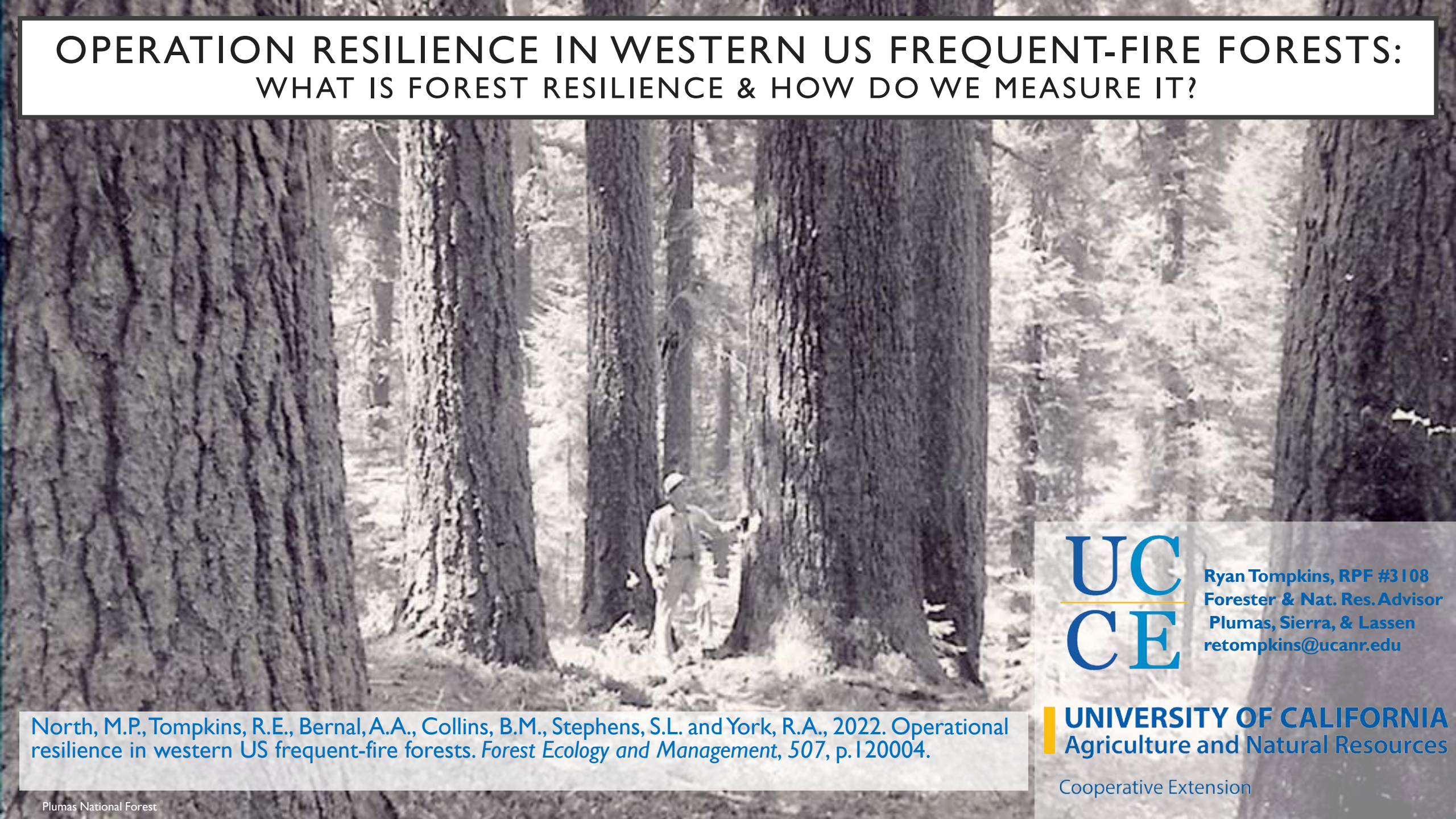
# OPERATION RESILIENCE IN WESTERN US FREQUENT-FIRE FORESTS:
## WHAT IS FOREST RESILIENCE & HOW DO WE MEASURE IT?

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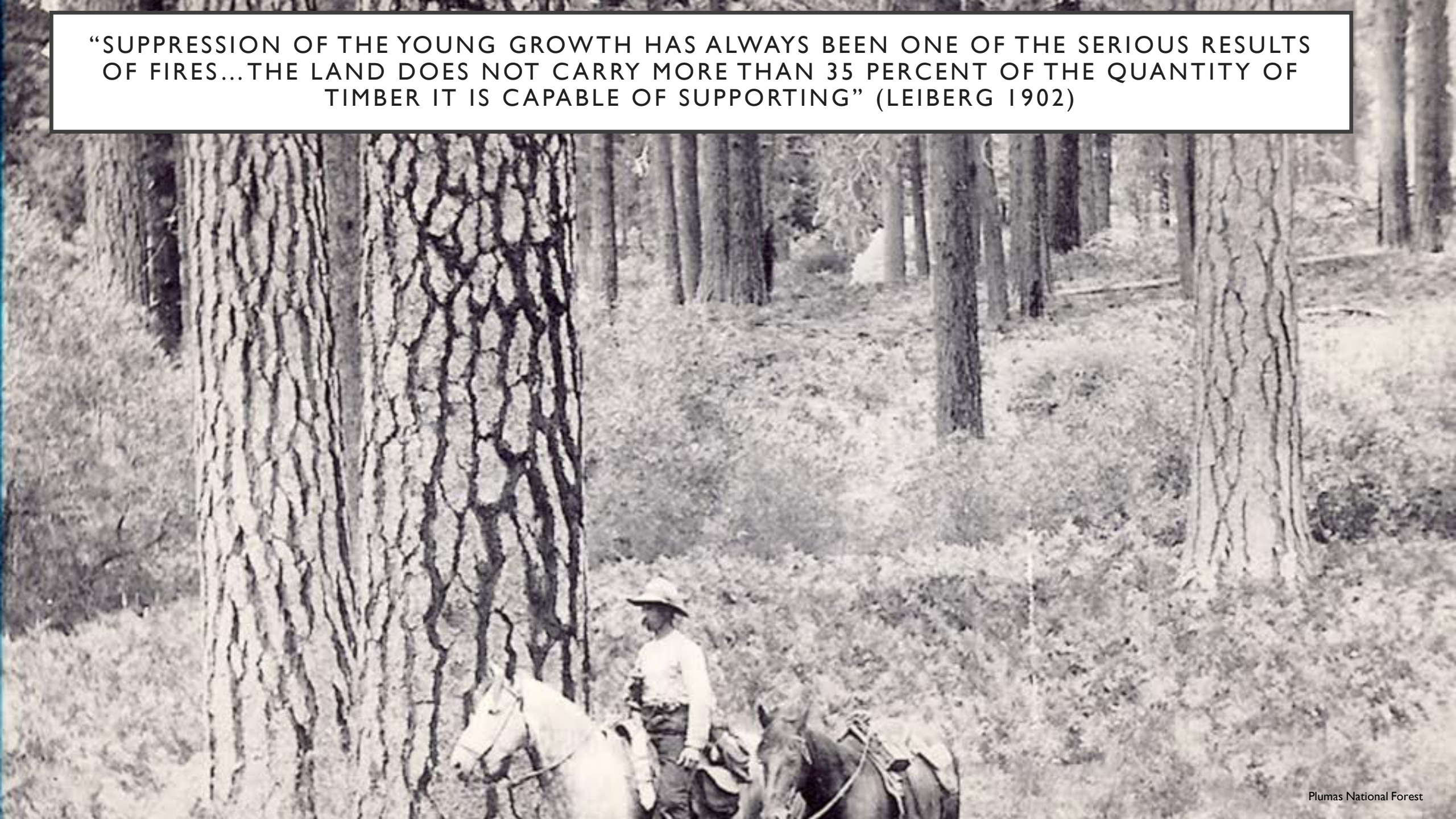
North, M.P., Tompkins, R.E., Bernal, A.A., Collins, B.M., Stephens, S.L. and York, R.A., 2022. Operational resilience in western US frequent-fire forests. *Forest Ecology and Management*, *507*, p.120004.


