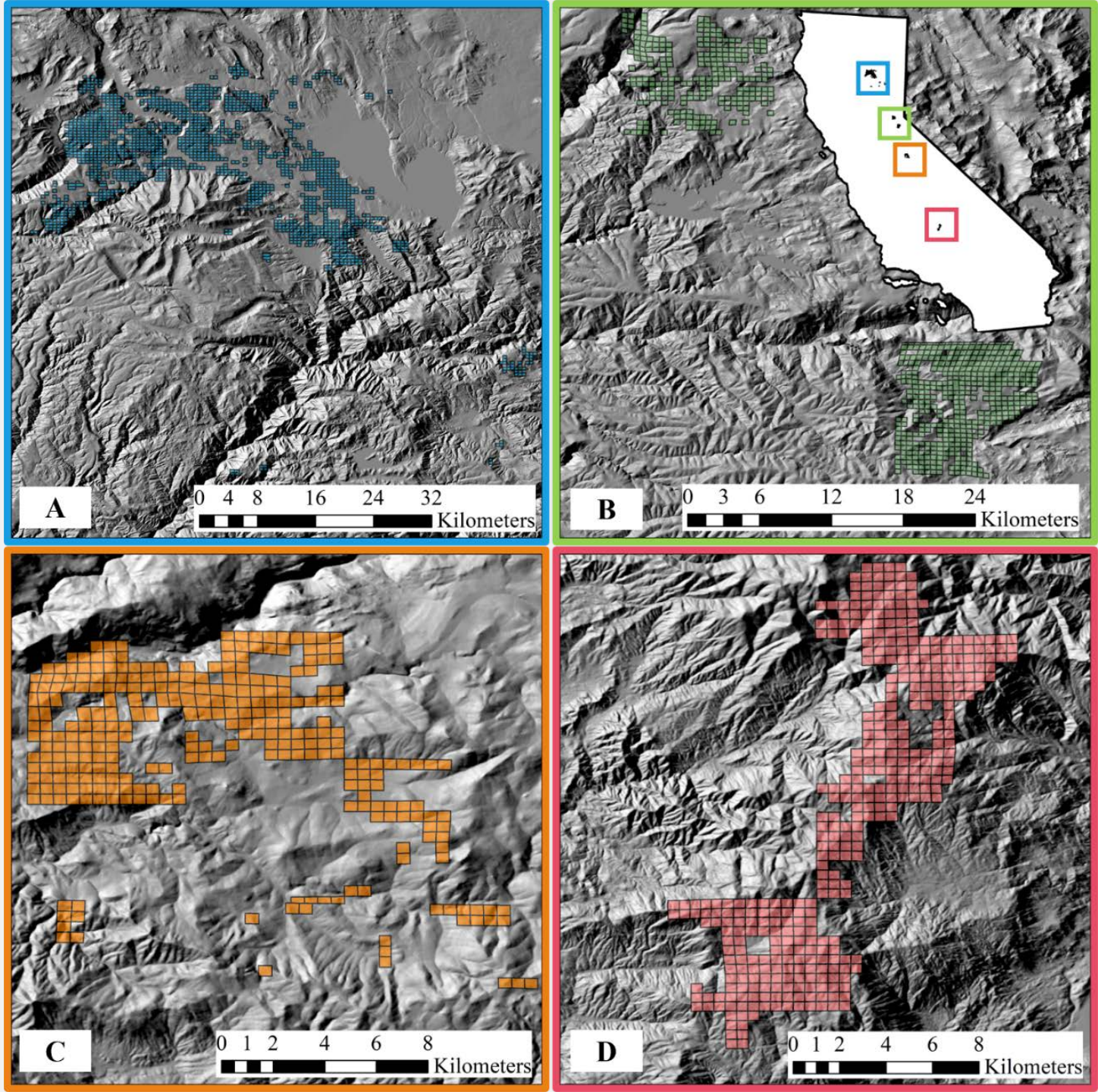

Stephens et al. 2015, *Ecosphere*

# HISTORICAL VS. CONTEMPORARY INVENTORY (REMEAS): PINE-MIXED-CONIFER FOREST, STANISLAUS NF AND YOSEMITE NP

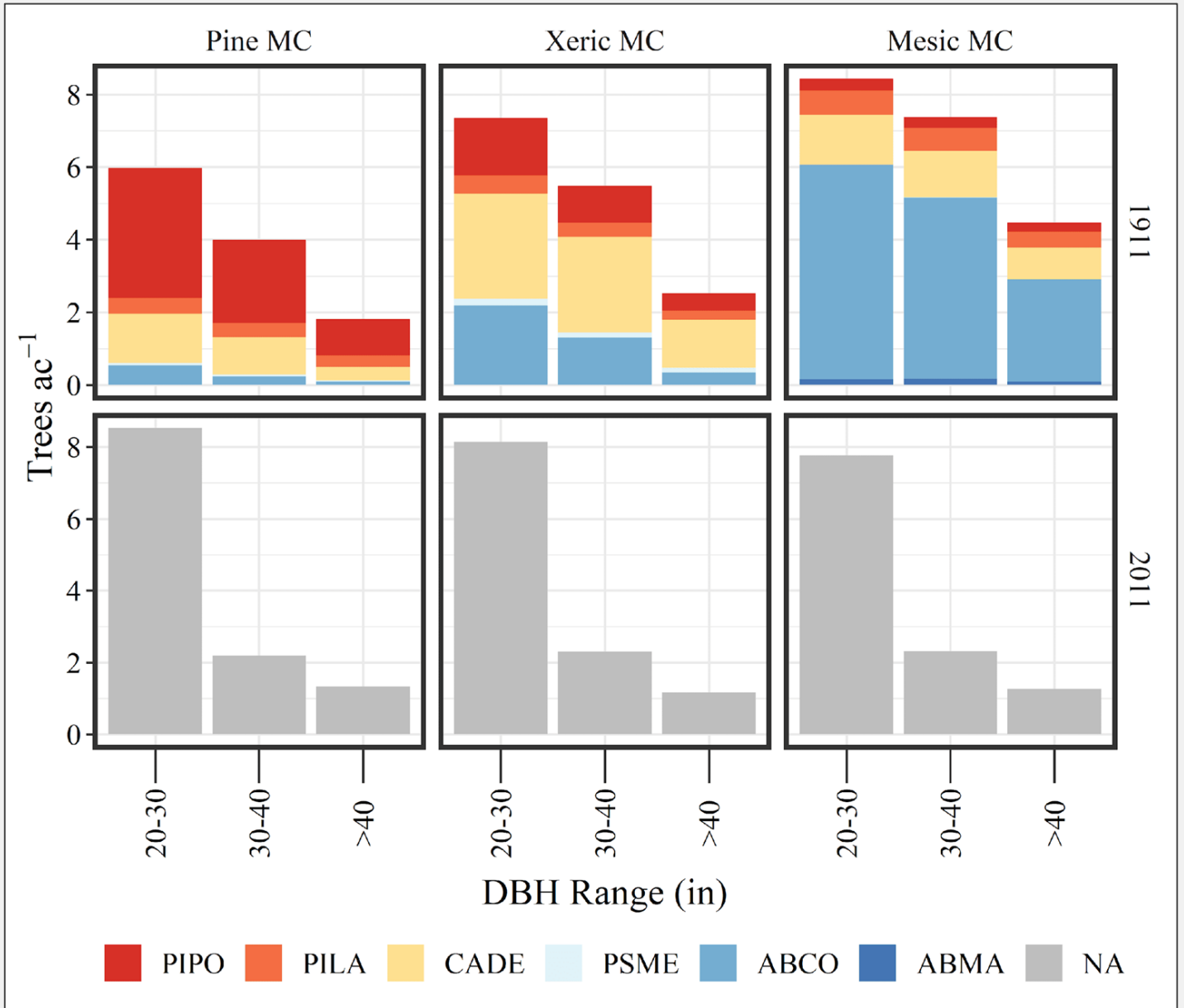
| Year | Basal area ($ft^2$ $ac^{-1}$) | Tree density ($ac^{-1}$; >6 in.) | | |
|---|---|---|---|---|
| | | Total | <24" DBH | >24 " DBH |
| 1911 | 87 | 22 | 12 | 10 |
| 2013 | 173 | 101 | 88 | 13 |

