Fighting drought with fire:
Can forest management increase resistance to drought?

Adapting to a hotter, drier future

Phil van Mantgem
USGS

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U.S. Department of the Interior
U.S. Geological Survey

Credit: N. Stephenson

Can forest thinning be used as a climate change adaptation tool?

- Drought and changing patterns of tree mortality
- Prescribed fire as an adaptation tool
- Evidence for increasing resistance and resilience

USGS

Credit: N. Stephenson

STATE

NOVEMBER 3, 2015

California gov. declares emergency over dead trees

The Associated Press

A census by the U.S. Forest Service found that 22 million trees have died during California's four-year drought, and tens of millions more are expected to follow.

USGS

Credit: N. Stephenson


The current drought as a possible preview of the future
Credit: N. Stephenson

The two components of drought are water supply and demand.

A leaky bucket analogy:

USGS

Credit: N. Stephenson

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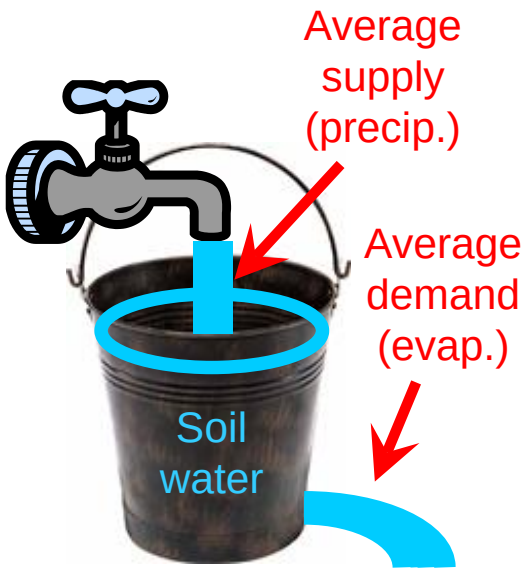
A leaky bucket analogy:

Average conditions



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Credit: N. Stephenson

The two components of drought are water supply and demand.

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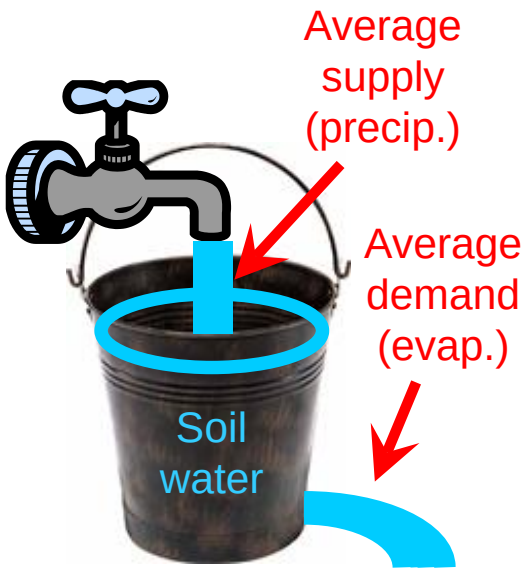
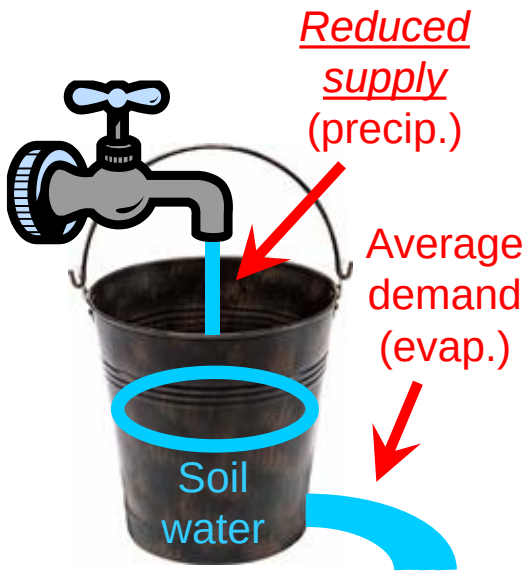


"Normal" drought



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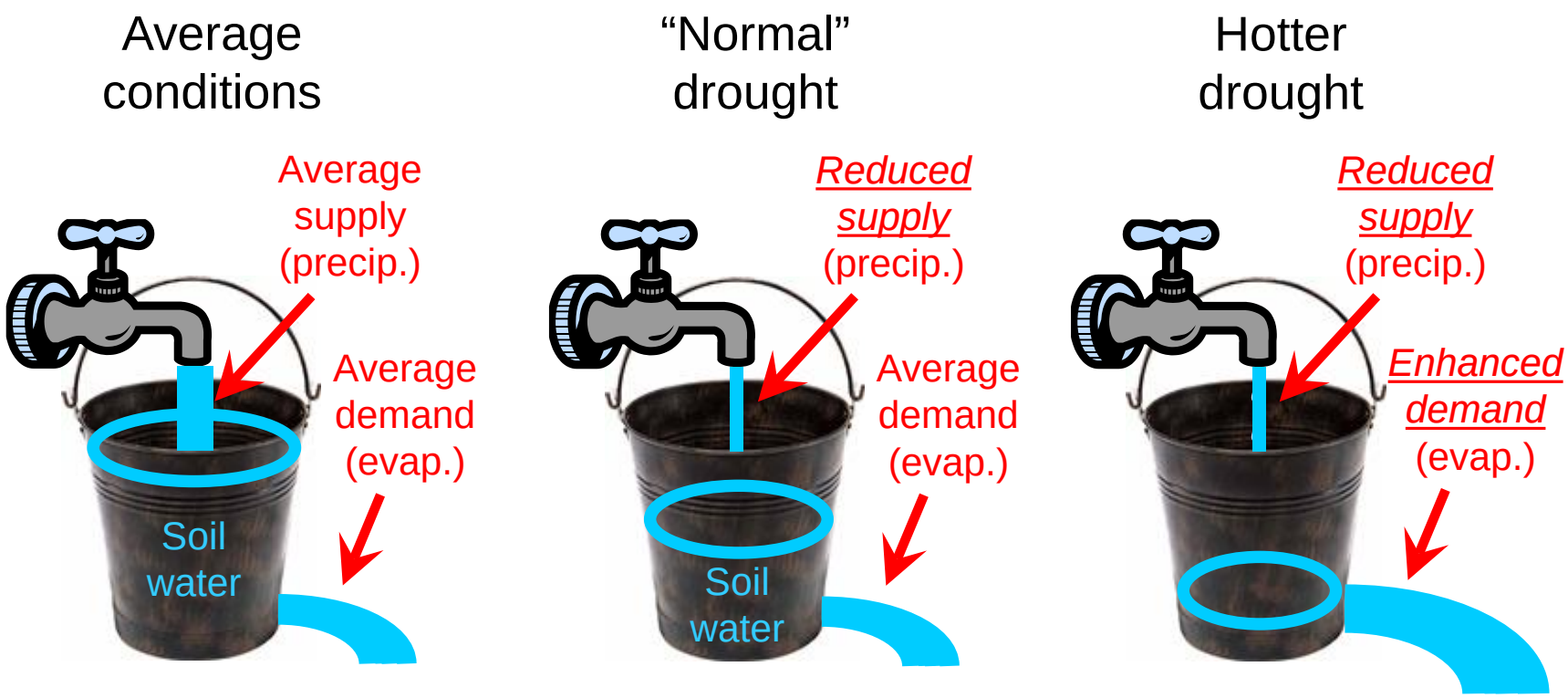
Credit: N. Stephenson

The two components of drought are water supply and demand.