Plumas National Forest

"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)



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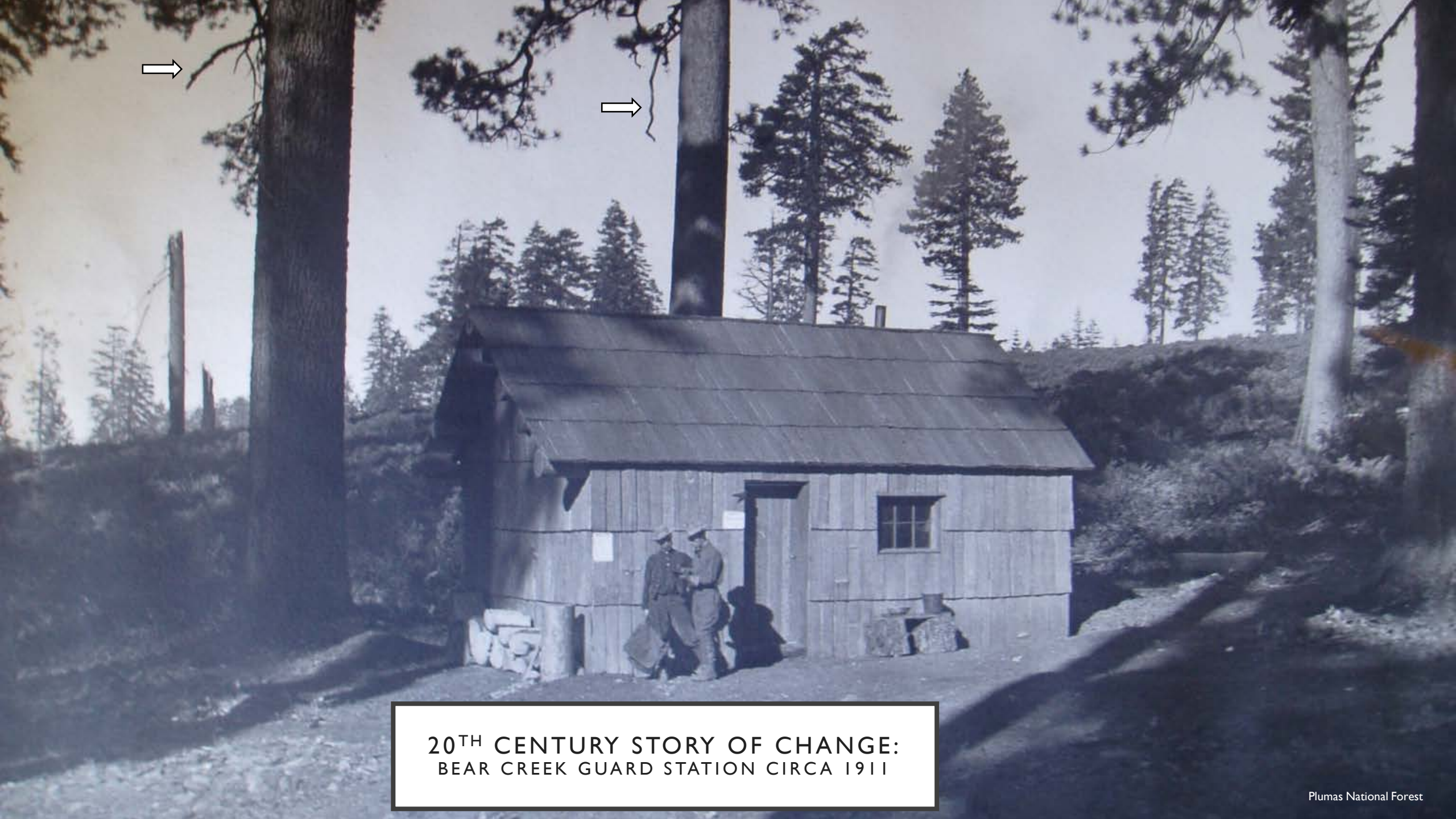
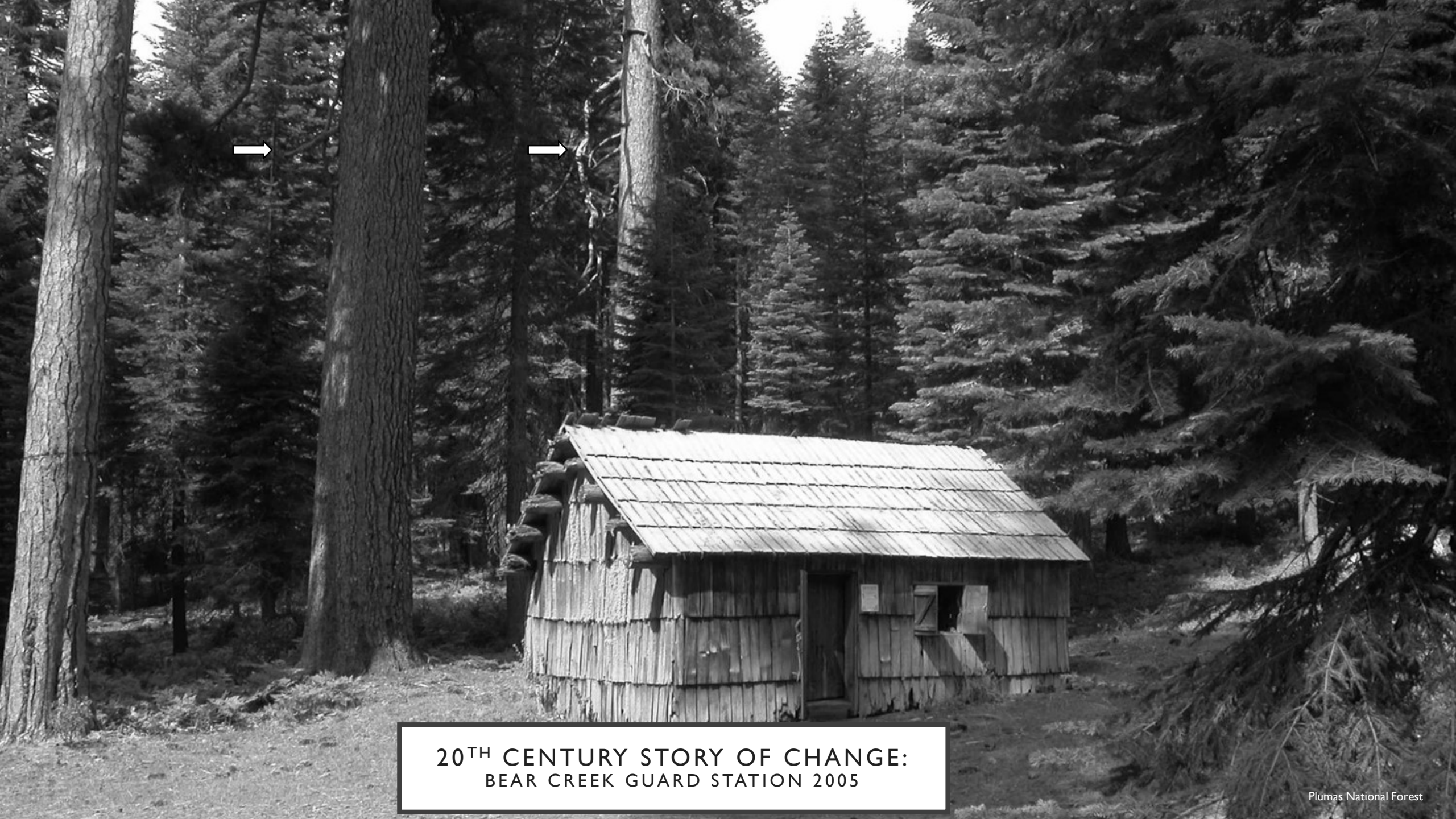


