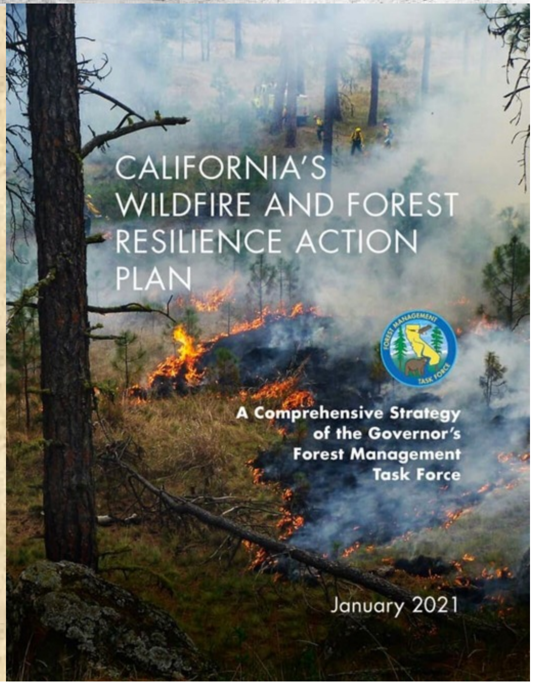
# Operational resilience in western US frequent-fire forests*

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

## Operationalizing forest resilience

- 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)
- However, resilience has been difficult to define: confusion over types (engineering, silvicultural or ecological resilience), scale (tree, ecosystem, landscape), terms (resistance, response, resilience), and variability between ecosystems
- "a [malleable] term that facilitates communication across disciplinary borders by creating shared vocabulary… (bridging) the gap between science and policy" (Brand and Jax 2007)
- Defining and operationalizing resilience may become more tractable in a specific ecological context—dry, FF forests



# 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 ➔little plant competition because herbivores proliferate, limiting plant growth more than resources

In the absence of suppression (like scarce predators), fire is frequent, limiting tree density more than resource availability (i.e., water, light, and nutrients)➔ significantly reduced 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 per cent of the quantity of timber it is capable of supporting" (Leiberg 1902)

## Frequent-fire forests may not be adapted to stress 'presses' such as competition

A corollary: In fire's absence, live tree density and biomass accumulate➔ competition for growth resources➔ reduced tree vigor

Inter-tree competition creates chronic growth reductions➔ increased tree susceptibility to stress and mortality

Competition reduces radial growth

FF forests resist stress 'pulses' (fire, pests), but may not be well adapted to internal (competition) stress 'presses'

This may explain why some restoration studies in dense, fire-suppressed forests have recorded mortality of long-lived trees following minor, recent stresses such as thinning small neighboring trees or re-introduction of low-intensity fire

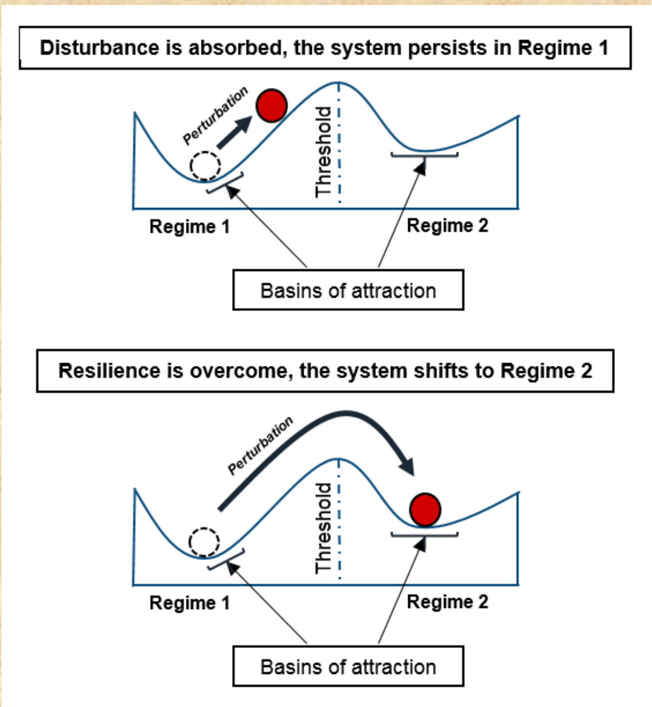
# Difference between resistance and resilience