Collins et al. 2017, *Ecol. Appl.*


# SYNTHESIS OF HISTORICAL INVENTORIES IN CA



# HISTORICAL VS. CONTEMPORARY
## LARGE TREE DIAMETER DISTRIBUTIONS
(NORTH ET AL 2022, FOREST ECOL. MANAGE.)



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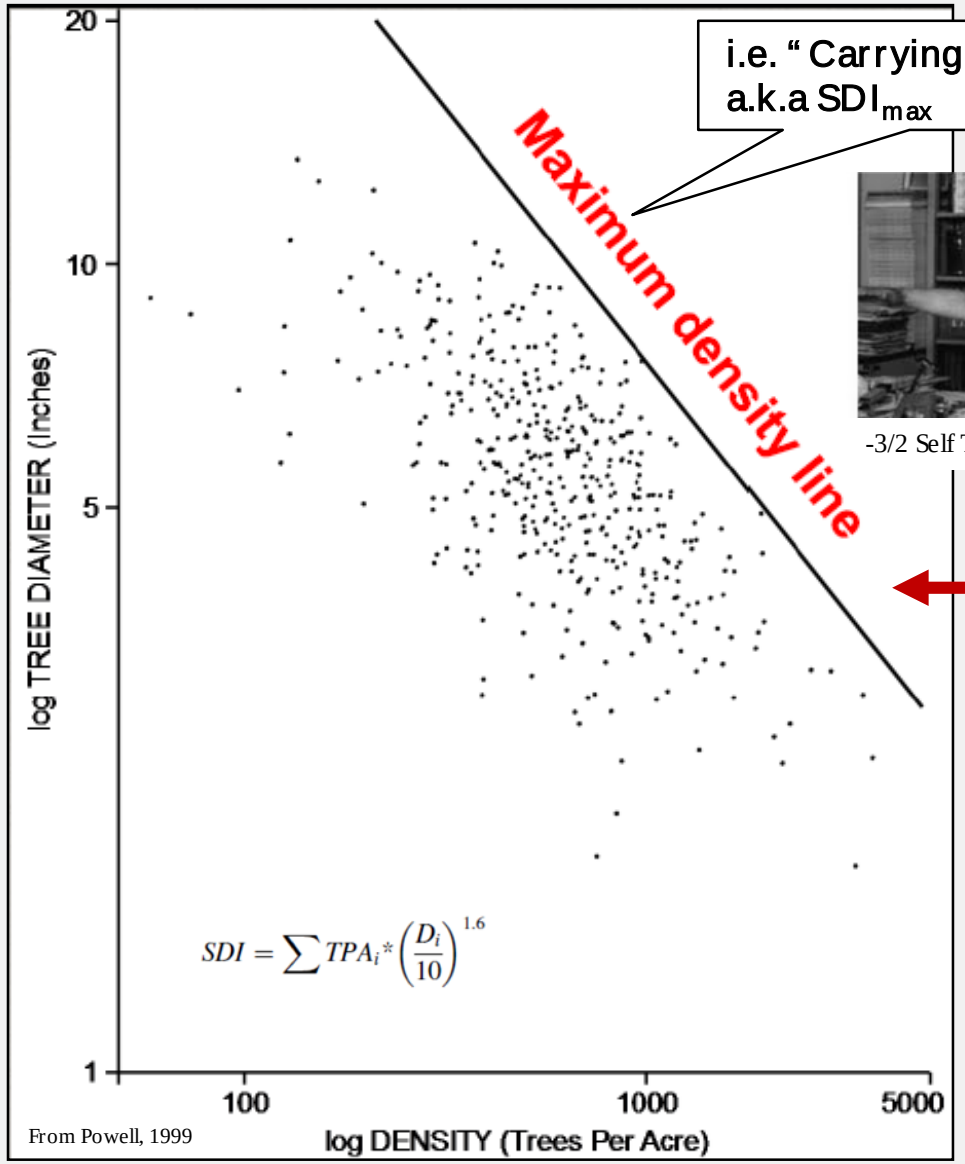
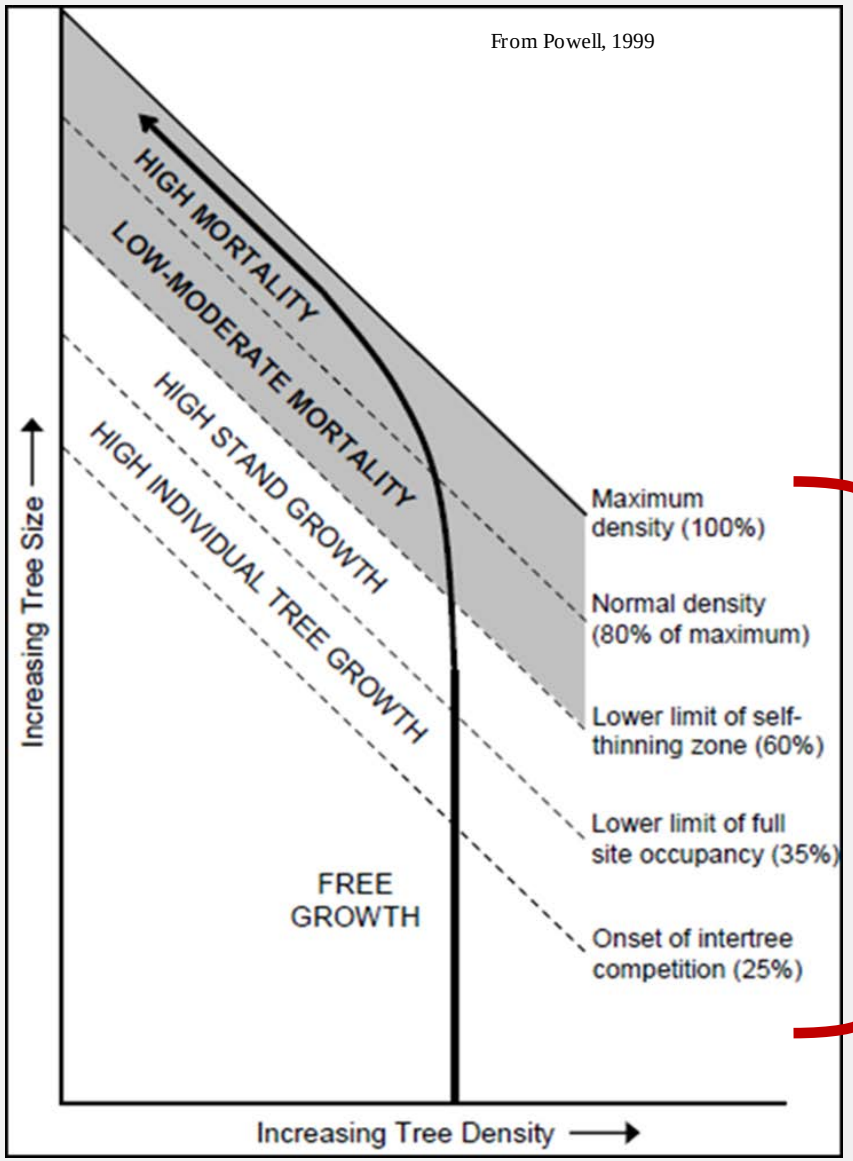
# ECOLOGICAL IMPORTANCE OF RELATIVE STAND DENSITY:
## CHARACTERIZING COMPETITION & GROWTH