# 20TH CENTURY STORY OF CHANGE:
## BEAR CREEK GUARD STATION CIRCA 1911

Plumas National Forest



# 20TH CENTURY STORY OF CHANGE:
## BEAR CREEK GUARD STATION 2005

Plumas National Forest

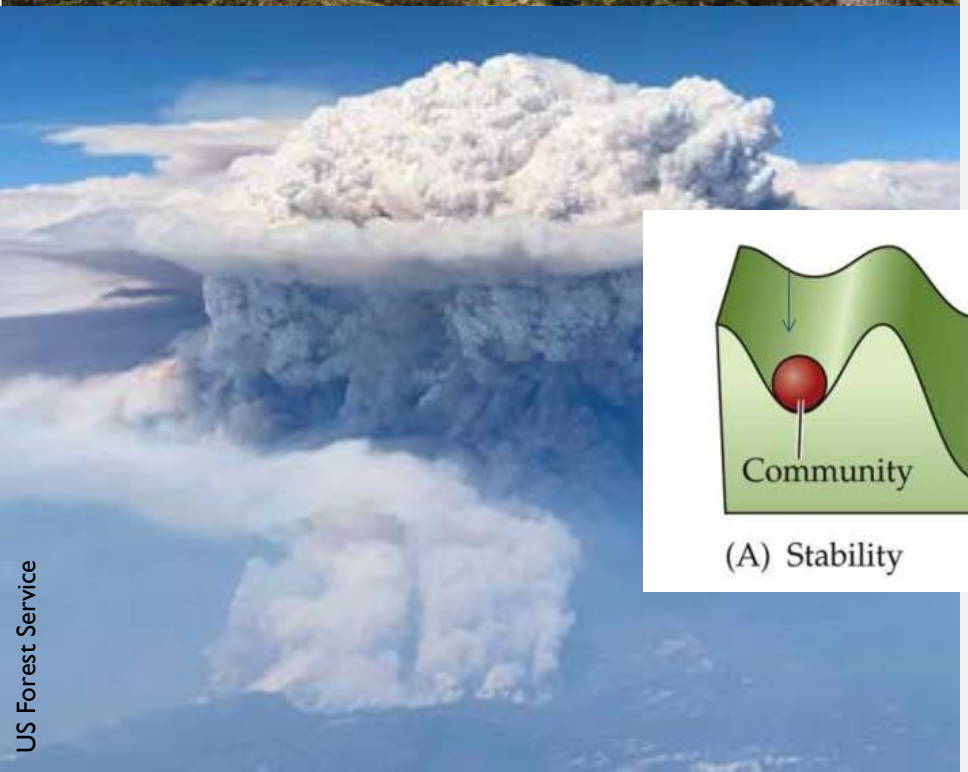

Photo: Plumas County Search and Rescue/KRCR

# 21ST CENTURY SHIFTS IN DISTURBANCE REGIMES:

## ALIGNMENT OF DROUGHT WITH LANDSCAPE LEVEL FOREST DENSITY & FUELS

# 21ST CENTURY STORY OF CHANGE:
## LOSS AT THE LANDSCAPE LEVEL


Fettig et al 2019


US Forest Service

Lights Creek in 2018, eleven years after 2007 Moonlight fire

Lights Creek after the 2021 Dixie Fire reburn

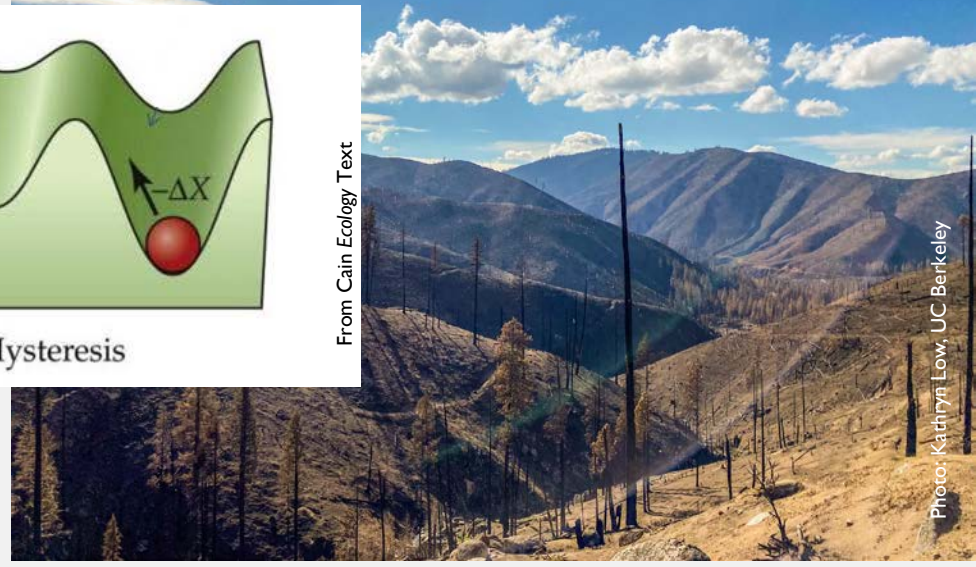
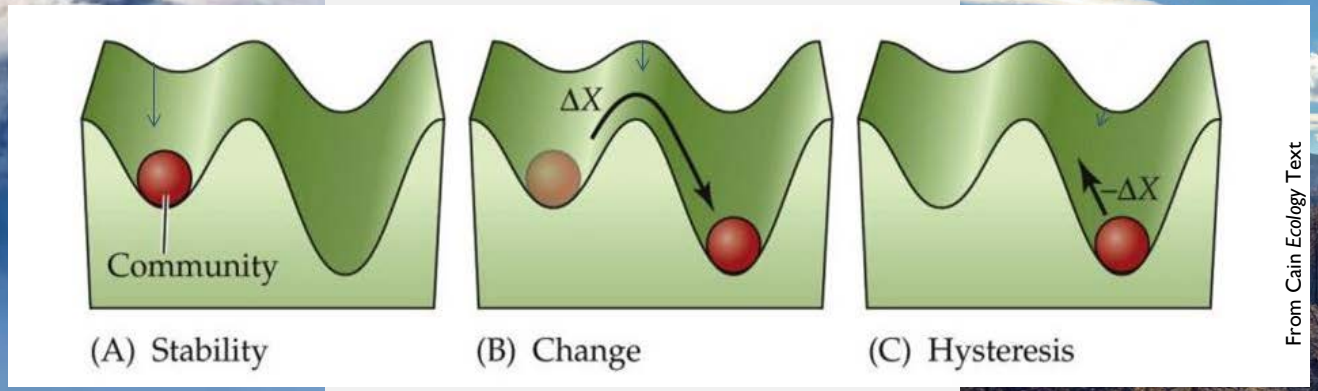