A leaky bucket analogy:



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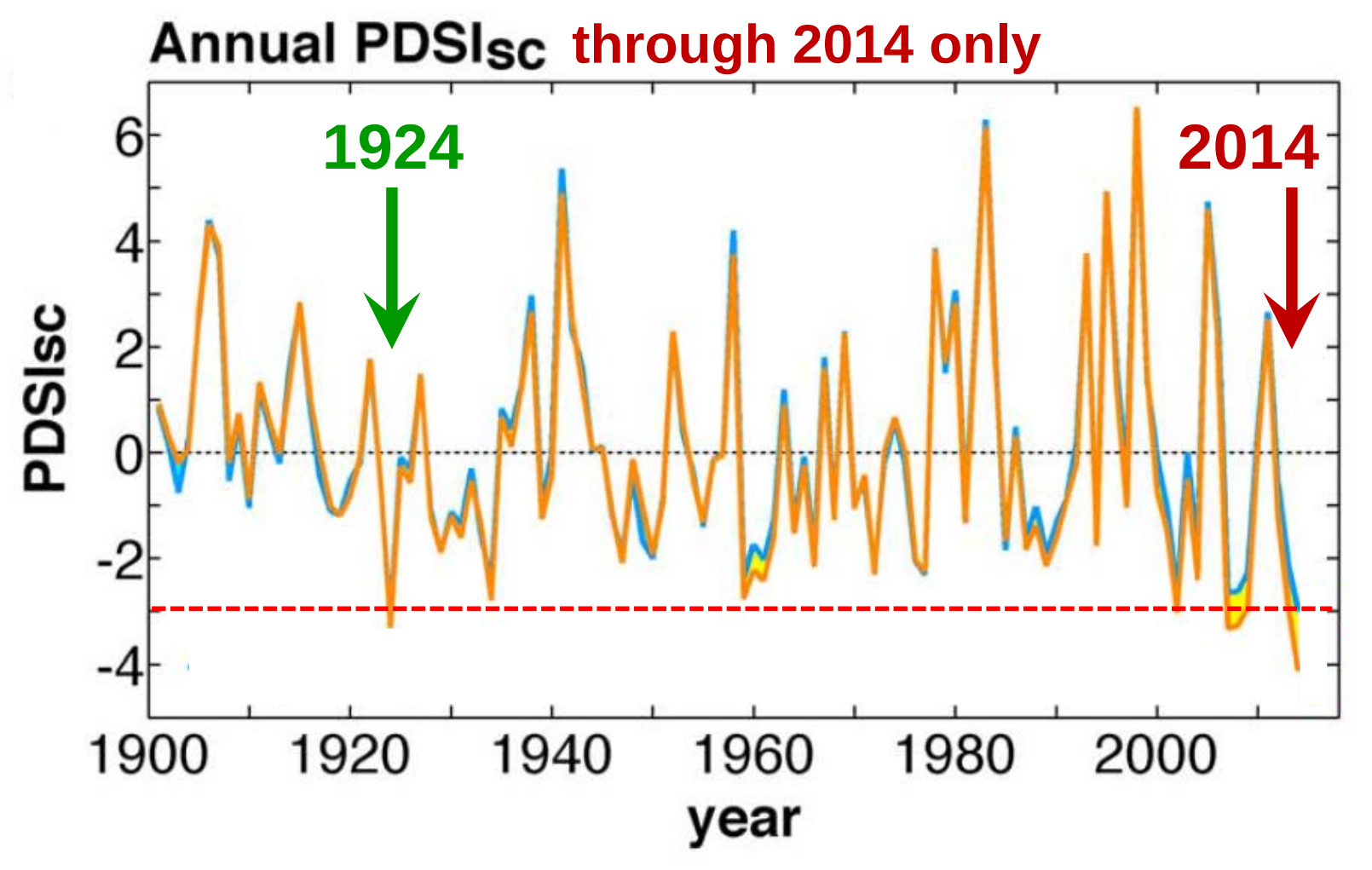
Credit: N. Stephenson

If all we had was a rain gauge, we'd think the current drought was comparable to the 1924 drought.

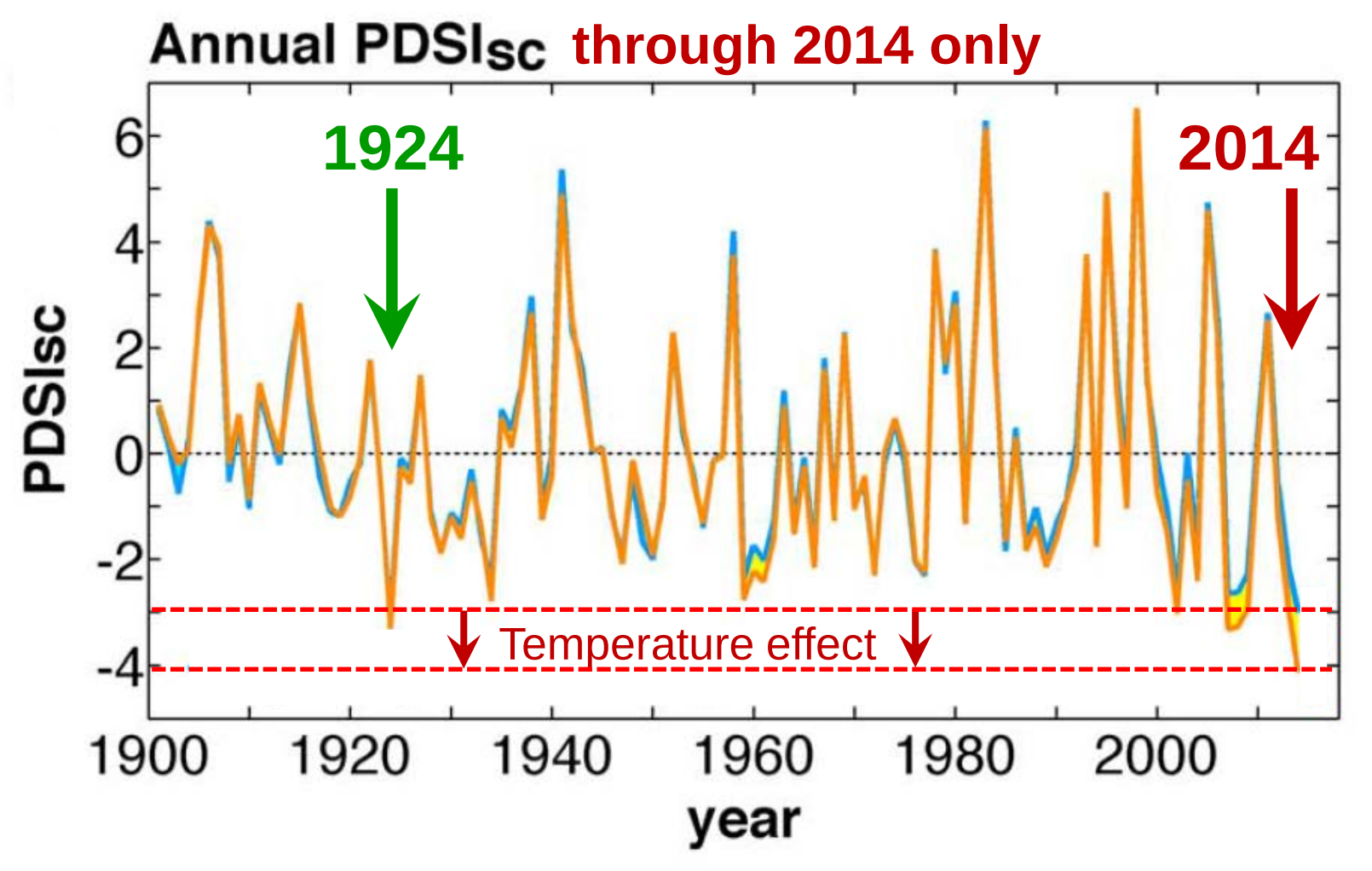


Williams et al. 2015, *Geophys. Res. Lett.*

USGS

Credit: N. Stephenson

But temperature-induced increases in evaporative demand have pushed the drought to historical extremes ...