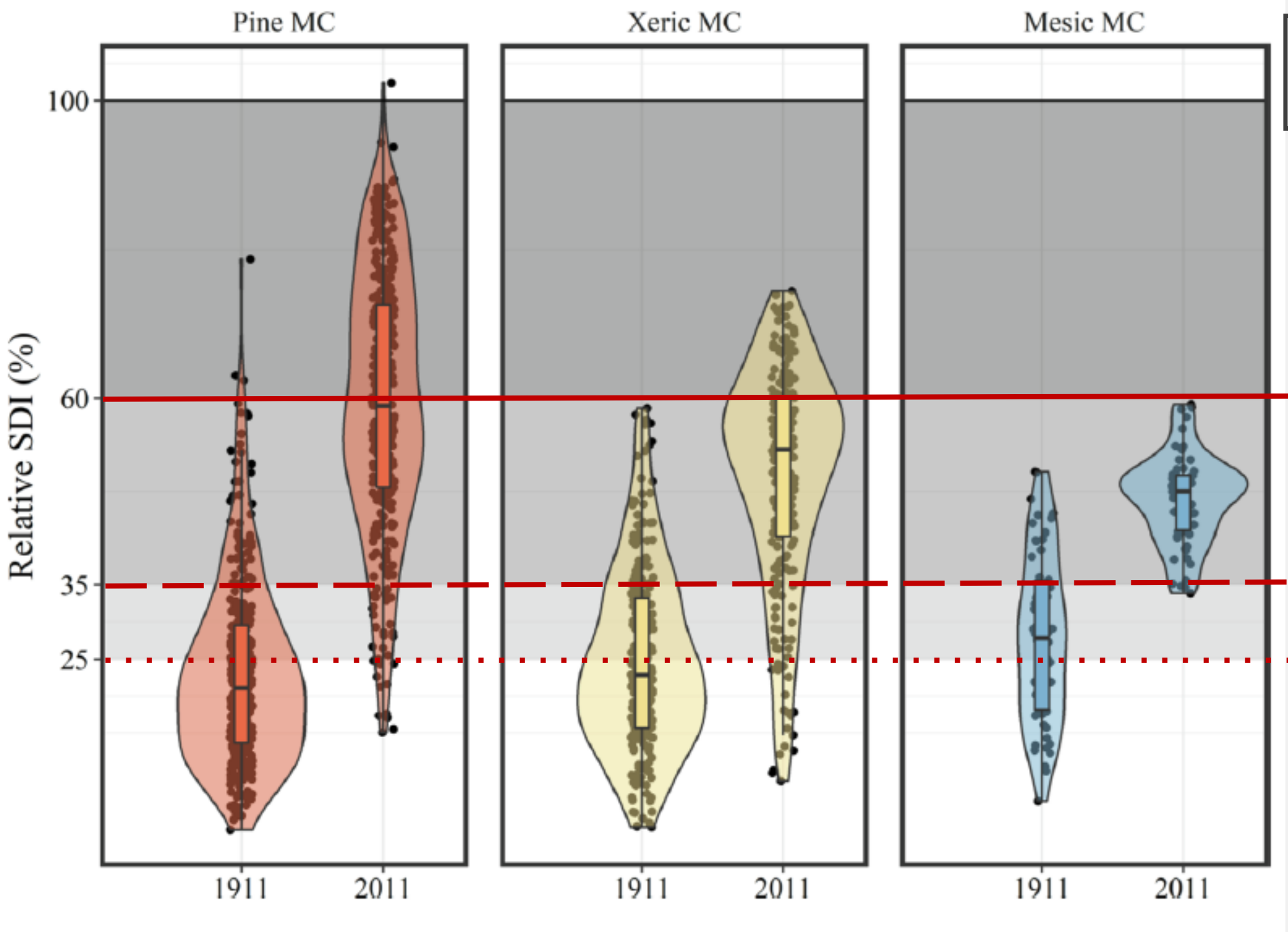



-3/2 Self Thinning Law (Yoda 1963)

Stand Density Index (Reinecke 1933)




Drew & Flewelling 1979 & Long 1985




RELATIVE DENSITY
ECOLOGICAL THRESHOLDS
OF COMPETITION

Zone of Imminent Mortality !!!!!

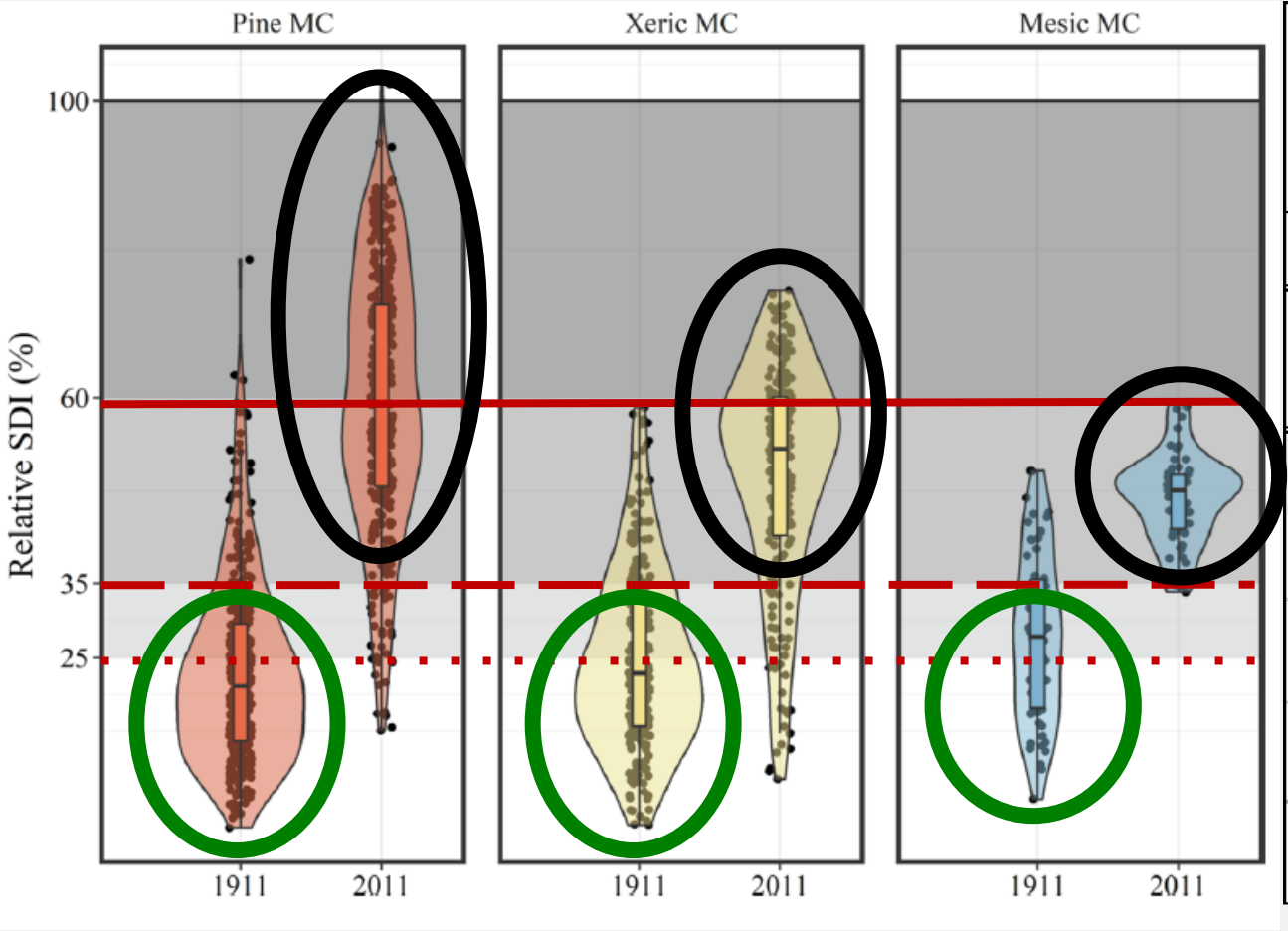
Full Site Occupancy
(a.k.a. full competition)

Onset of Competition
(a.k.a. partial competition)

Free of Competition
(a.k.a. Free Growth)

# SHIFTS IN THE COMPETITIVE ENVIRONMENT

## RELATIVE DENSITY AS A RESILIENCE METRIC




| | Pine MC | | Xeric MC | | Mesic MC | |
|---|---|---|---|---|---|---|
| **A) Absolute SDI** | | | | | | |
| | 1911 | 2011 | 1911 | 2011 | 1911 | 2011 |
| **$SDI_{metric}$** | 206 (123-267) | 535 (433-655) | 275 (175-370) | 551 (462-668) | 378 (247-483) | 632 (575-674) |
| **$SDI_{english}$** | 83 (50-108) | 216 (174-265) | 111 (71-150) | 223 (187-270) | 153 (100-196) | 256 (233-273) |
| **B) Relative SDI (% of $SDI_{max}$)** | | | | | | |
| **Mean (Range)** | 23 (14-30) | 59 (48-73) | 25 (16-33) | 50 (42-60) | 28 (18-36) | 46 (42-50) |
| **C) % of Relative SDI Observations In Each Competitive Benchmark** | | | | | | |
| **Free (<25% $SDI_{max}$)** | 64 | 4 | 58 | 9 | 44 | 0 |
| **Partial (25-34% $SDI_{max}$)** | 21 | 6 | 21 | 9 | 29 | 5 |
| **Full (35-59% $SDI_{max}$)** | 14 | 42 | 20 | 57 | 27 | 95 |
| **IM (≥60% $SDI_{max}$)** | <1 | 48 | 0 | 25 | 0 | 0 |

In historic Forests (1911): 73-85% of stands were below full occupancy (free of competition or partial competition)

In contemporary Forests (2011): 82-95% of stands were in full competition or in the zone of imminent mortality

# HOW LOW RELATIVE STAND DENSITY PROMOTES RESILIENCE:

## QUANTIFIED METRIC FOR DEFINING LARGE TREE HABITAT REQUIREMENTS

- Fires limiting competition from onset of regeneration
- Low stand density minimizes competition for resources (e.g. WATER!)
- Low competition maximizes individual tree growth & vigor
  - Resistance to drought, insects, & disease
  - Adaptations with greater resistance to wildfire
- Low densities of large drought/fire resistant trees are the "backbone" of resilient dry mixed conifer forests