Resistance is a measure of persistence when exposed to a stress

Focused on minimizing change, resistance treatments are often designed for **specific stresses** (i.e., current fuels reduction)

Resistance is one element of a broader community-level response, resilience, where an ecosystem is impacted by stress but retains its essential structure and composition.

Resilience is a measure of the forest's adaptability to **a range of stresses** and reflects ecosystem functional integrity.




Obligatory cup and ball schematic

## Hypothesis

Resilience treatments need to restore tree vigor by creating the very low densities characterized by little resource competition that sustained frequent-fire forests.

## Operational measure:

Relative Stand Density Index ($SDI_{max}$): silvicultural measure of resource competition combining tree size and density as a percentage of the maximum that a forest type can reach.

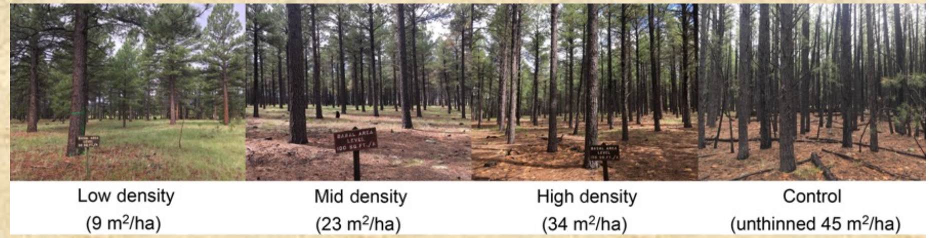
# What is stand density index (SDI) and why is it useful

Stand density index (SDI) is a measure that combines the number of trees per acre and their size (measured by their diameter) to assess the total biomass of the local forest

The relative SDI assesses how that local stand compares to a maximum amount of biomass that can be supported for that particular forest type (such as Jeffrey pine or mixed conifer) and is expressed as a percentage of that maximum

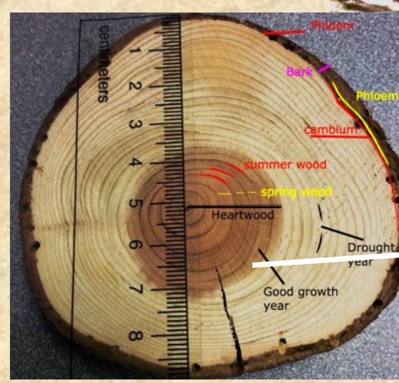
Relative SDI is useful because it measures how crowded or open a forest is, assessing how much competition there is between trees and how fast they are growing

In open stands that have little competition, trees are growing rapidly (measured by large increases in their ring width) and this growth vigor is their best defense against stresses such as fire, drought, bark beetles and **climate change**




**Different tree densities and sizes**

**A forest at maximum biomass**




**Tree section showing different annual growth rings**

**Vigorous growth supports tree defense against bark beetles: pitch blob has entombed beetle**

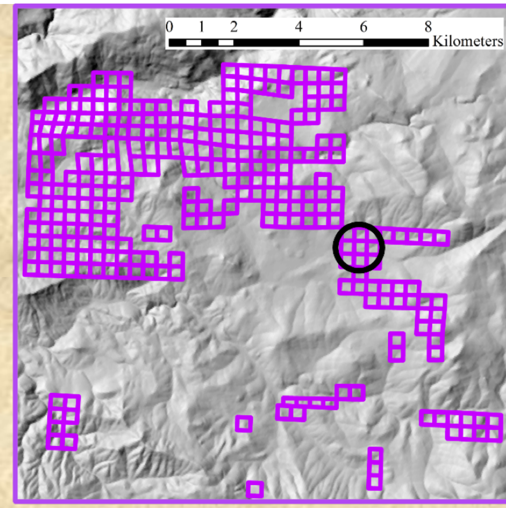
# Testing of this Resilience Concept with Historical Data