Williams et al. 2015, *Geophys. Res. Lett.*

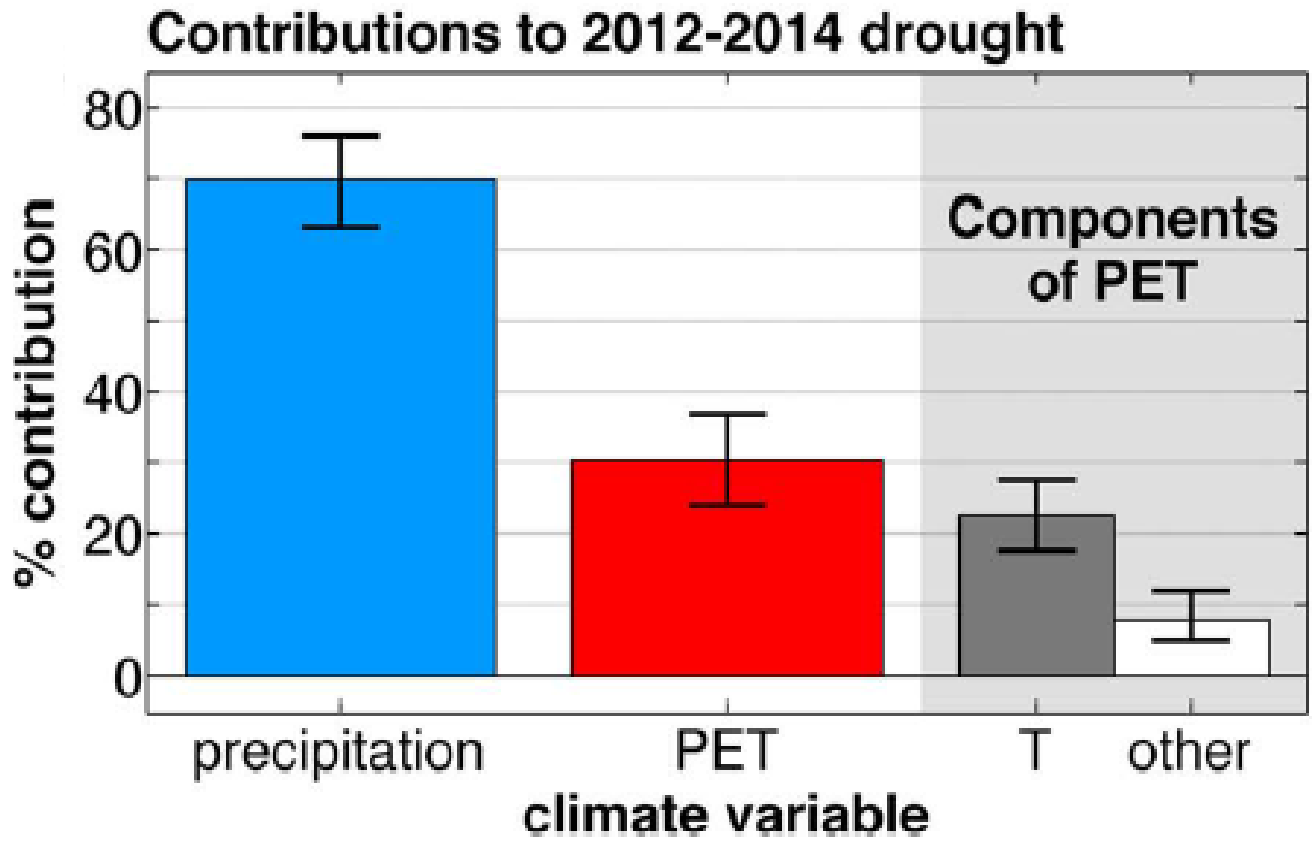
USGS

Credit: N. Stephenson

California drought

Don’t blame it all on the rain

“…anthropogenic warming is estimated to have accounted for 8–27% of the observed drought anomaly in 2012–2014…”