Relative Stand Density Provides:

- Competition Metric
- Ecological thresholds for treatment efficacy & longevity
- Characterizes habitat requirements for large tree development

Plumas National Forest s

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# MANAGEMENT IMPLICATIONS

The resilience/resistance work to do:

Average dbh much smaller than a century ago

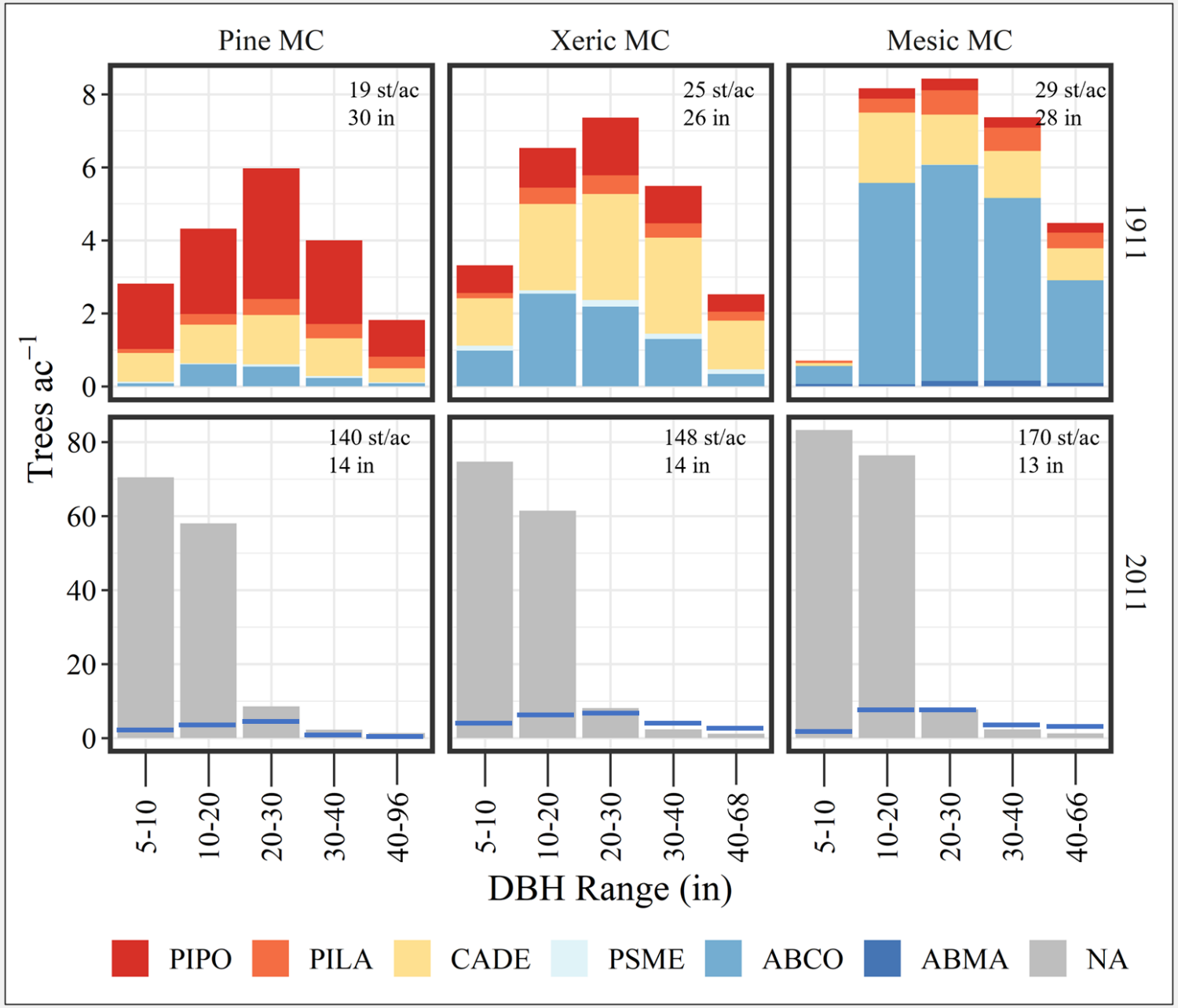
- *Mostly* from ingrowth of small trees, not removal of large trees (at least on USFS land)

Density reductions can mostly be in the smaller size classes (<20" dbh)