Photo: Kathryn Low, UC Berkeley

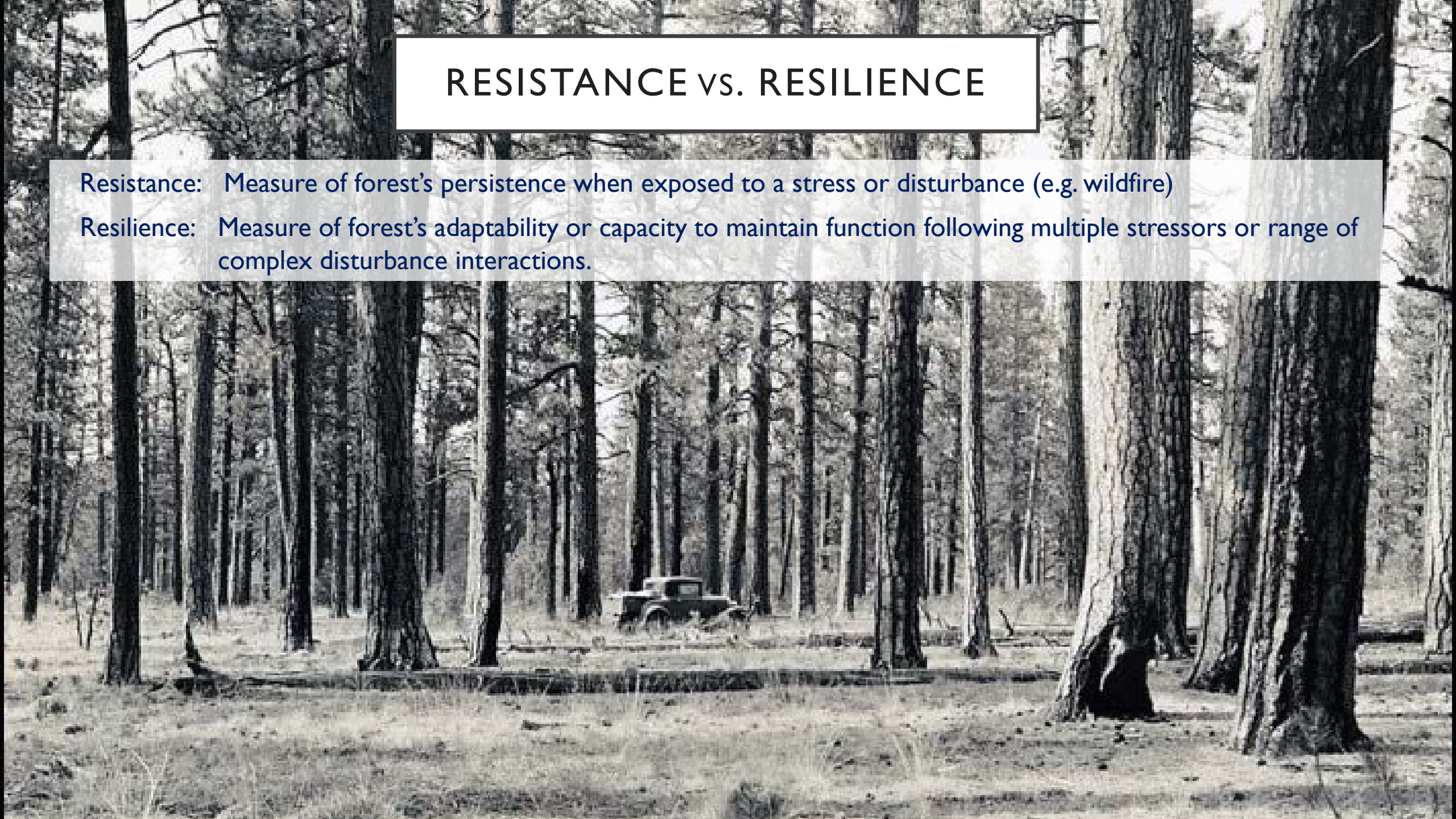


From Cain *Ecology* Text

# RESISTANCE vs. RESILIENCE

Resistance: Measure of forest's persistence when exposed to a stress or disturbance (e.g. wildfire)

Resilience: Measure of forest's adaptability or capacity to maintain function following multiple stressors or range of complex disturbance interactions.



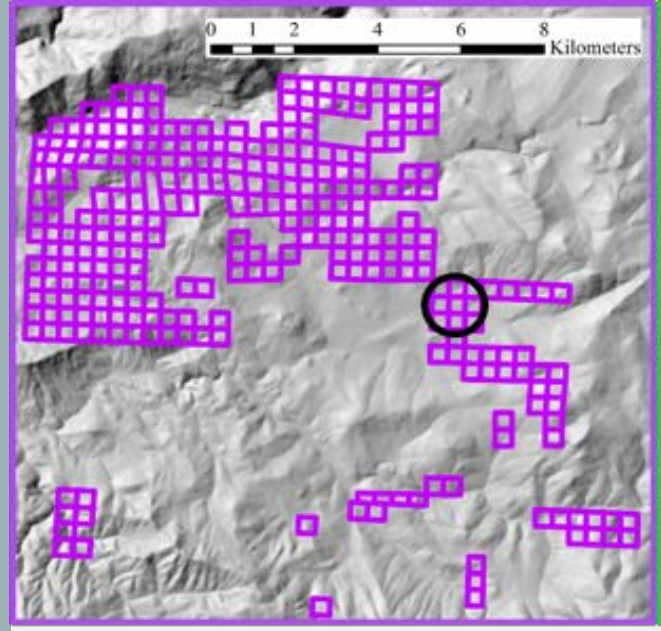
# STUDY DESIGN

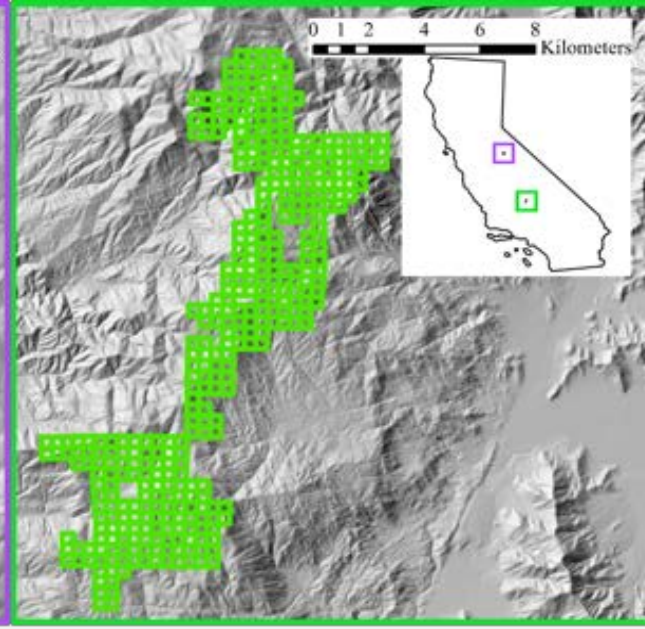
Utilized1911 Forest Inventory data from Stanislaus & Sequoia National Forests (Collins et al. 2015 & Stephens et al. 2015)

- Total of 644, Quarter-Quarter sections covering over 24,000 acres
- Belt transects 1-2 chains x 20 chains
- 5-10% sample intensity
- Trees > 6.0 inches

2011 forest conditions assessed with USFS F3 data: FIA, FVS, & FastEmap. (Huang et al 2018)

| Examined 3 Forest Types based on historical data | |
|---|---|
| Pine Mixed Conifer | > 50% pine |
| Xeric Mixed Conifer | ≤ 50% pine & ≤ 50% fir |
| Mesic Mixed Conifer | > 50% fir |