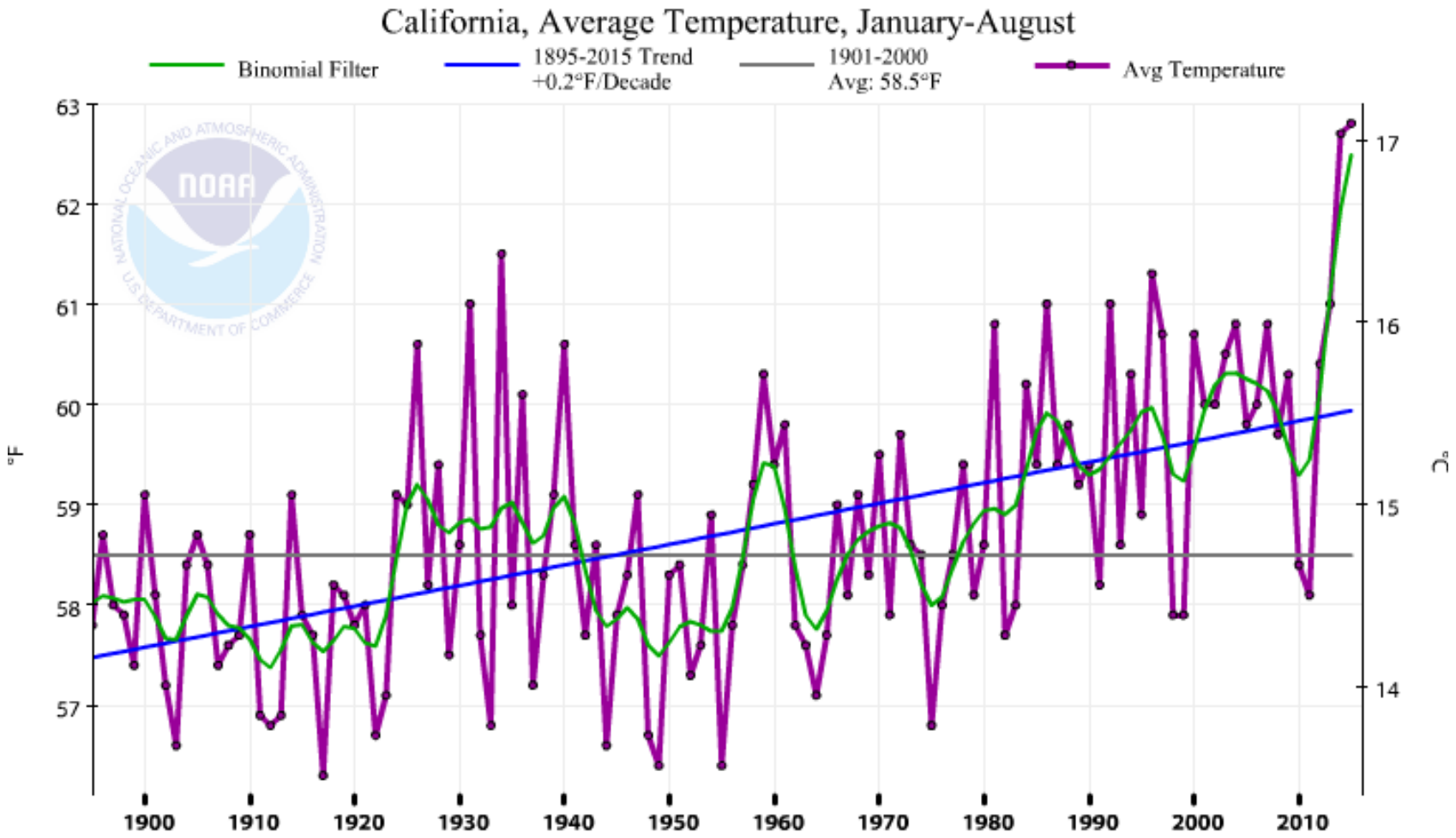


Williams et al. *Geophys. Res. Let.* 2015

USGS

California's long-term warming trend

2015 warmest year on record



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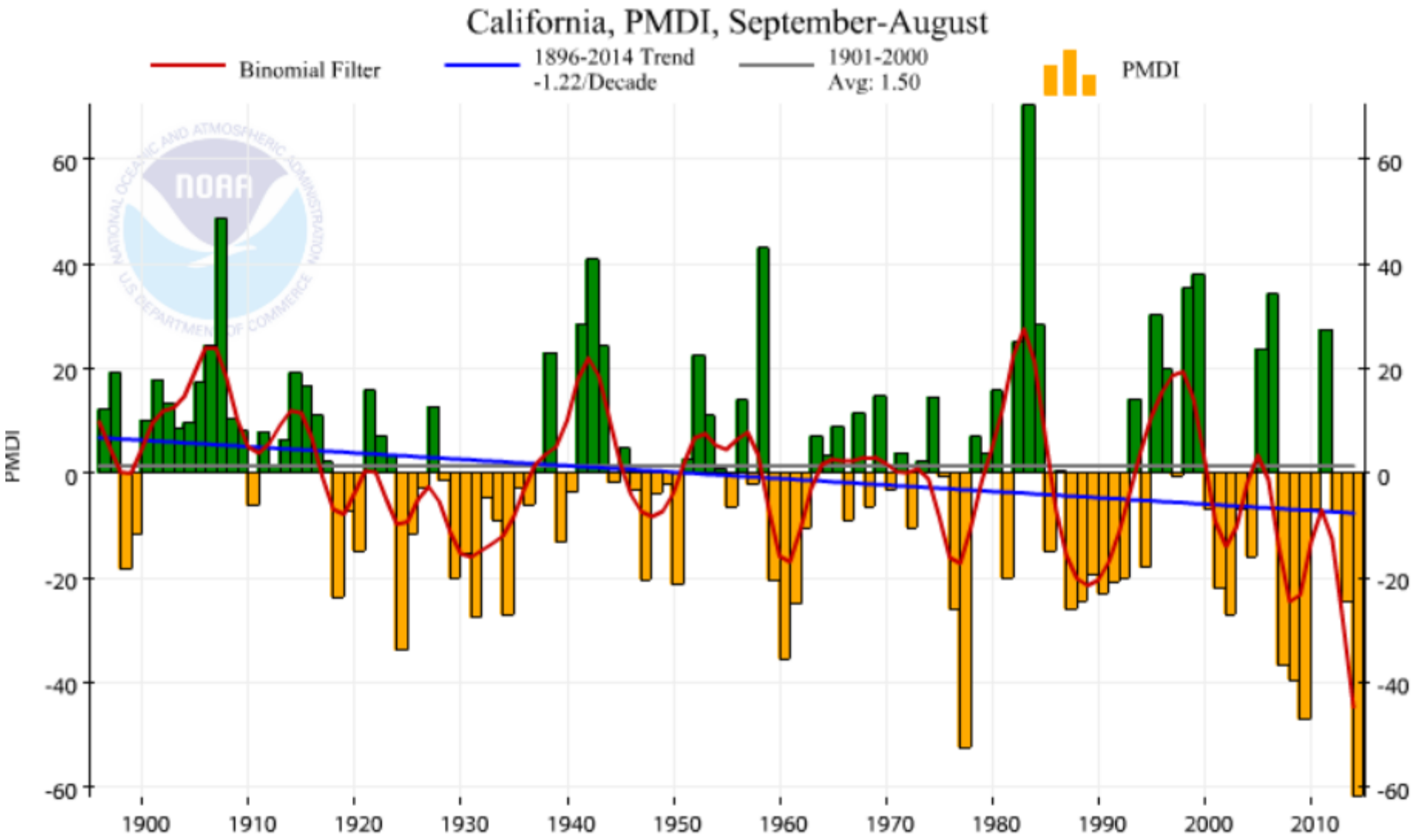
(NOAA/NCDC)

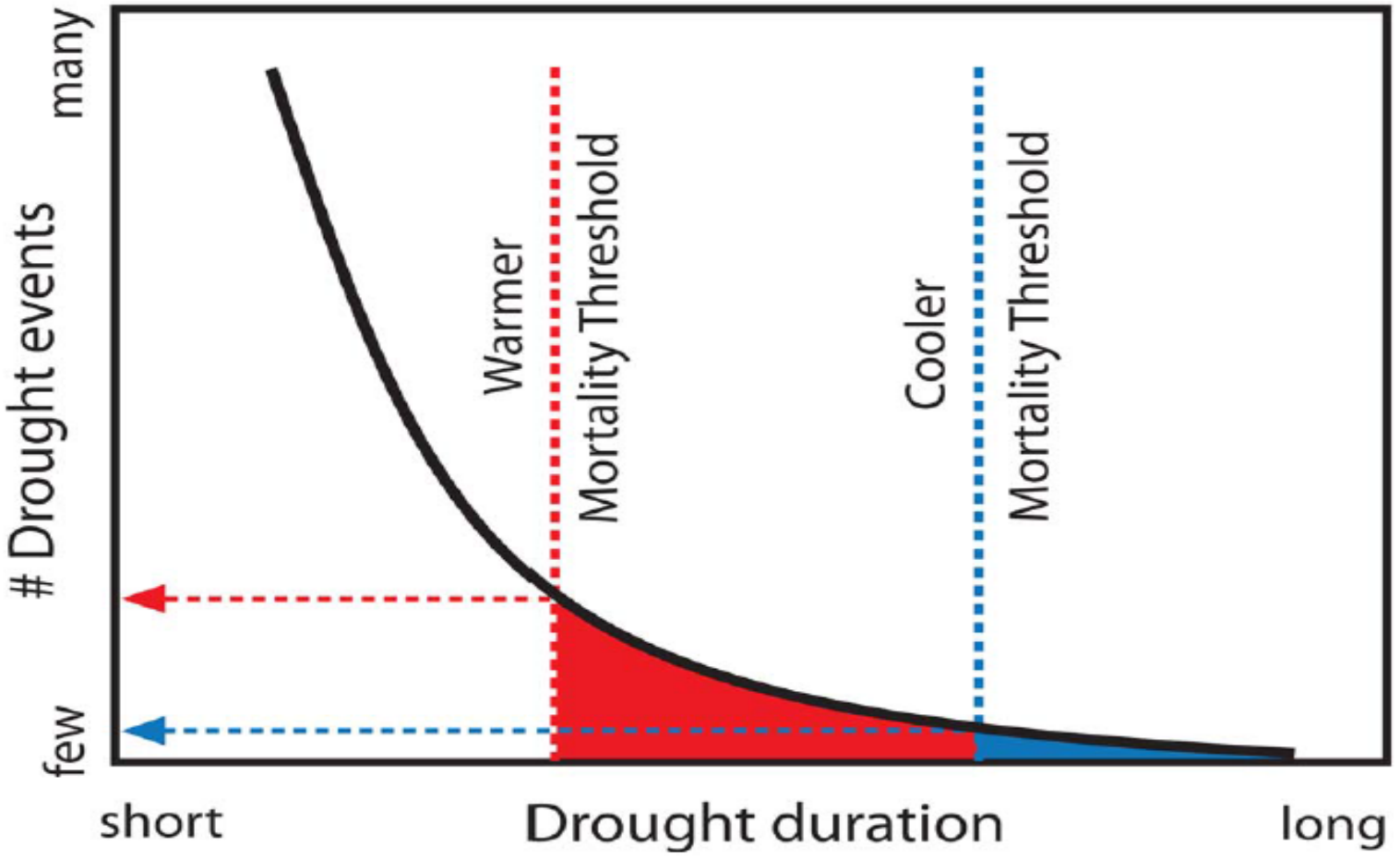
Trends in (modified) Palmer Drought Severity Index for California



USGS

(NOAA/NCDC)

Lethal droughts are likely to become more common



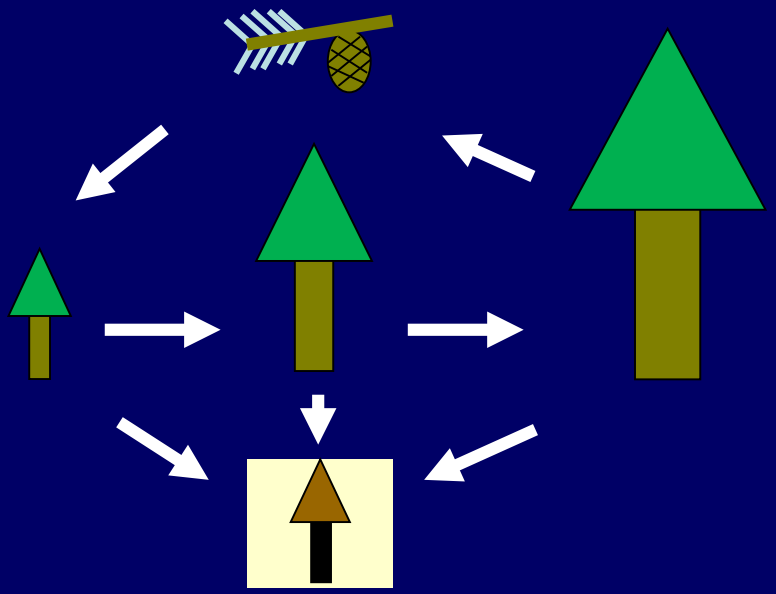
(Allen et al. 2015 *Ecosphere*)

USGS

Credit: N. Stephenson

Why tree mortality?