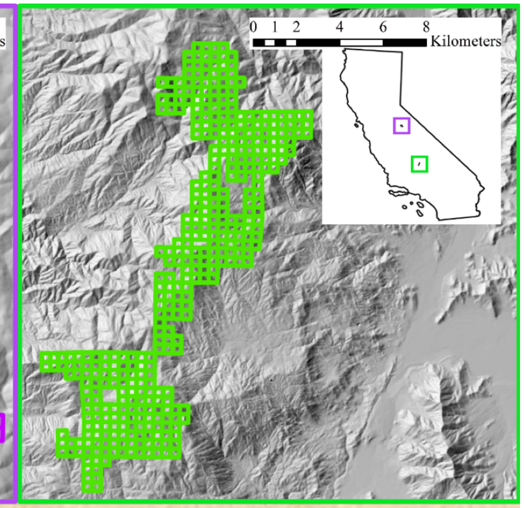
1911 timber inventories in the Stanislaus (upper left) and Sequoia (upper right) National Forests

Each historical inventory used 20.1 m to 40.2 m wide by 402 m long belt transects across each 16.2 ha quarter-quarter (QQ) section

High sampling intensity (5-10% of each QQ section), totaling 644 samples over >10,000 ha

2011 forest conditions in same area assessed with F3 (combination of LiDAR, FIA, field plots)




Location of QQ sections. The circle indicates approximate location for the 1941 photo (bottom row). Note the large clump of pines in the photo center and the surrounding ingrowth, showing how forest conditions are starting to transition from historical to contemporary conditions.

## Criticism of cutting trees: Chad Hanson's Fresno Bee Op-Ed reprinted in The Sheet

- *Study promotes "removing 80% of the trees...through commercial logging"* Small trees would be removed with thinning and/or fire costing agencies (≈$1-2,000/ac)

- *"study was authored by scientists funded by the US Forest Service…that financially benefits from commercial logging"* Only 1.5 (North, Collins) of the 6 authors are Forest Service

- *"study used 2011 to represent current conditions…and failed to mention these forests have [now] almost entirely burned"* 2011 was used because it is 100 years after the first survey in 1911. The point that these forests have burned is ???

- *"denser forests…burn at lower intensity", "logging…increases fire intensity by changing the microclimate", "removing trees…will [not] curb fire intensity", "promotes the ['misleading'] notion of overgrown Sierra Nevada forests"*