- At least for now…

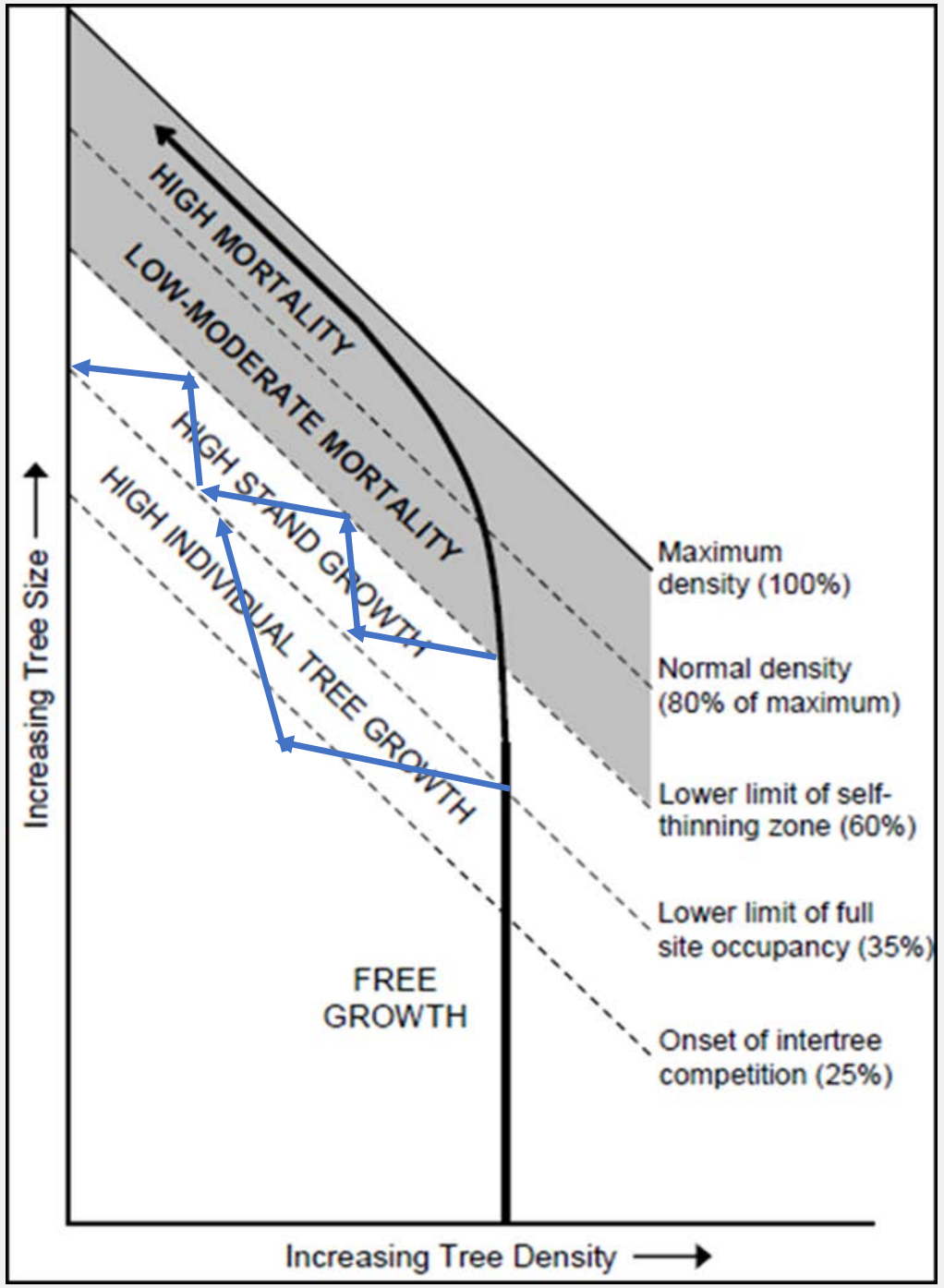
Management *challenge:*

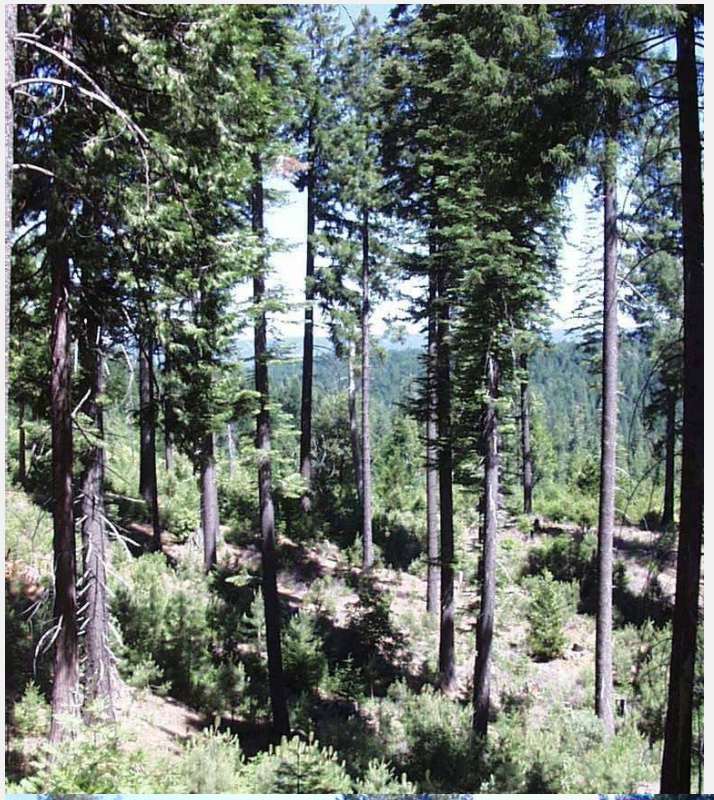
- Removal of "unmerchantable" tree sizes is paramount



# IMPLICATIONS

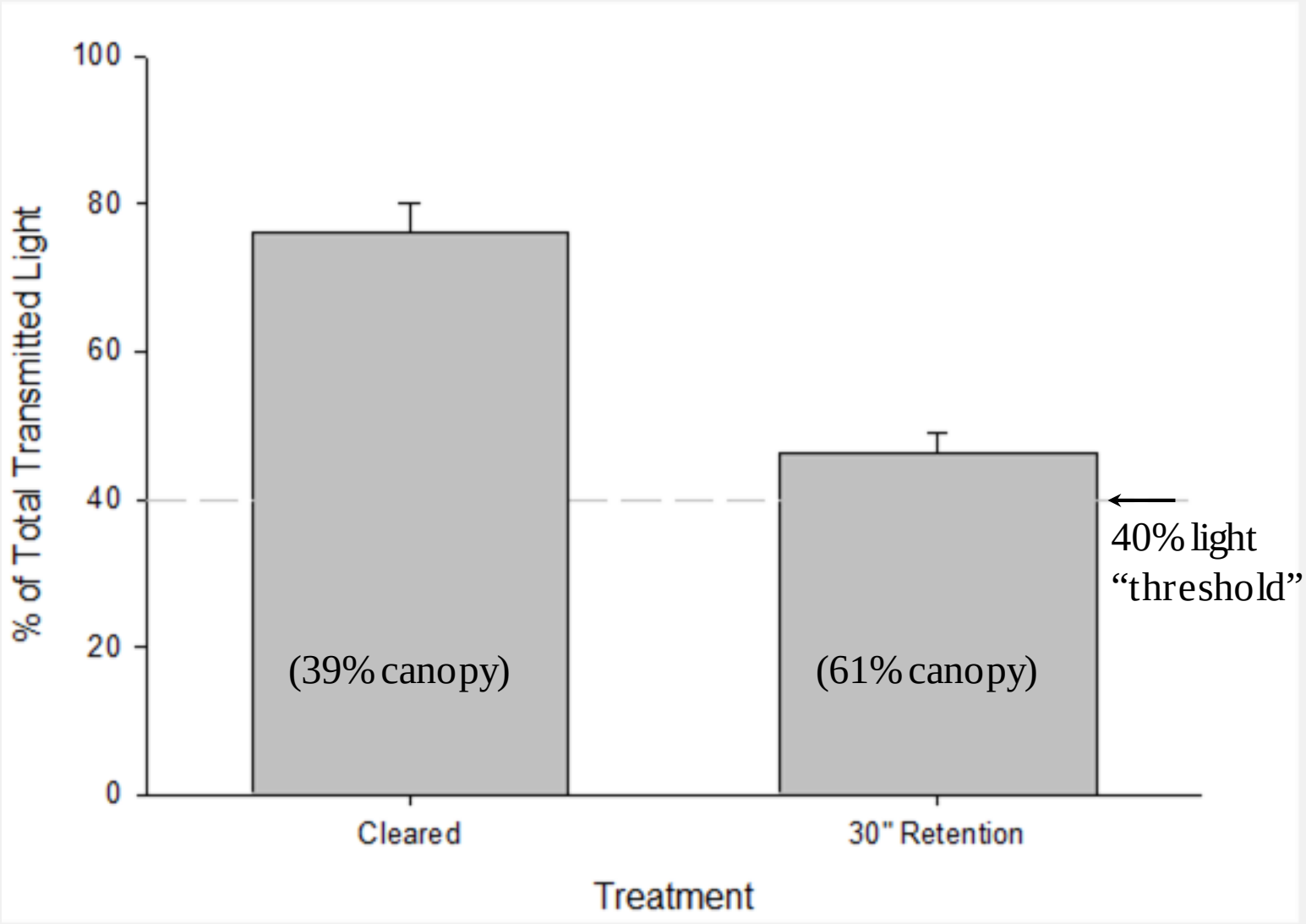
- Competition is twice as high as it used to be
  - 2012-2016 drought would have killed trees… but not 150 M!
- Thin earlier, thin heavier
- Fire and humans were NOT managing for timber, pre-1911
  - Timber: aim for 35 to 60% SDI
    - Great for maximizing timber growth and yield
  - Fire and Native Americans: 15 to 35% SDI
    - Does not maximize sustained yield
    - Does maintain ecological support for the existence of yield





# WE CAN'T THIN FOREVER…

## GAP CREATION WITH AND WITHOUT 30" RETENTION



# MANAGEMENT CHALLENGES

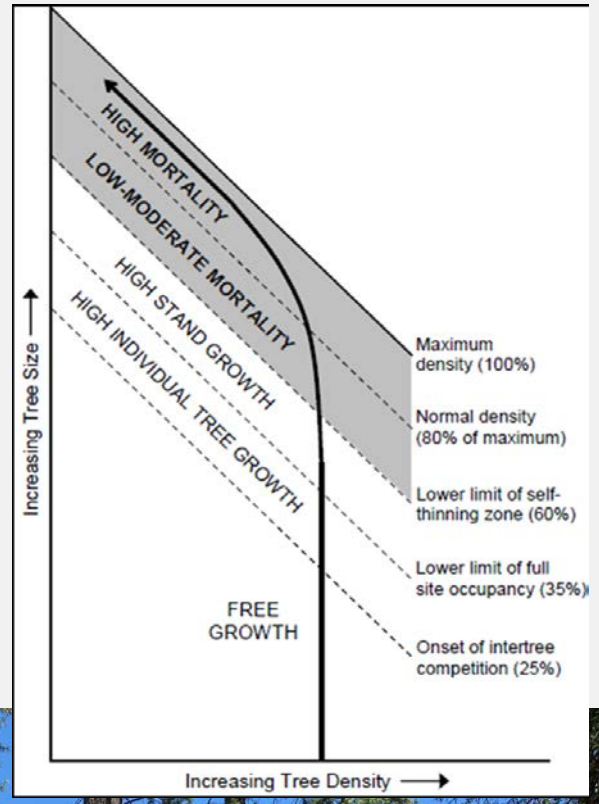
1. Managing for low-competition environments would currently or eventually require either cutting or burning large trees (>30” dbh)