Tree populations are highly sensitive to changes in mortality rate



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Ecological implications of widespread tree mortality

- Accelerated **type conversions**, even **biome shifts** (e.g. forest to savannahs, shrublands, grasslands)
- Loss or **displacement of wildlife habitat**
- Degradation of **watershed ecohydrological processes**
- Reduced **carbon sequestration** potential

The central, key question is thus:

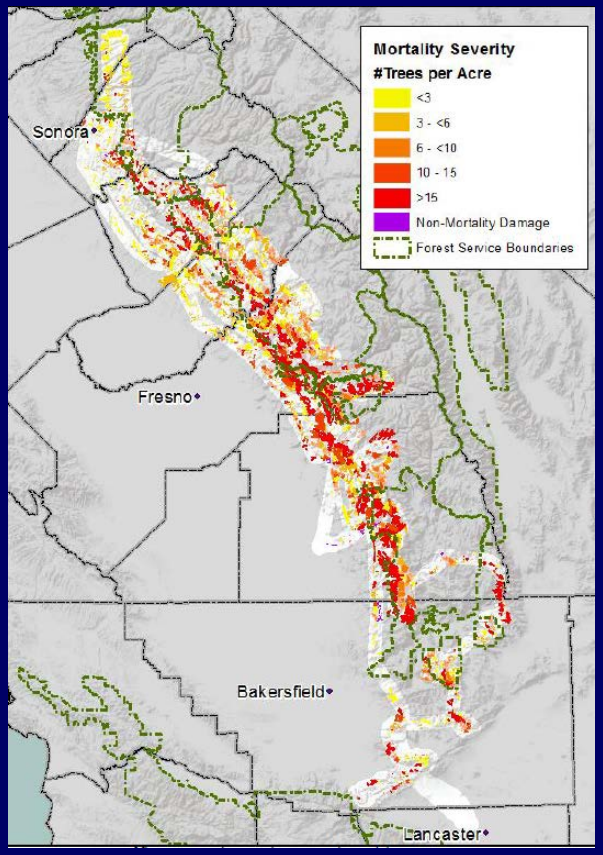
CAN MANAGEMENT ACTIONS COMPENSATE FOR DROUGHT AND TEMPERATURE CHANGE TO OFFSET TREE MORTALITY?

Allen *et al.* 2015, *EcoSphere*

USGS

Southern Sierra Nevada die-back event of 2015

USFS Region 5 Aerial Detection Survey – July 6th to 7th , 2015
Area surveyed: 3.6 million acres
Areas with mortality: 0.5 million acres
Estimated number of trees killed: 6 million



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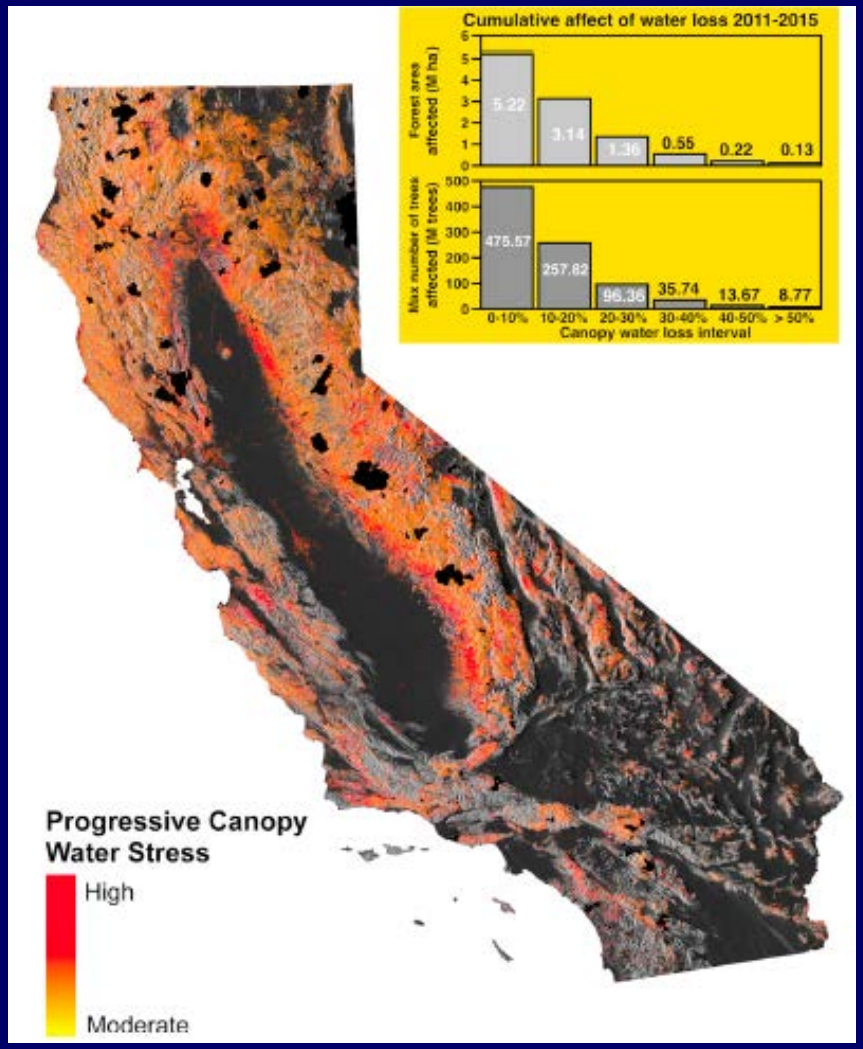
http://www.fs.usda.gov/detail/r5/forest-grasslandhealth/?cid=fsbdev3_046696

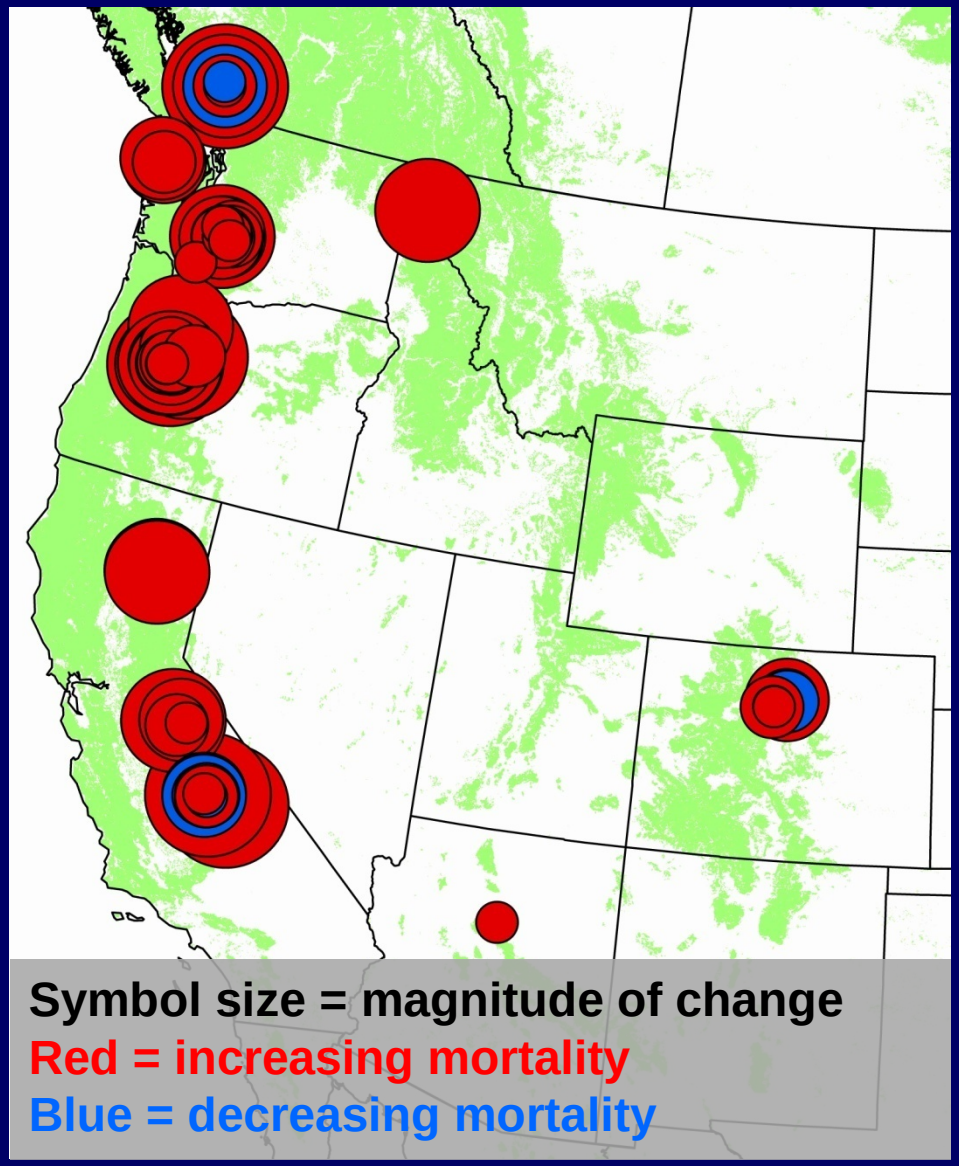
California state-wide die-back event?