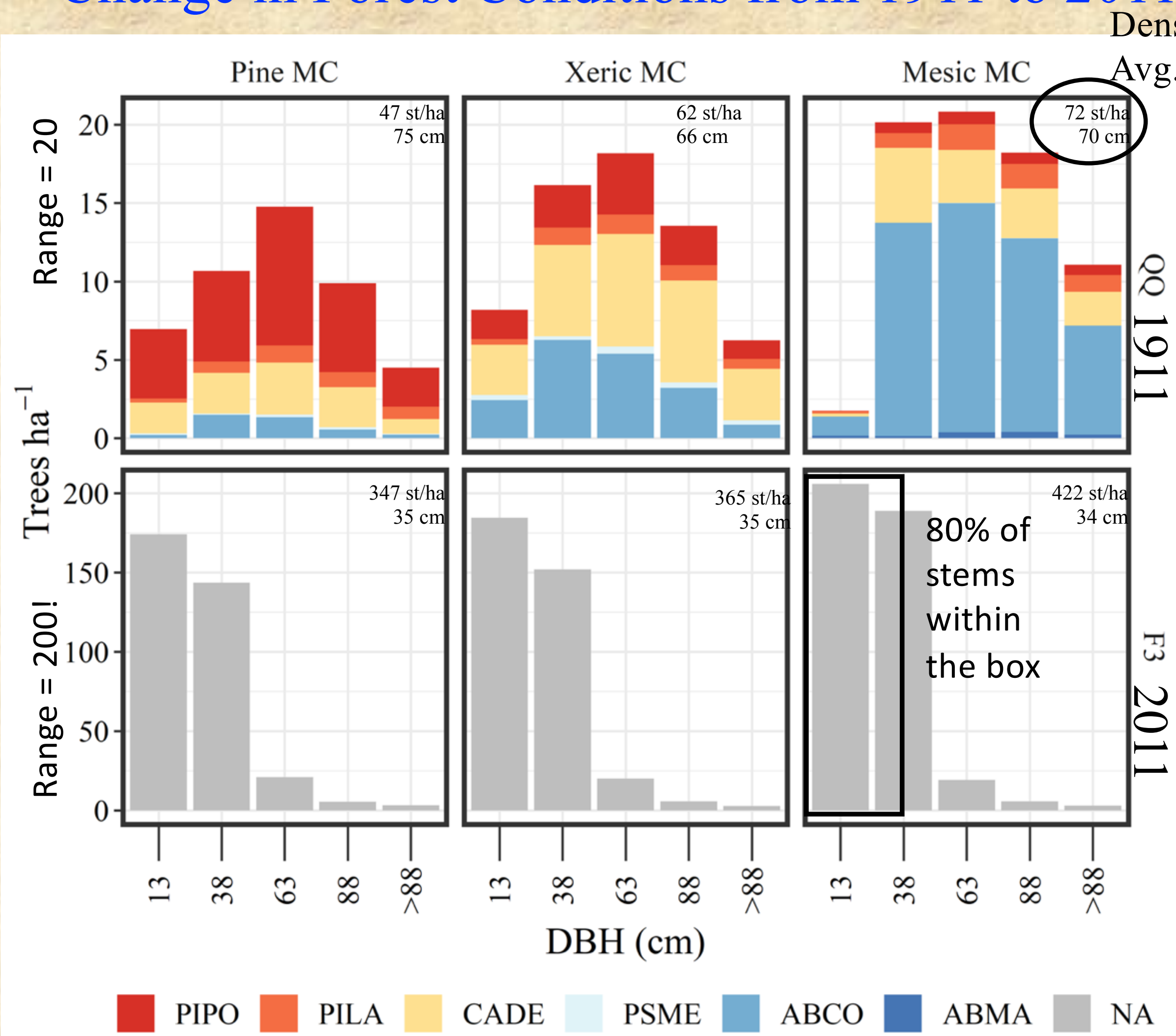
*"Why did the North study conceal all of this important information from the public?"* Because the 'research', all authored by Hanson, DellaSala and Baker, has been widely discredited, including in a recent systematic review* of these claims authored by >50 of the leading forest and fire researchers.

* Ecological Applications issue 31 (2021)