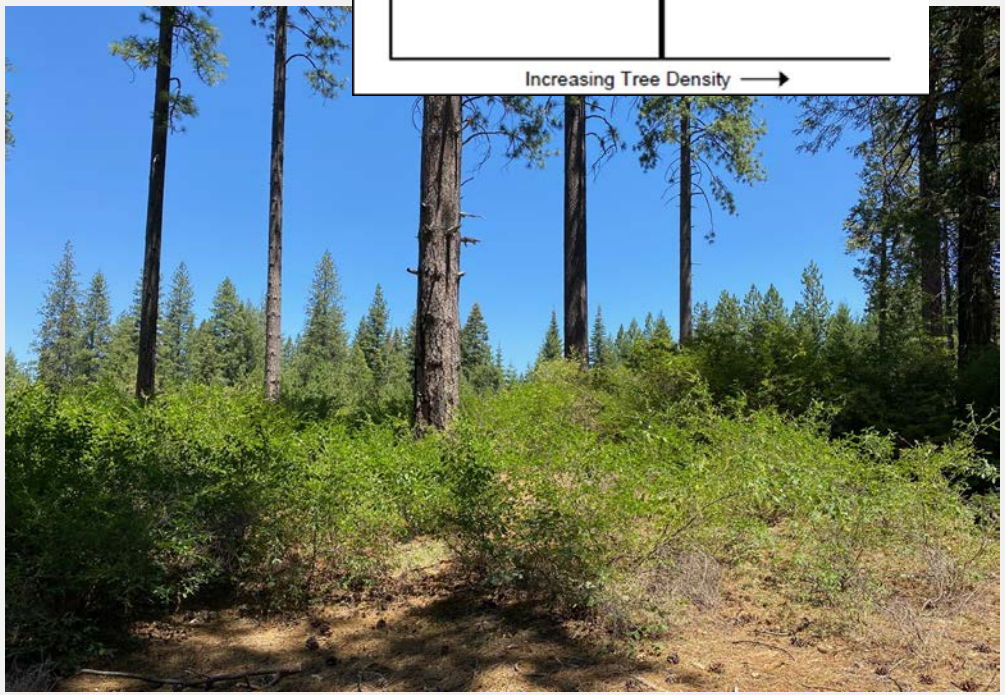
1. Long-term timber yields would be lower than max

1. Even more material removed = more utilization/disposal hurdles

1. Shrub and regeneration growth would be rapid
   - How to manage (herbicide, fire, mechanical)

5. Retention standards on private and federal lands



# WHAT DOES A LOW-COMPETITION STAND LOOK LIKE?

Burned **three times** in the past 20 years

- Not this one
- Still much too dense
- Fire severity? No worries.
- Drought severity? Worries.

## A STAND THAT IS PRETTY CLOSE:

- Gap based silviculture PLUS
- Low basal area target PLUS
- Mastication
- Led to…. Effective winter prescribed fire
- Must be repeated to sustain

## PYRO SILVICULTURAL **SYSTEMS** TO BUILD RESILIENCE:

- Traditional planning tools are still useful:
  - SDI, rotation age, frequency, intermediate tx's, regeneration
- It is less the tools, and more the targets, that need to be new

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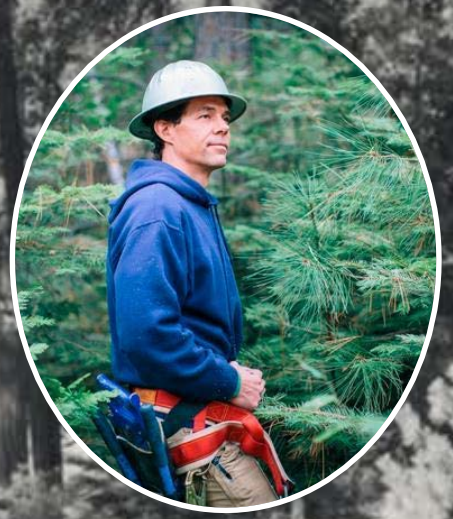

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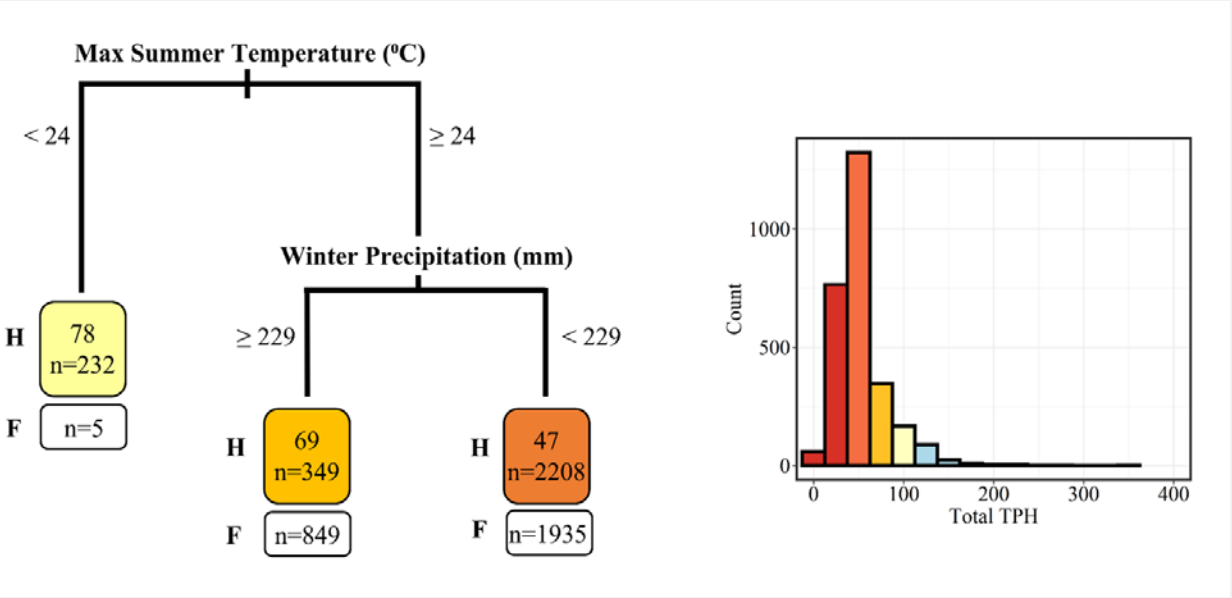
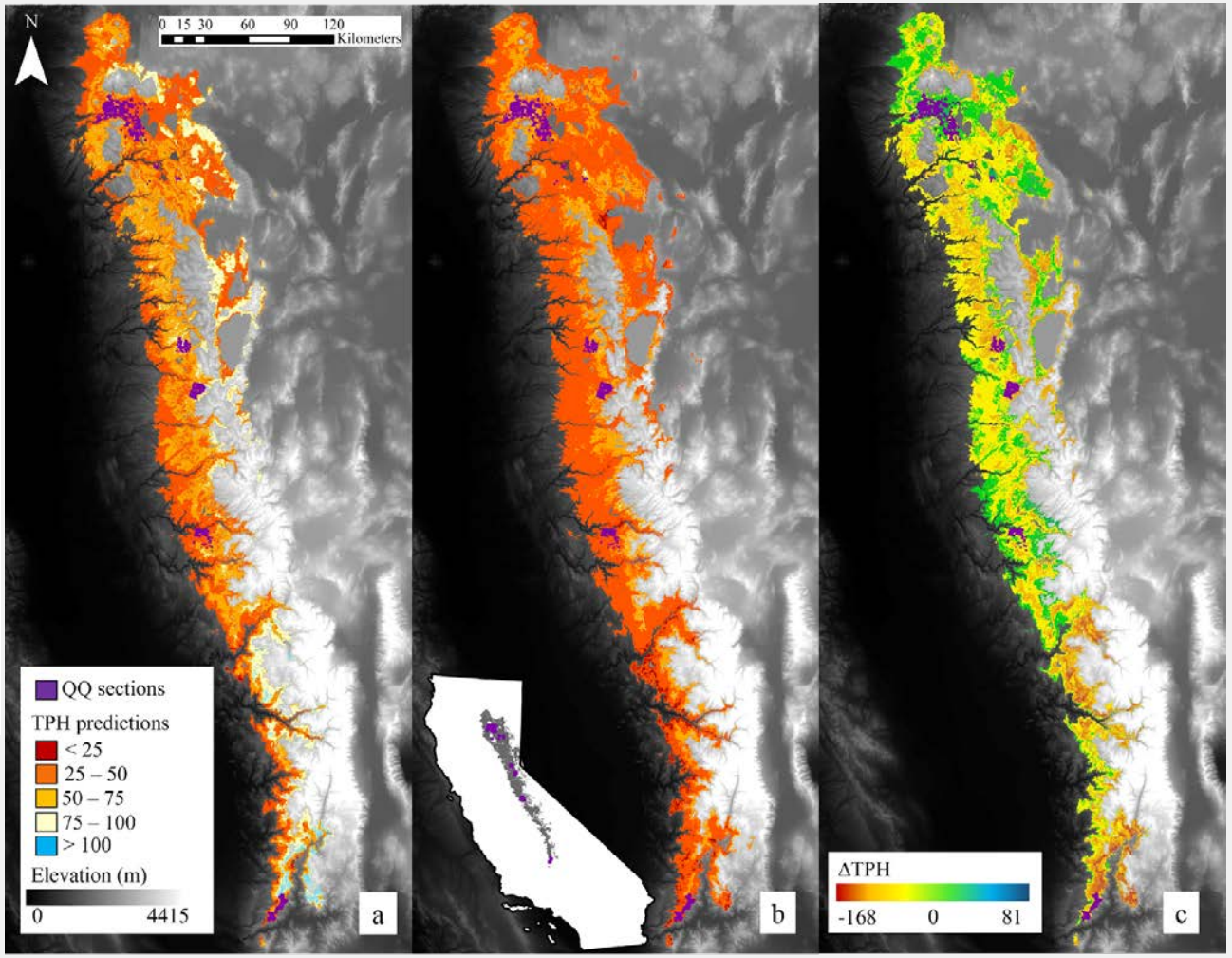
# WHAT DOES RESILIENCE LOOK LIKE AT LARGE SCALES?