Approximately 10.6 million ha of forest containing up to 888 million large trees experienced measurable loss in canopy water content… Asner et al. 2016 *PNAS*

USGS

‘Background’ tree mortality rates are increasing



- 76 plots in undisturbed old forests
- observed from ~1981 to ~ 2004
- 87% of plots increasing mort. rate *P* <0.0001
- mort. rate ~18 yr DOUBLING period
- temporal trend, *P* <0.0001

van Mantgem *et al.* 2009, *Science*

USGS

‘Background’ tree mortality rates are increasing

Developing a mechanistic understanding

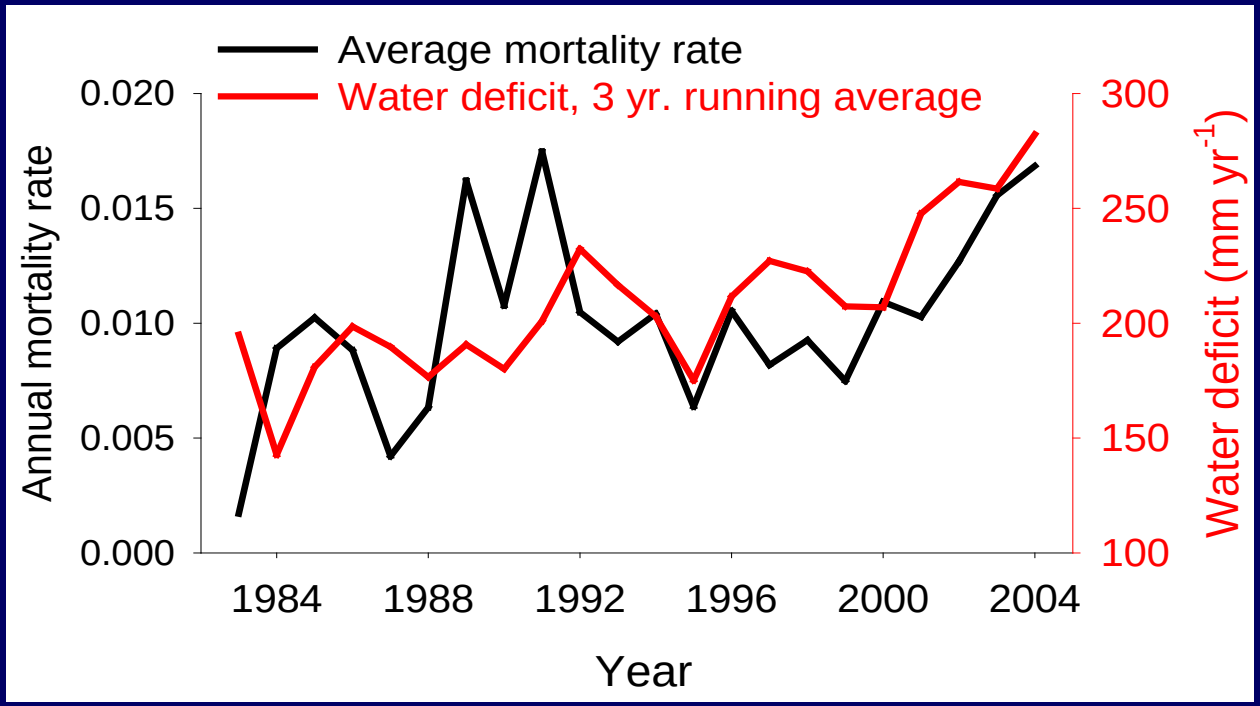
Stress mortality (standing dead: insects, fungi, or no symptoms)