Early 20th century Sierra Nevada forest


After the 2013 Rim fire

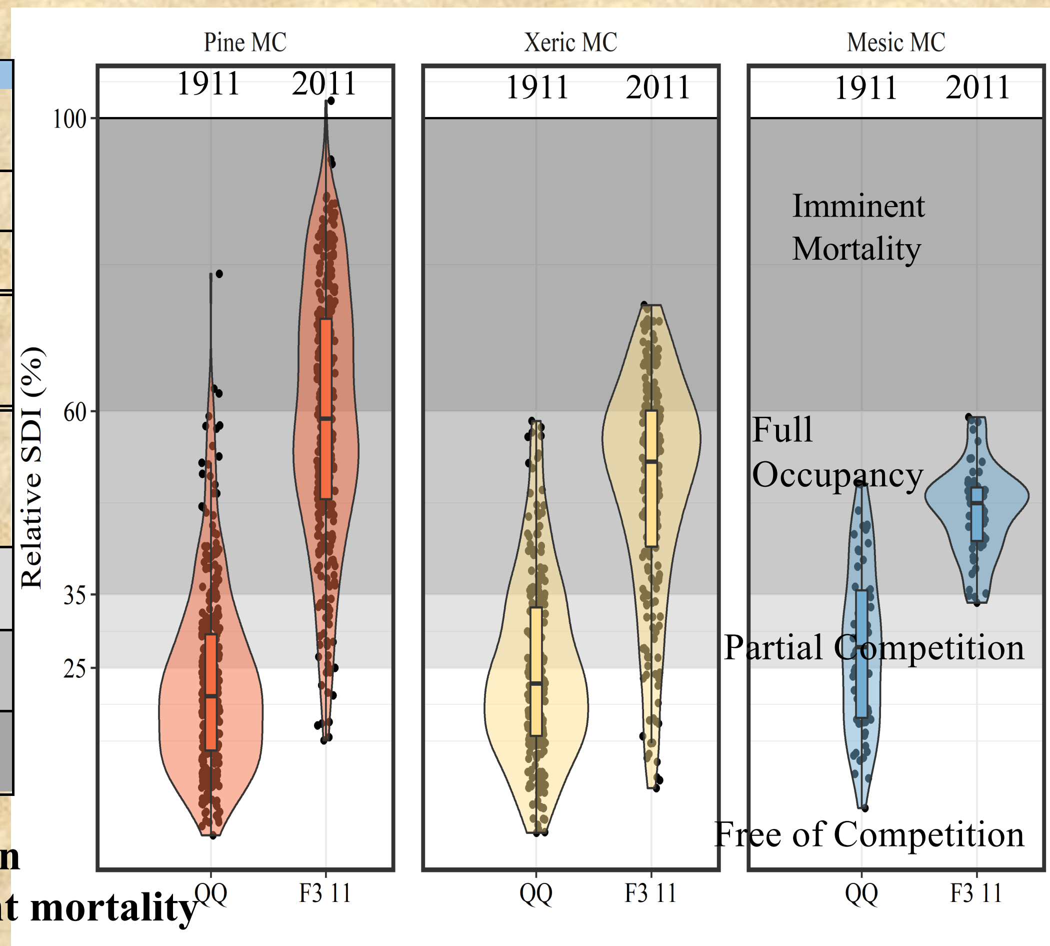
# Change in Forest Conditions from 1911 to 2011




Bear Creek R.S. in 1911 (top) and 2005 (bottom)

# Change in Forest Competitive Environment from 1911 to 2011

| | 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 |




**1911: 73-85% of forest in free of to partial competition**

**2011: 82-95% of forest in full competition to imminent mortality**

## Resilient forests historically were low density with little competition…so what?

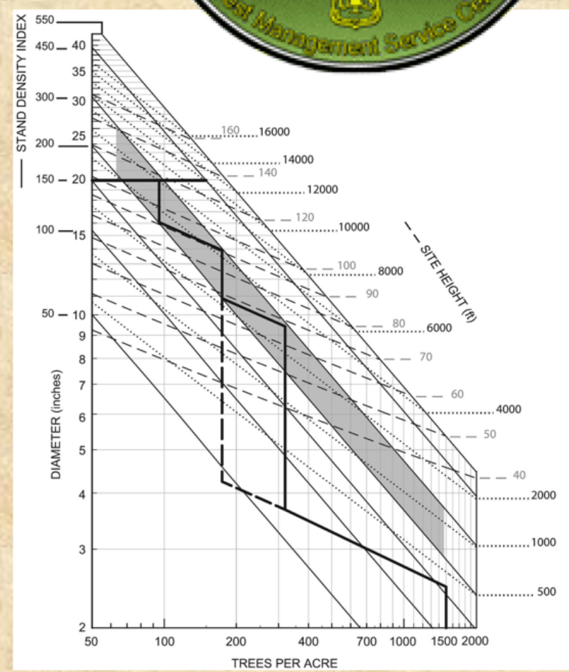
Competition is the driver of how forest stands are managed, when thinning occurs, and which trees are favored due to their size