Historical (1911-1936) Future (2040-2069) Δ Tree density




Bernal et al. 2022; Environmental Research Letters

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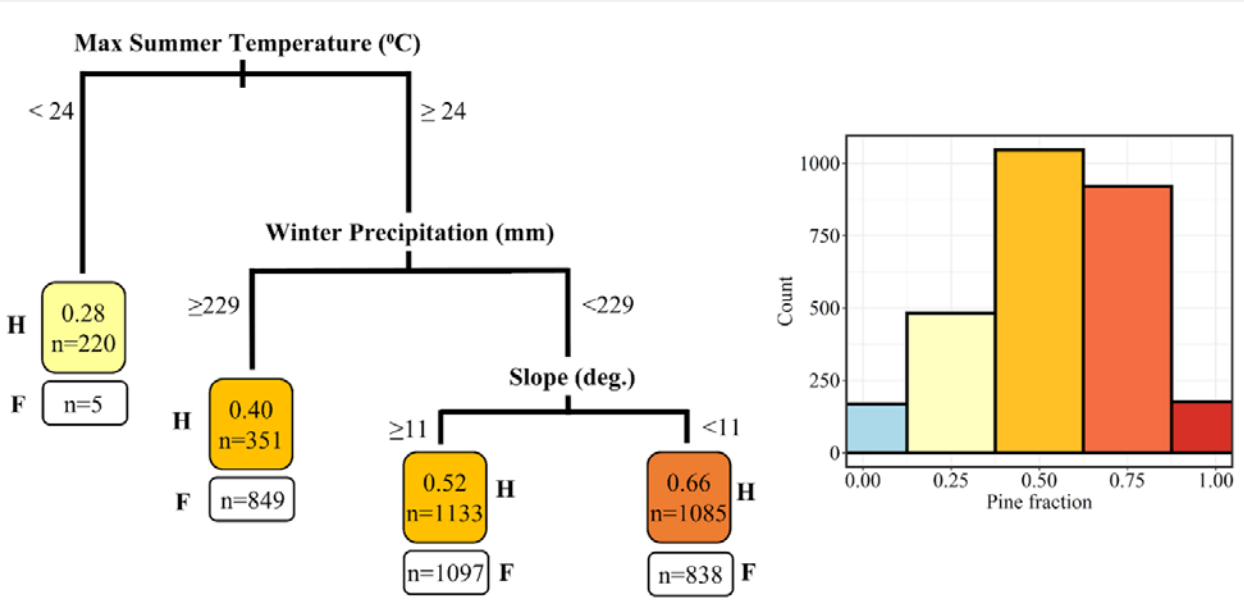
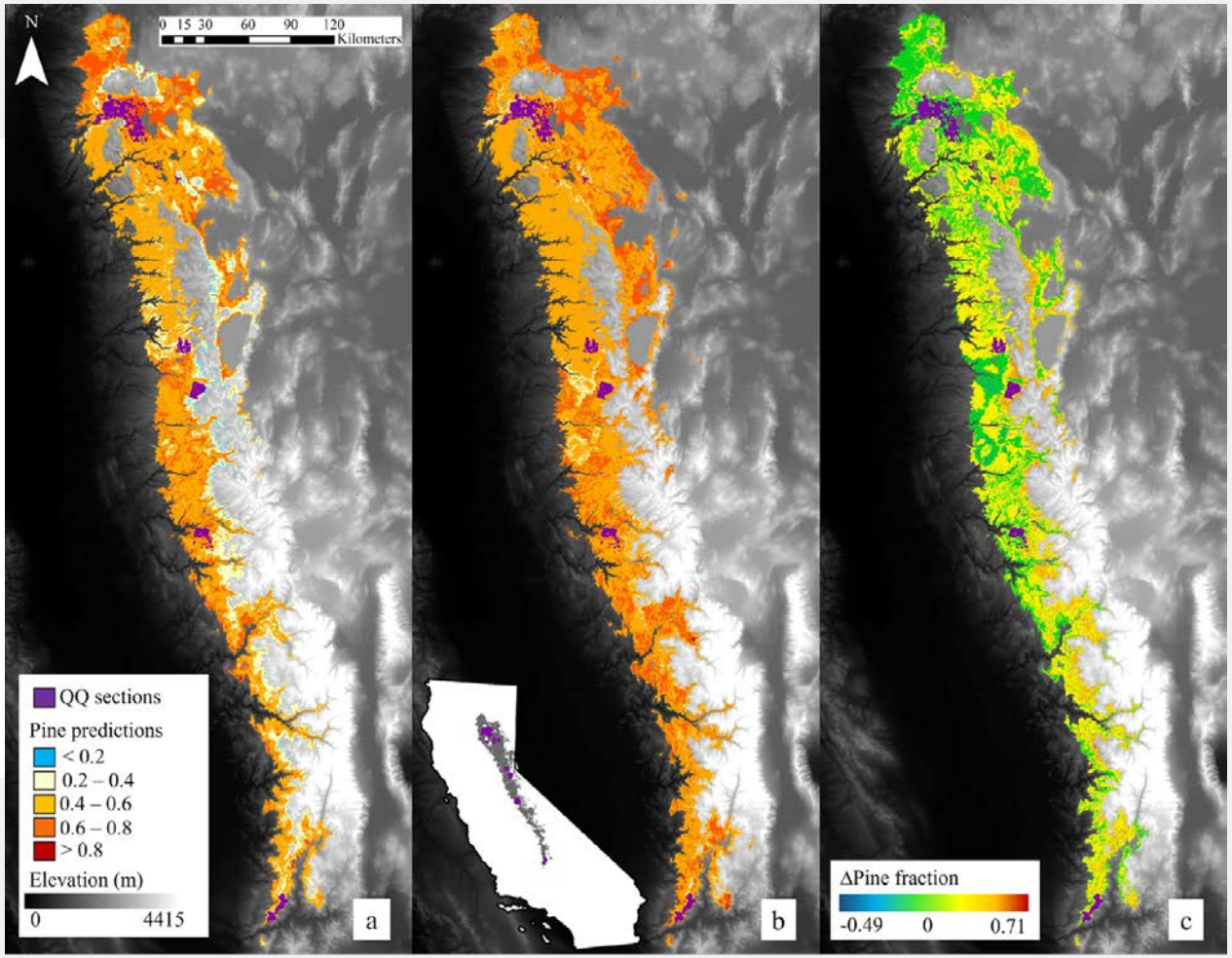