Related to water deficit

Stress-biotic mortality

β_{year} = 0.01, s.e. = 0.01, P = 0.58

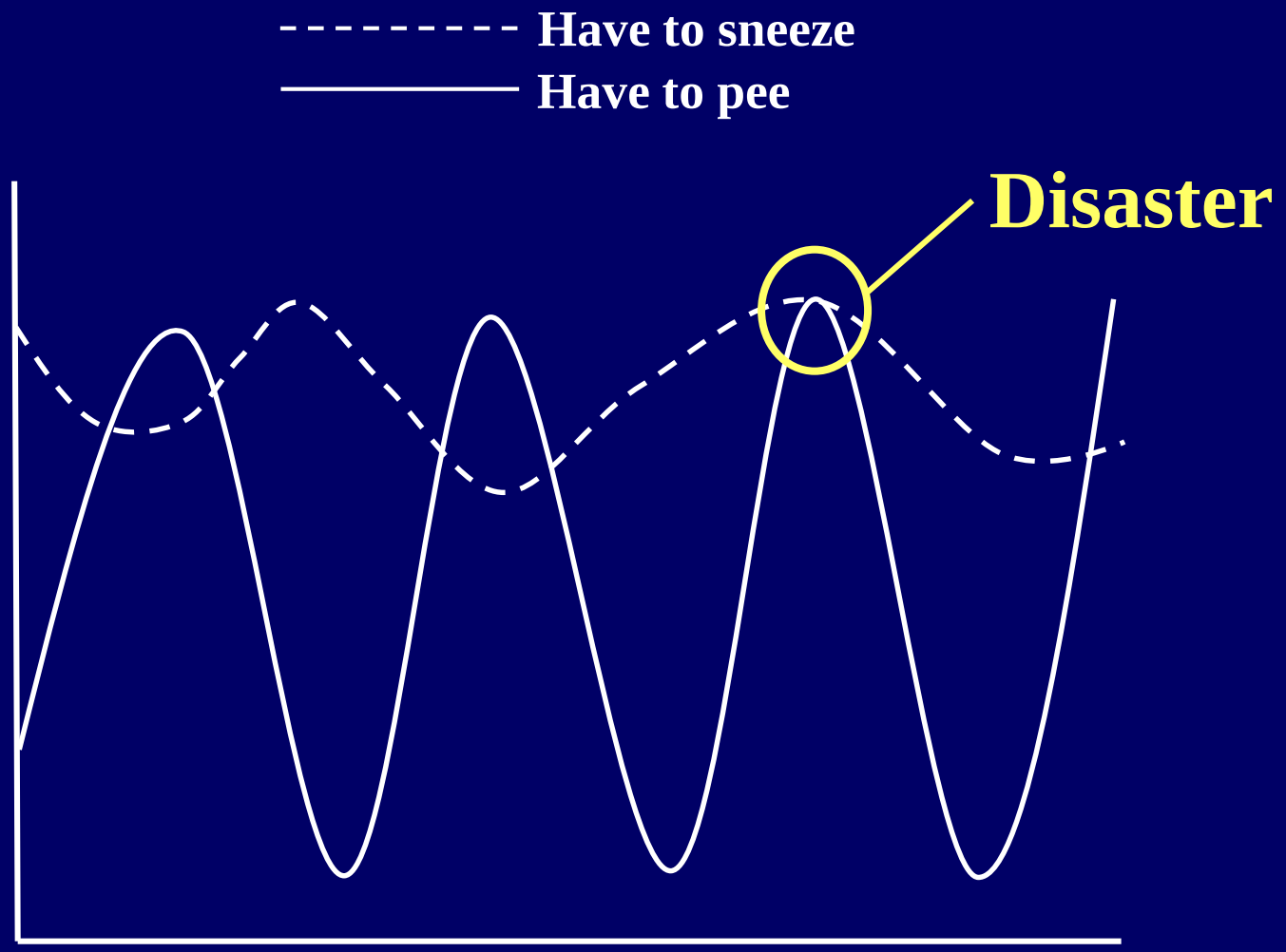
β_{D} = 0.005, s.e. = 0.001, P = 0.0002



van Mantgem & Stephenson 2007, *Ecol. Lett.*

USGS

Interactions of stressors



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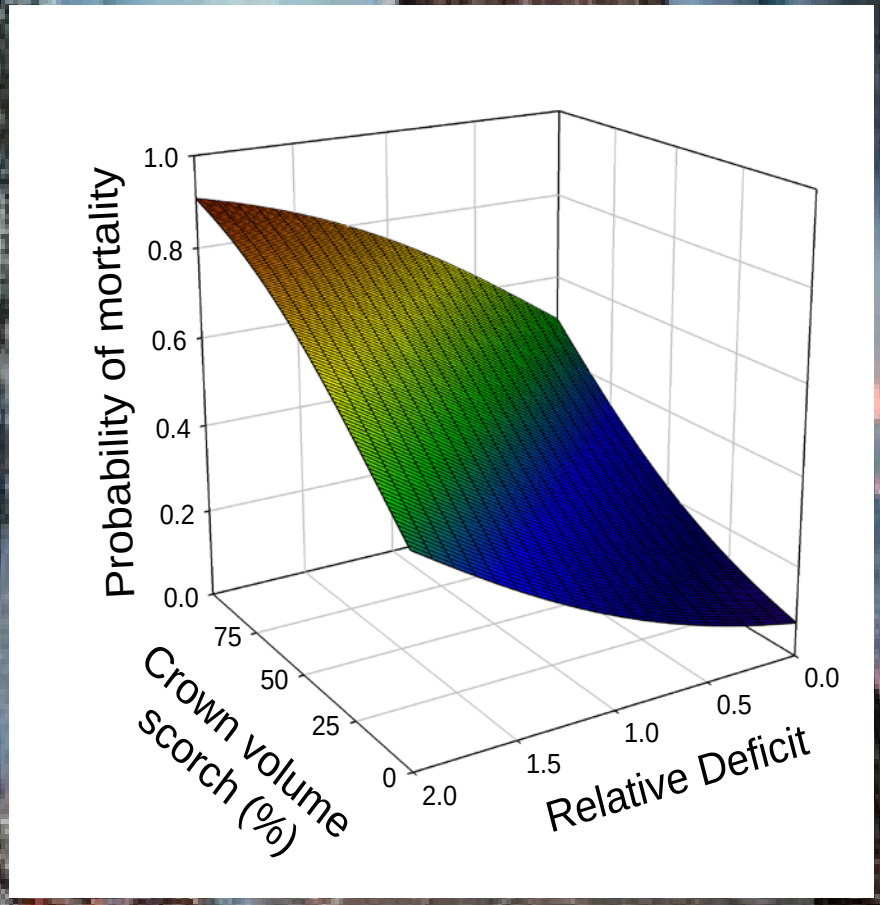
from Martin 2012, *This is a Book*

Climatic stress increases forest fire severity across the western United States

- Data from NPS and USFS
- 18 sites
- >250 plots
- >7000 trees
- dominated by *P. ponderosa* and *A. concolor*

(also *Pseudotsuga menziesii,* *Calocedrus decurrens* and *P. lambertiana)*



van Mantgem *et al.* 2013, *Ecol. Lett.*

USGS

Credit: N. Stephenson

Can forest thinning be used as a climate change adaptation tool?

- Drought and changing patterns of tree mortality
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USGS

Credit: N. Stephenson

The fuels problem in western US forests

USGS

Credit: USGS

Can forest thinning be used as a climate change adaptation tool?