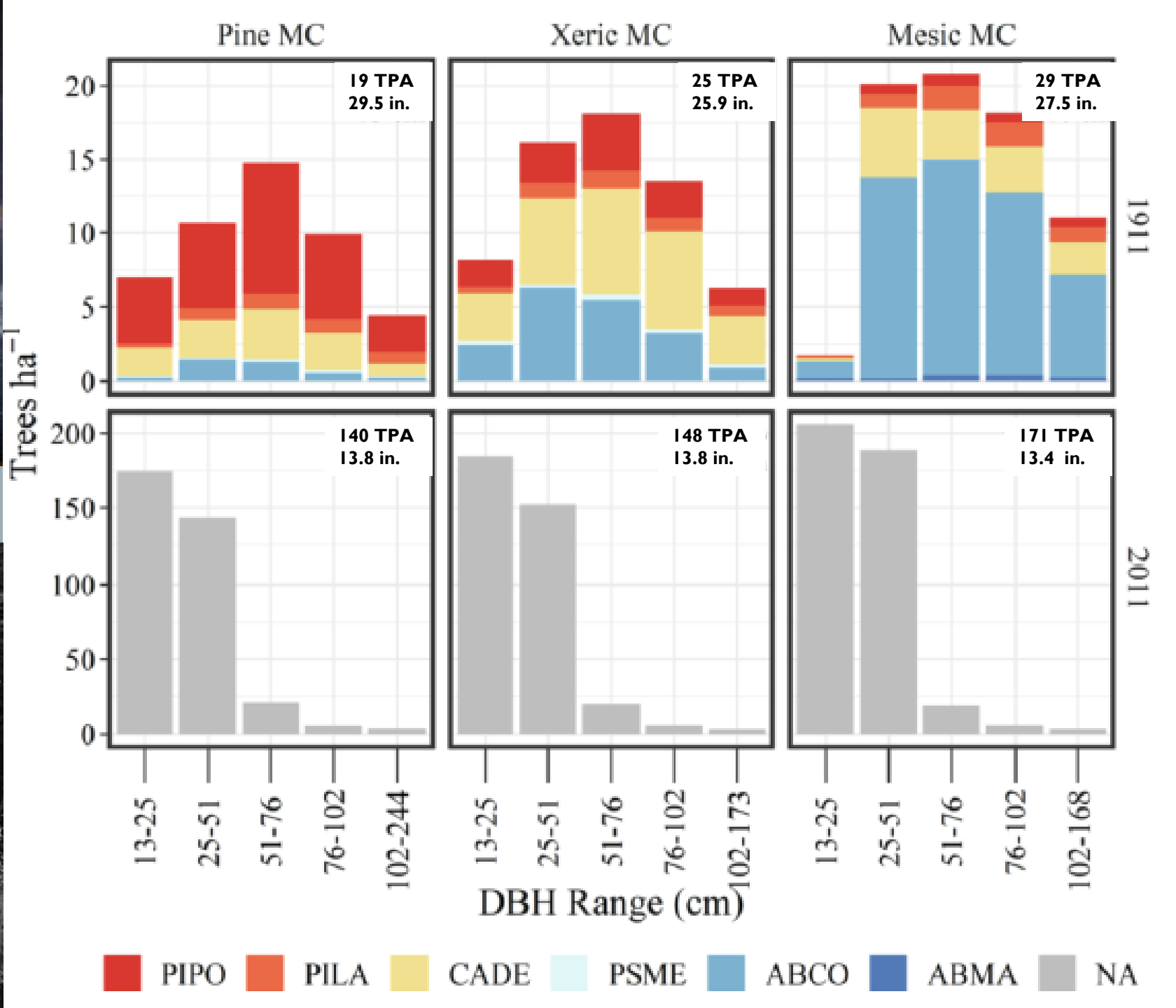


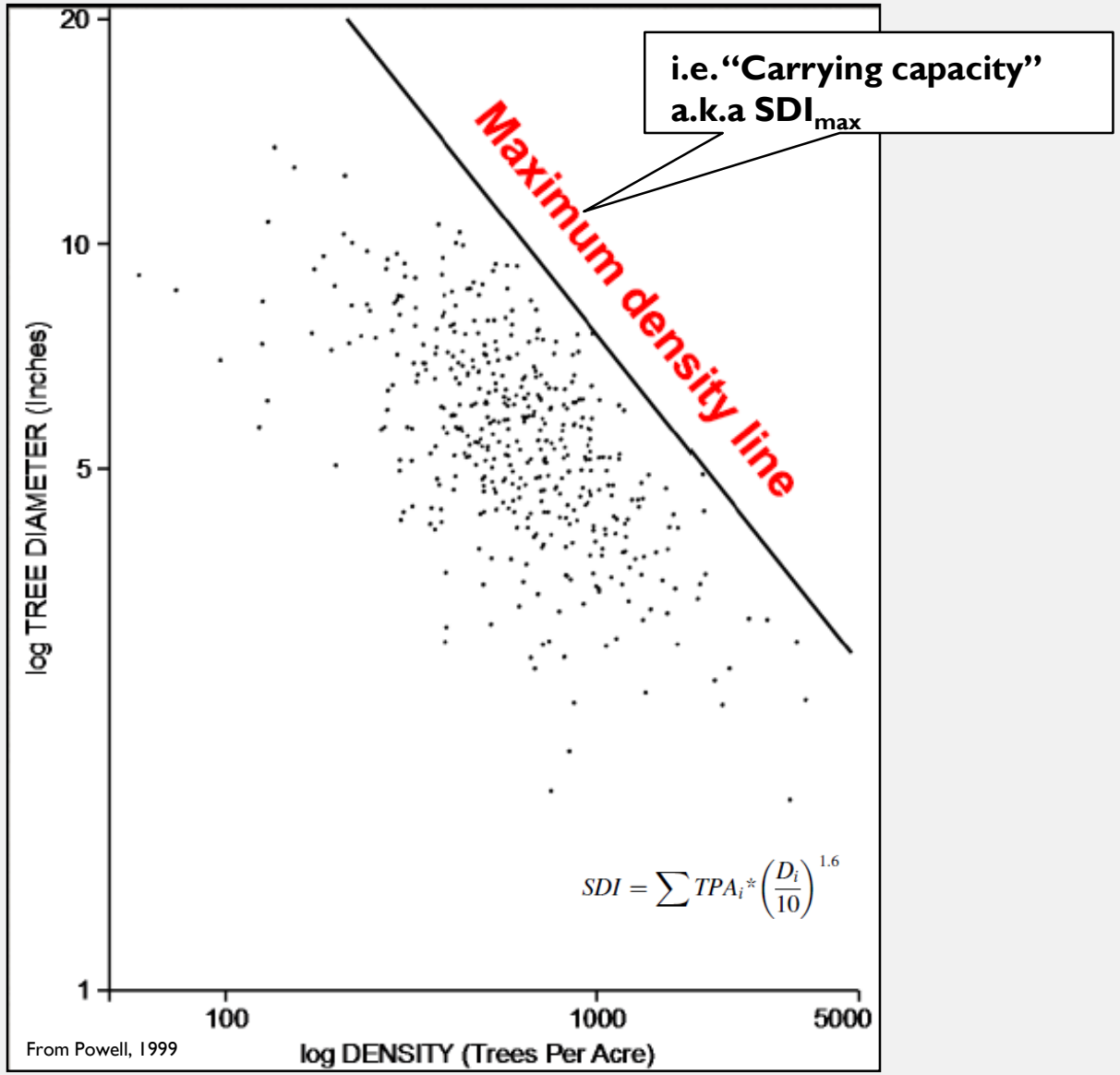


1911

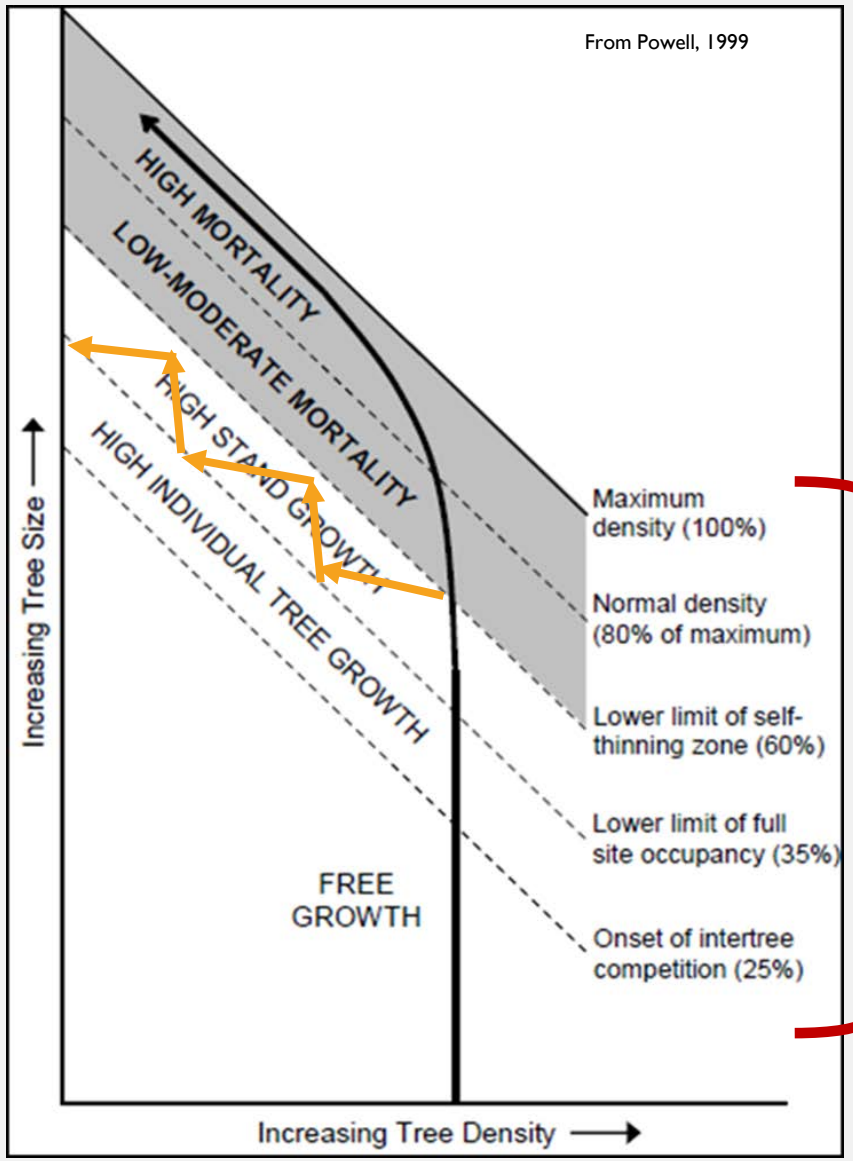

2005


Pine MC
Xeric MC
Mesic MC
19 TPA
29.5 in.
25 TPA
25.9 in.
29 TPA
27.5 in.
140 TPA
13.8 in.
148 TPA
13.8 in.
171 TPA
13.4 in.
1911
2011
Trees ha⁻¹
0
5
10