Historical (1911-1936) Future (2040-2069) Δ Pine fraction

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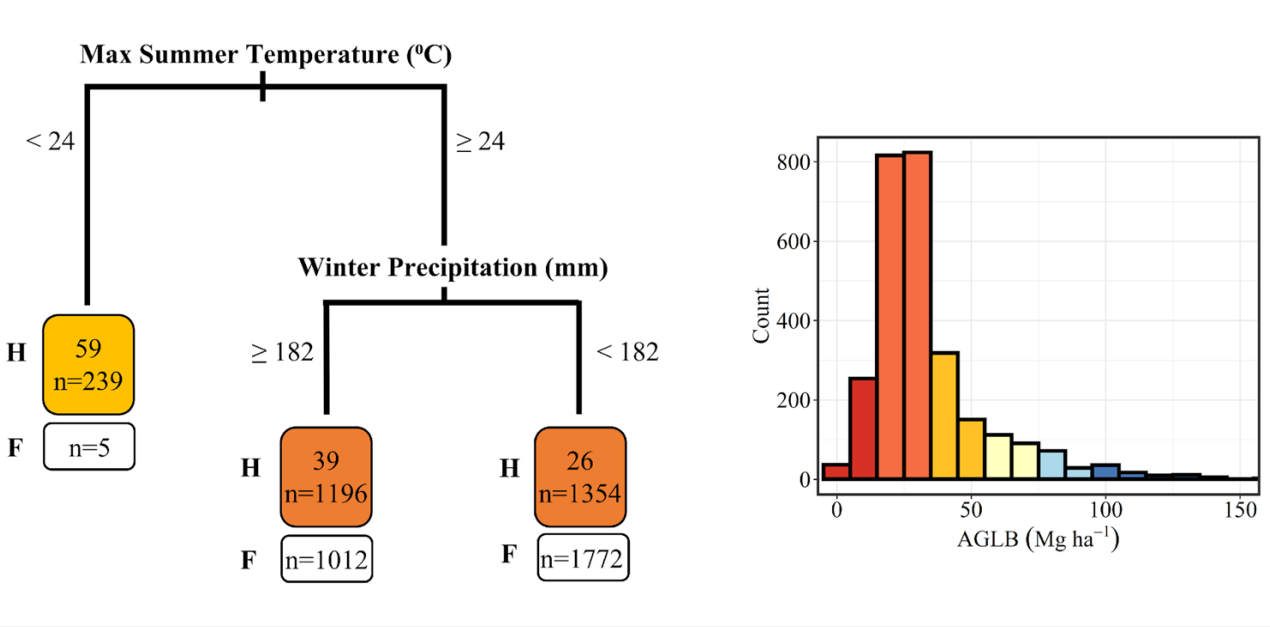
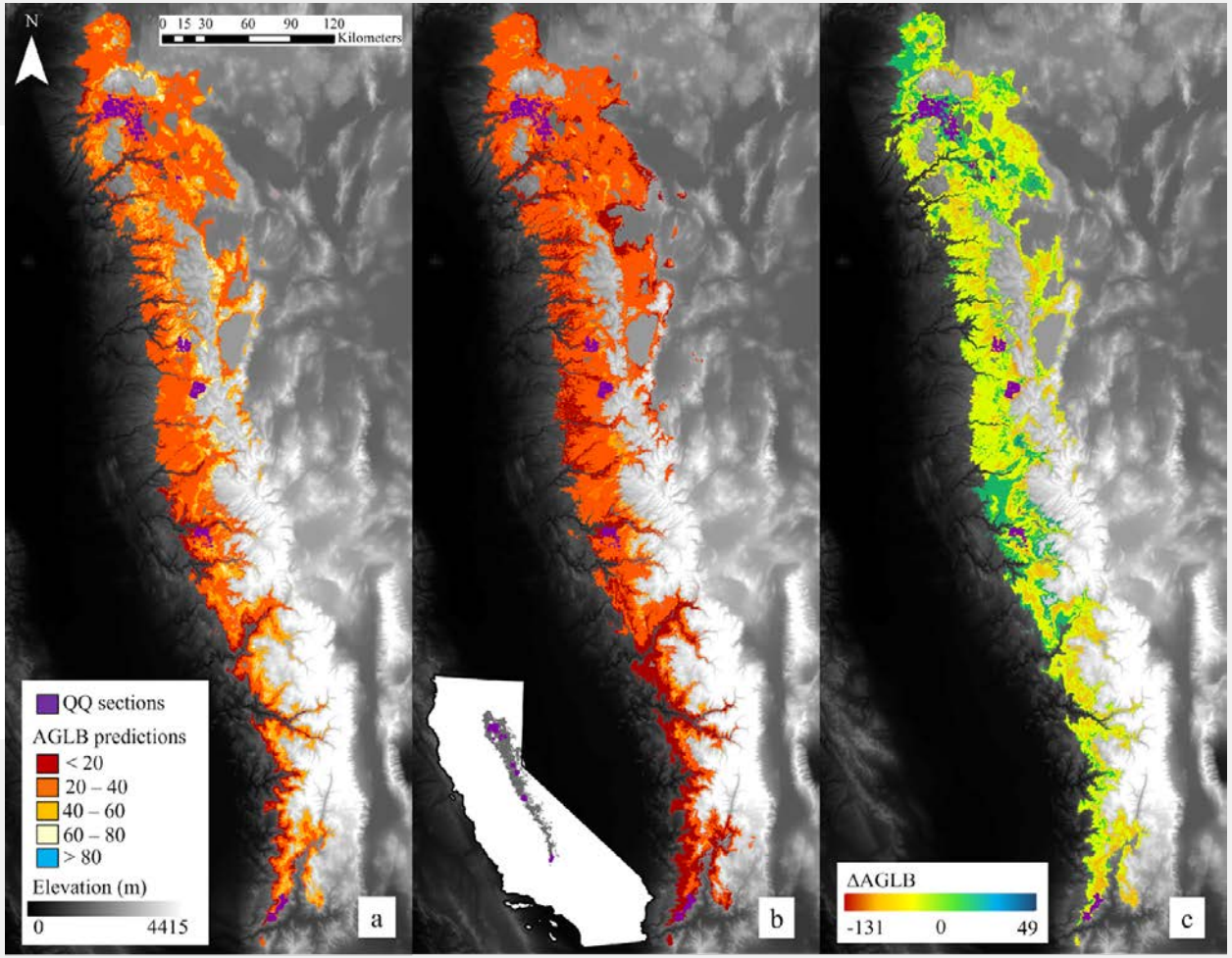


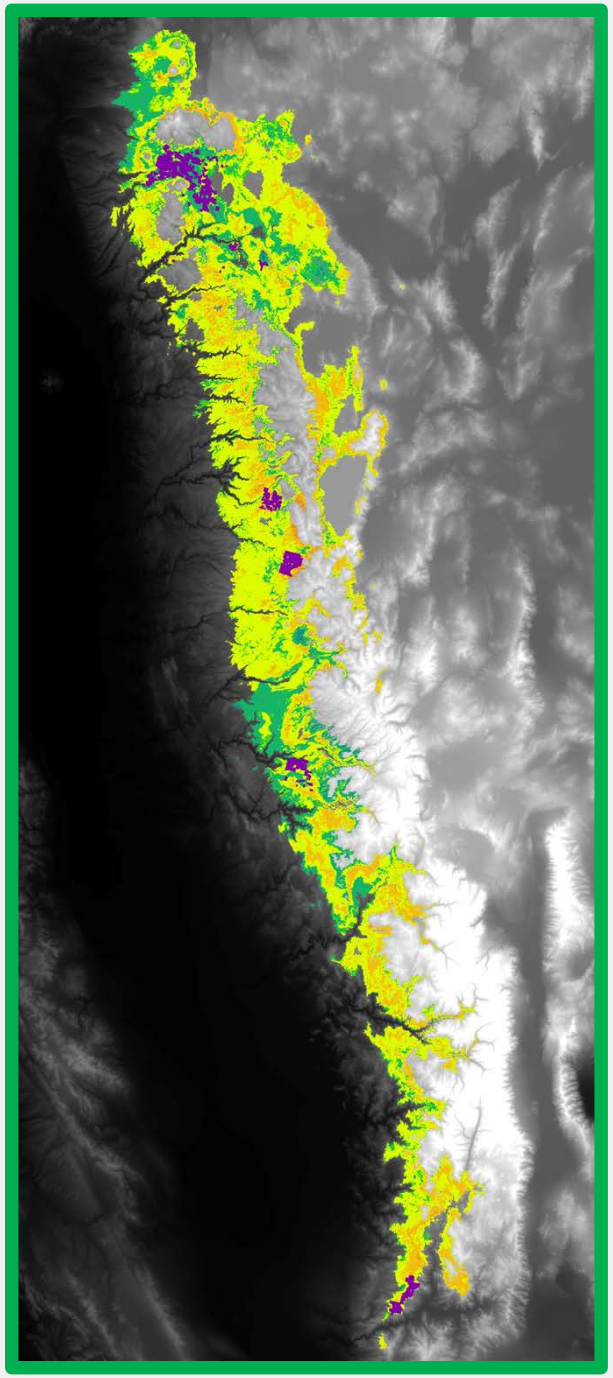

Historical (1911-1936) Future (2040-2069) Δ AGLB




Bernal et al. 2022; Environmental Research Letters

# IMPLICATIONS

- Historical resiliency = low tree density, high pine dominance, low AGLB
  - Convergent forest conditions
- Future resiliency = lower tree density, higher pine dominance, lower AGLB
  - Low end of natural range of variation
- Restoration could work, but there's some caveats
  - Variability
  - Novel interactions
- Future forests can only support <25% of current AGLB
  - Doesn't align with current GHG reduction policies
  - Doesn't align with current forest practice rules




THANK YOU!