Forestry practices often maintain stocking above 35% of $SDI_{max}$ to sustain tree growth, and schedule thinnings as SDI approaches 60% of $SDI_{max}$ to 'capture' density-dependent mortality

Many current forestry practices may be misaligned with creating resilience

Implications:

Relative SDI of 35% should be a **maximum** not a *minimum*
Using a relative $SDI_{max}$ ≥60%, Region 5 would treat only 48%, 25% and 0% of our contemporary pine, xeric, and mesic mixed-conifer types. Treatments to minimize competition would be much higher: 96%, 91% and 100% of the 3 forest types.



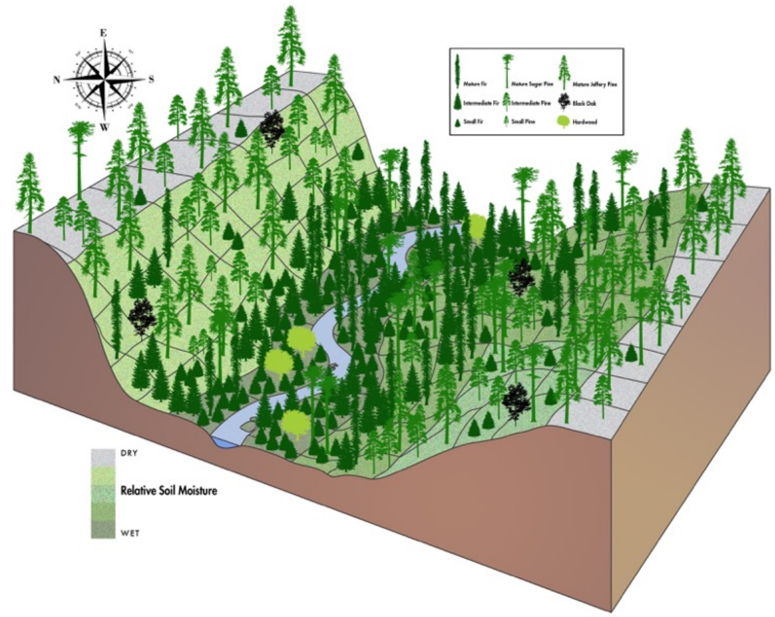
Stand density management diagram

# Using SDI

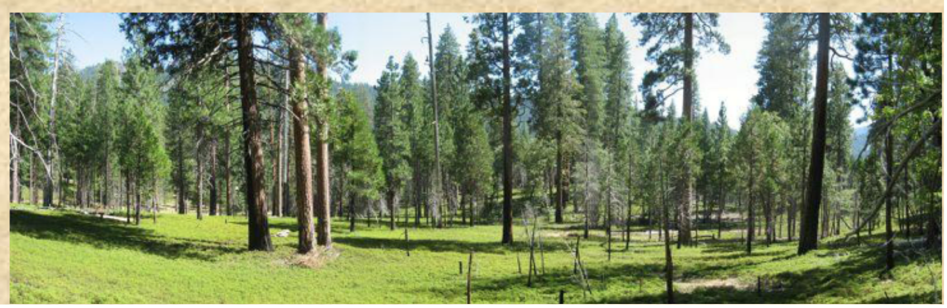
Mean relative SDI values were 23-28% of maximum, but the range was 14-39%
This provides flexibility so that managers could provide denser forests (i.e., owl habitat) on sites with greater soil moisture (often the limiting growth resource) and more open forest on drier sites (i.e., steep slopes, thin-soil ridge tops).

Reducing competition does not equate to planting and thinning treatments that maximize regular tree spacing.

Creating a more complex spatial pattern combining individual trees, clumps of trees and openings (i.e., ICO), create forests that are more resistant and resilient to high-severity fire and drought




Forest density & composition in sync with topographic moisture availability



ICO pattern in Yosemite NP
(photo: Marc Meyer)


Questions?
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