15
20
50
100
150
200
13-25
25-51
51-76
76-102
102-244
102-173
102-168
DBH Range (cm)
PIPO
PILA
CADE
PSME
ABCO
ABMA
NA

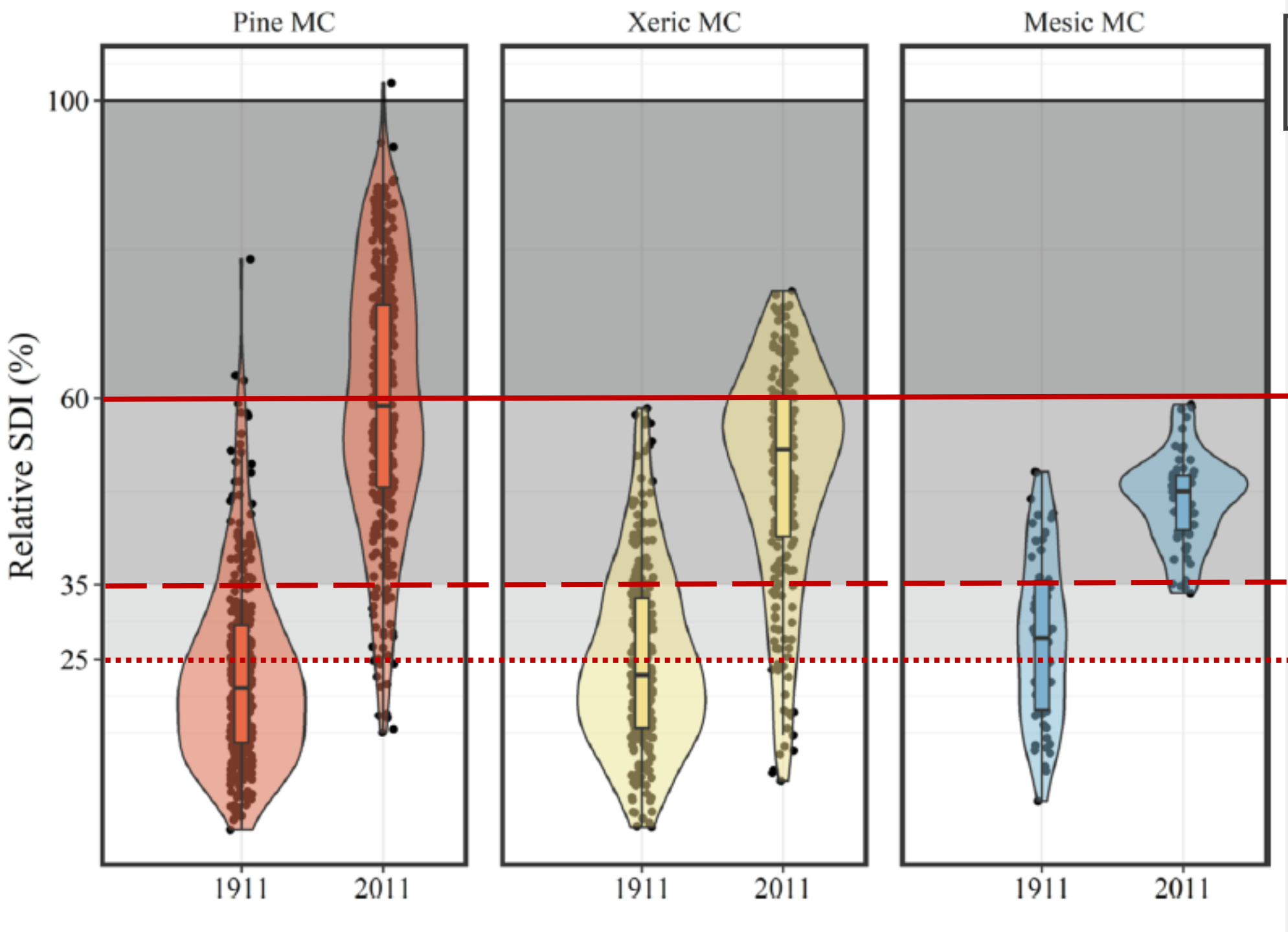
# ECOLOGICAL IMPORTANCE OF RELATIVE STAND DENSITY:
## CHARACTERIZING COMPETITION & GROWTH




Stand Density Index (Reinecke 1933)




Drew & Flewelling 1979 & Long 1985




RELATIVE DENSITY ECOLOGICAL THRESHOLDS OF COMPETITION

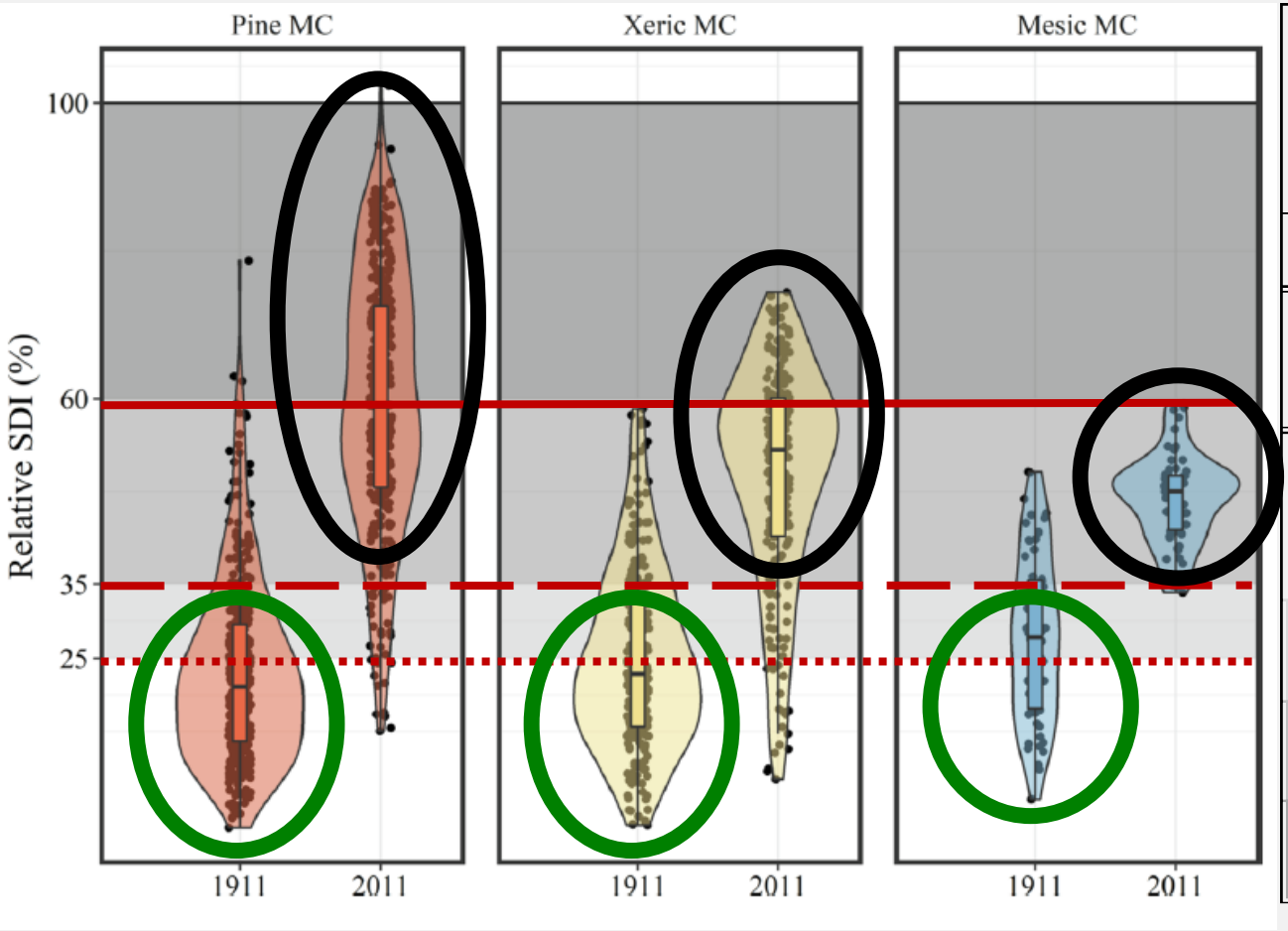
**ZONE OF IMMINENT MORTALITY !!!!!**

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

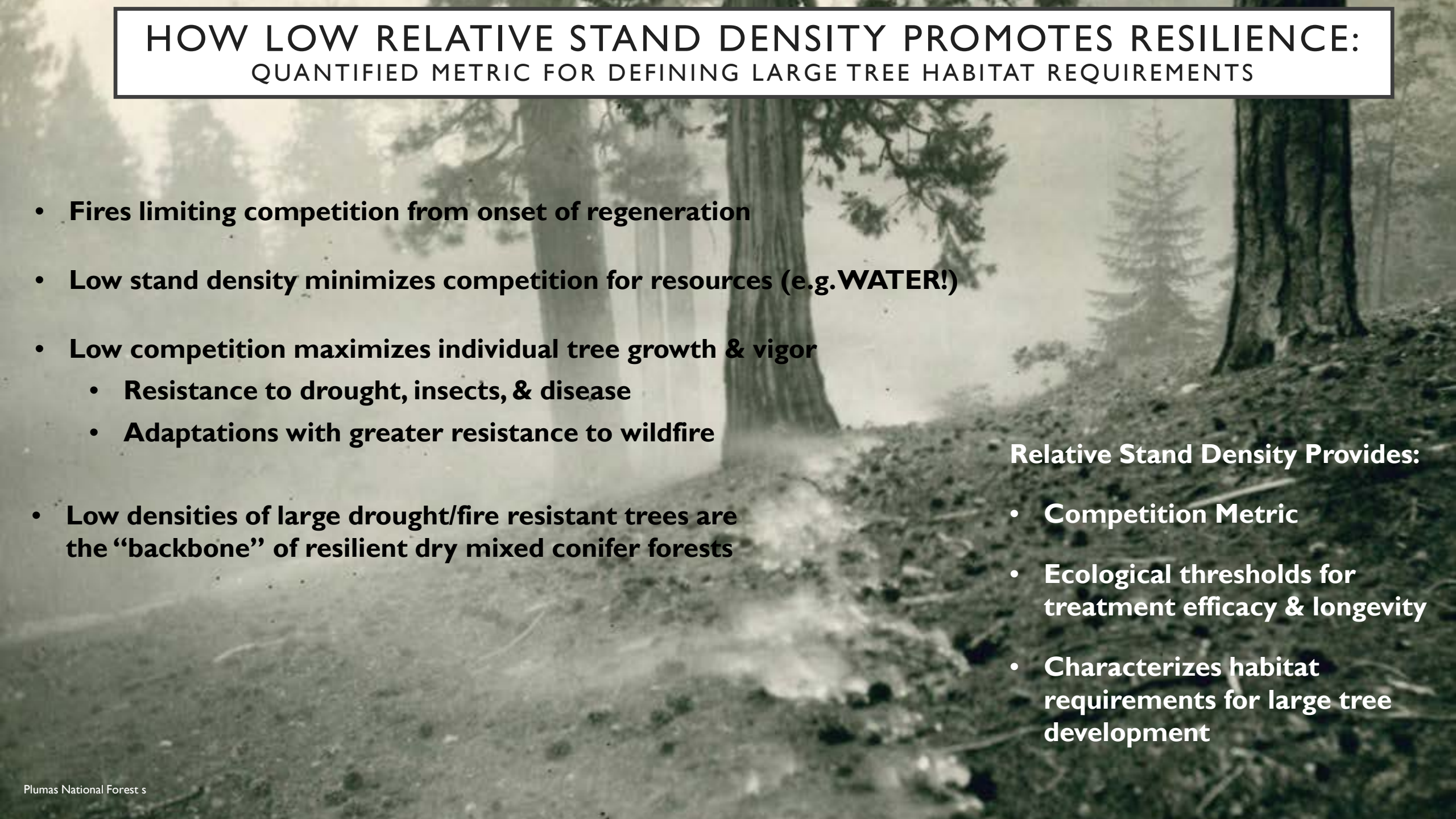



| | Pine MC | | Xeric MC | | Mesic MC | |
|---|---|---|---|---|---|---|
| **A) Absolute SDI** | | | | | | |
| | 1911 | 2011 | 1911 | 2011 | 1911 | 2011 |
| $SDI_{metric}$ | 206 (123-267) | 535 (433-655) | 275 (175-370) | 551 (462-668) | 378 (247-483) | 632 (575-674) |
| $SDI_{english}$ | 83 (50-108) | 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**

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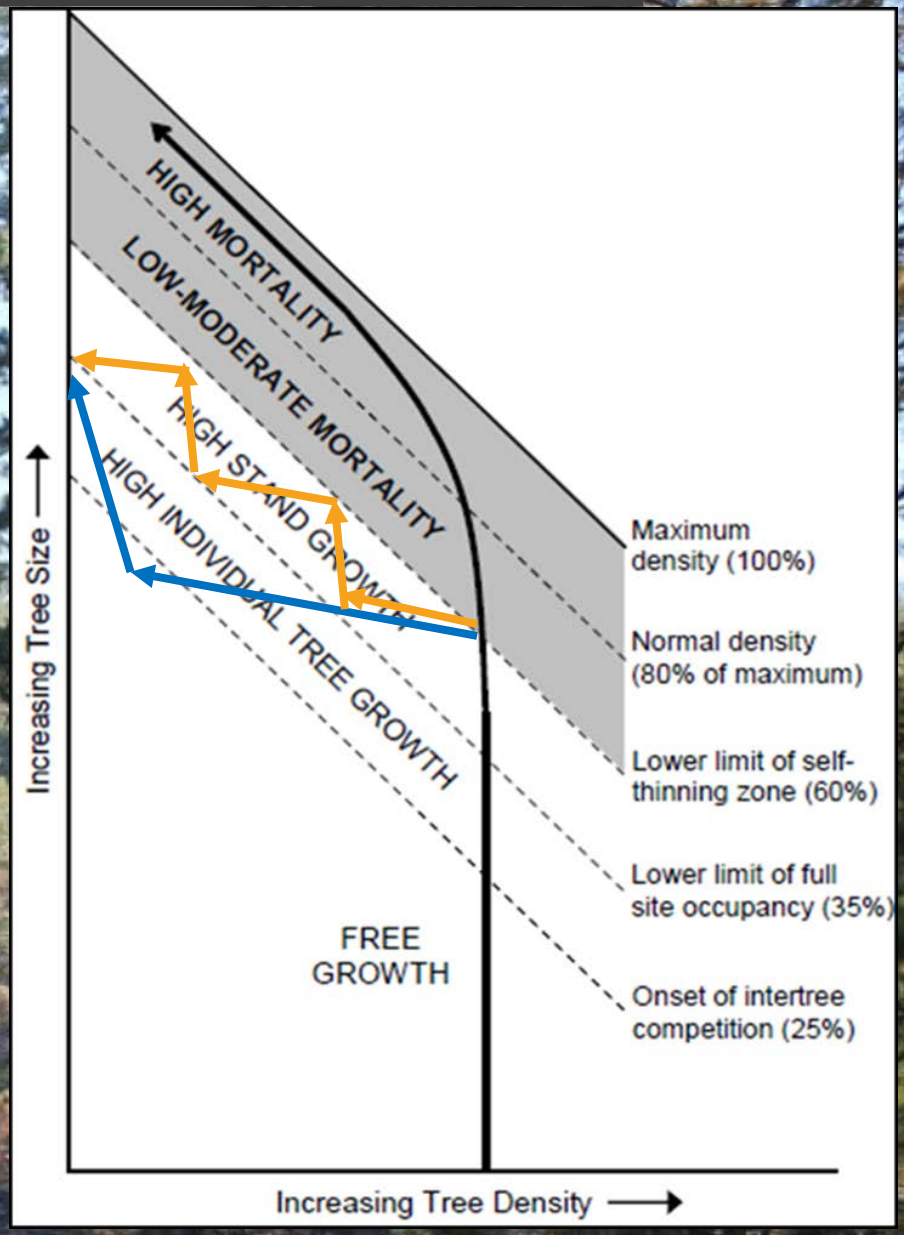
# MANAGEMENT & POLICY IMPLICATIONS:

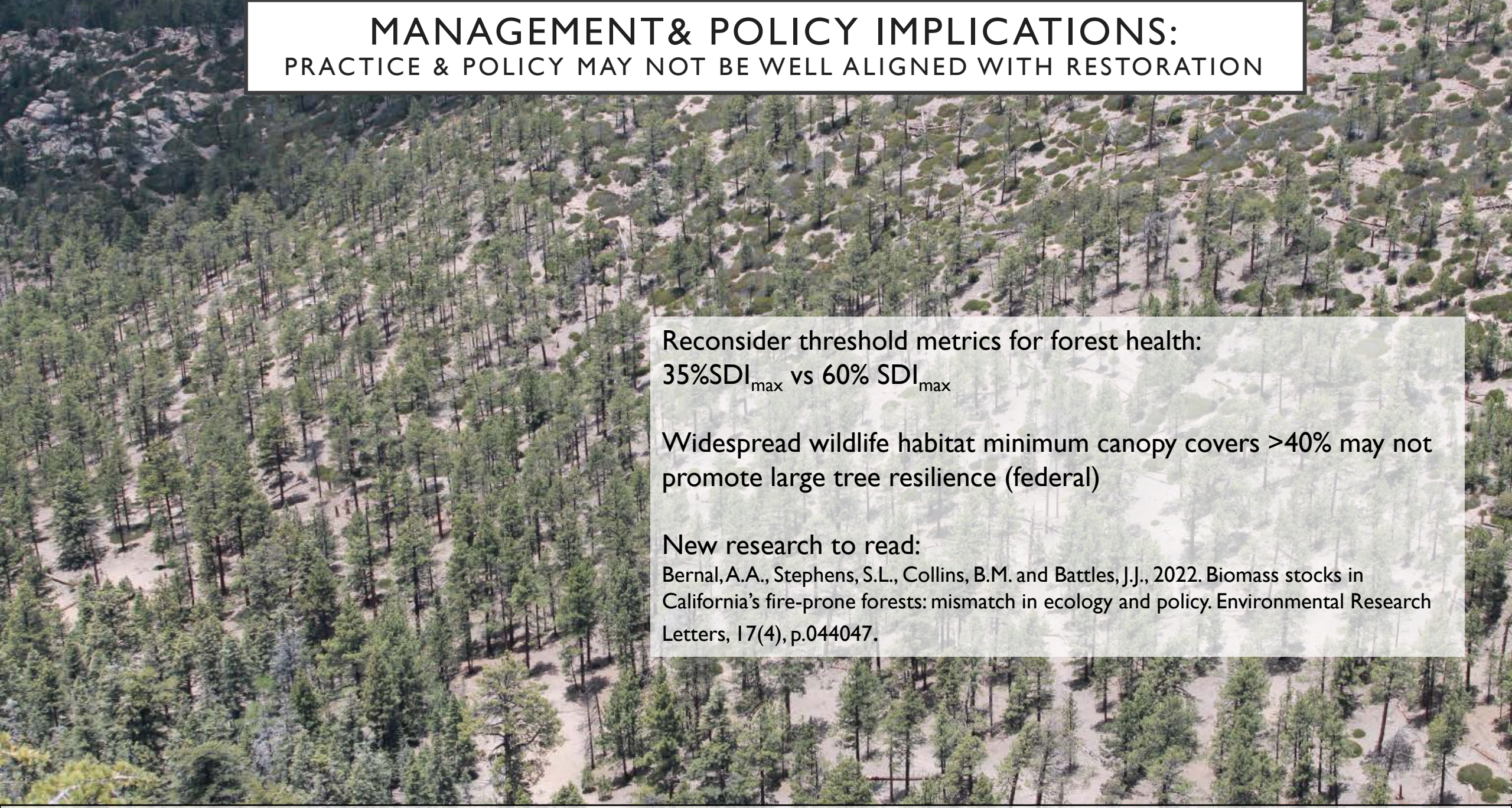
## LOW RELATIVE DENSITIES CAN BE WELL PAIRED WITH HETEROGENEITY

# SO WHAT? MANAGEMENT & POLICY IMPLICATIONS:
## TARGETS BASED ON COMPETITIVE ENVIRONMENT

- Favor individual tree growth over stand growth
- Greater intensity of initial harvest in far departed stands
- Longer cutting cycles with periodic yields less than maximum
- Shifts from intermediate harvests to understory management
- Economic considerations for land managers



# MANAGEMENT& POLICY IMPLICATIONS:
## PRACTICE & POLICY MAY NOT BE WELL ALIGNED WITH RESTORATION



Reconsider threshold metrics for forest health:
35%$SDI_{max}$ vs 60% $SDI_{max}$

Widespread wildlife habitat minimum canopy covers >40% may not promote large tree resilience (federal)

New research to read:
Bernal, A.A., Stephens, S.L., Collins, B.M. and Battles, J.J., 2022. Biomass stocks in California's fire-prone forests: mismatch in ecology and policy. Environmental Research Letters, 17(4), p.044047.

Murphy, J.S., York, R., Huerta, H.R. and Stephens, S.L., 2021. Characteristics and metrics of resilient forests in the Sierra de San Pedro Martír, Mexico. *Forest Ecology and Management*, *482*, p.118864.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