Prescribed fire

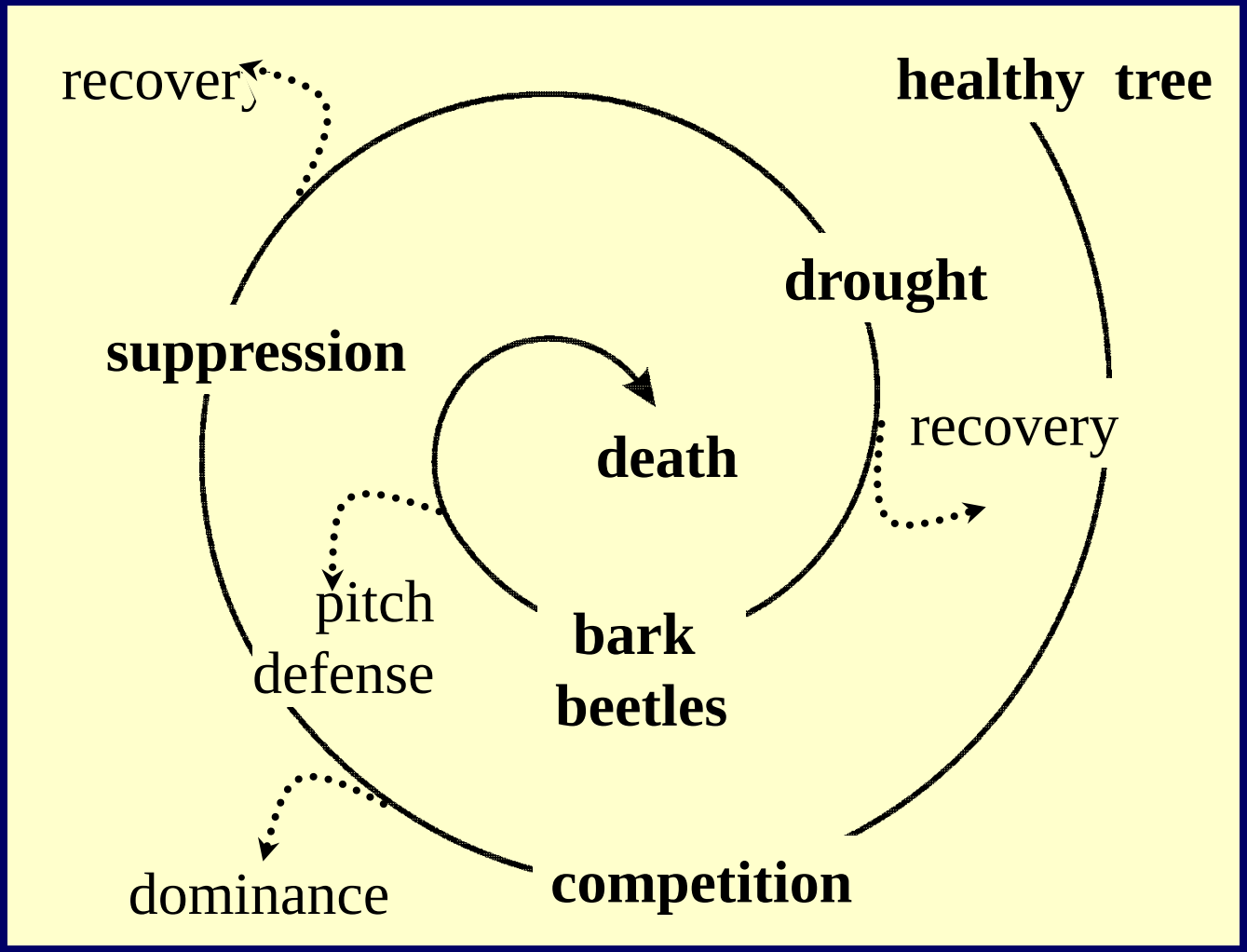
Credit: USGS

Mechanical thinning

Credit: Denver Post

USGS

The decline spiral model of tree death



Franklin, 1987 *Bioscience*

USGS

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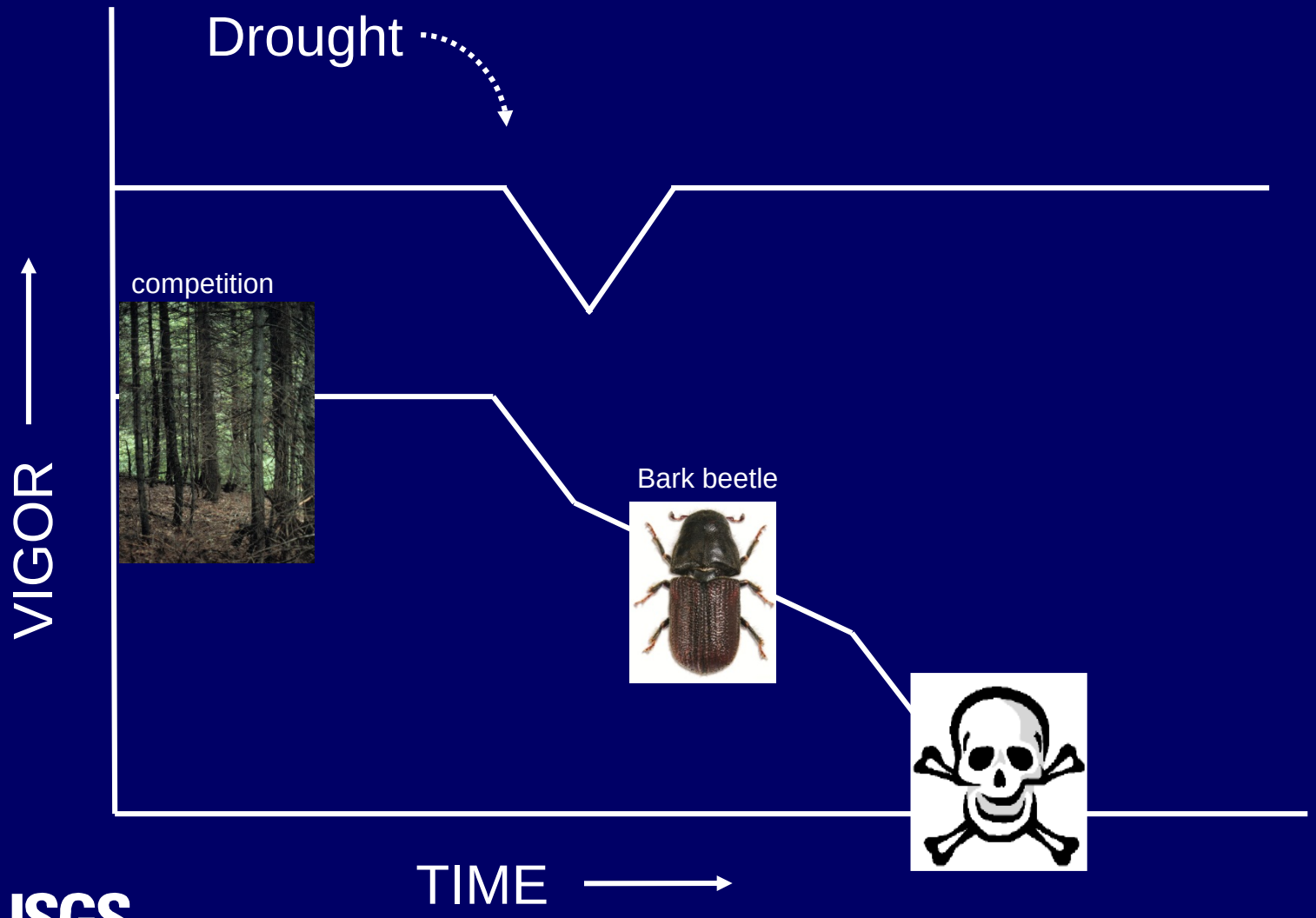

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Pederson 1998, *Ecol. Appl.*

Adaptation strategies

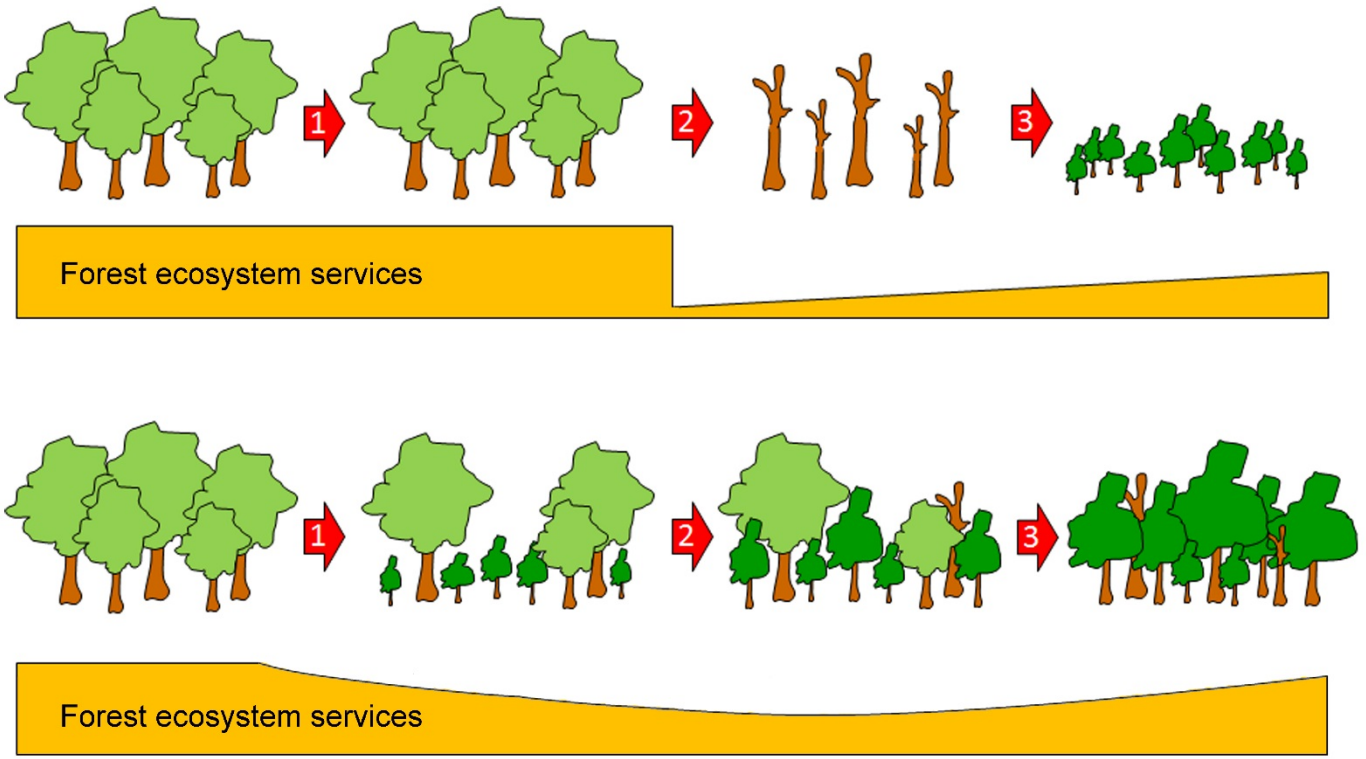
Resistance: ability to remain essentially unchanged following disturbance

Resilience: ability to recover quickly from disturbance

USGS

Credit: N. Stephenson

Adaptation:
Can forest management increase resistance/resilience to drought?



Millar and Stephenson, 2015 *Science*

USGS

Credit: N. Stephenson

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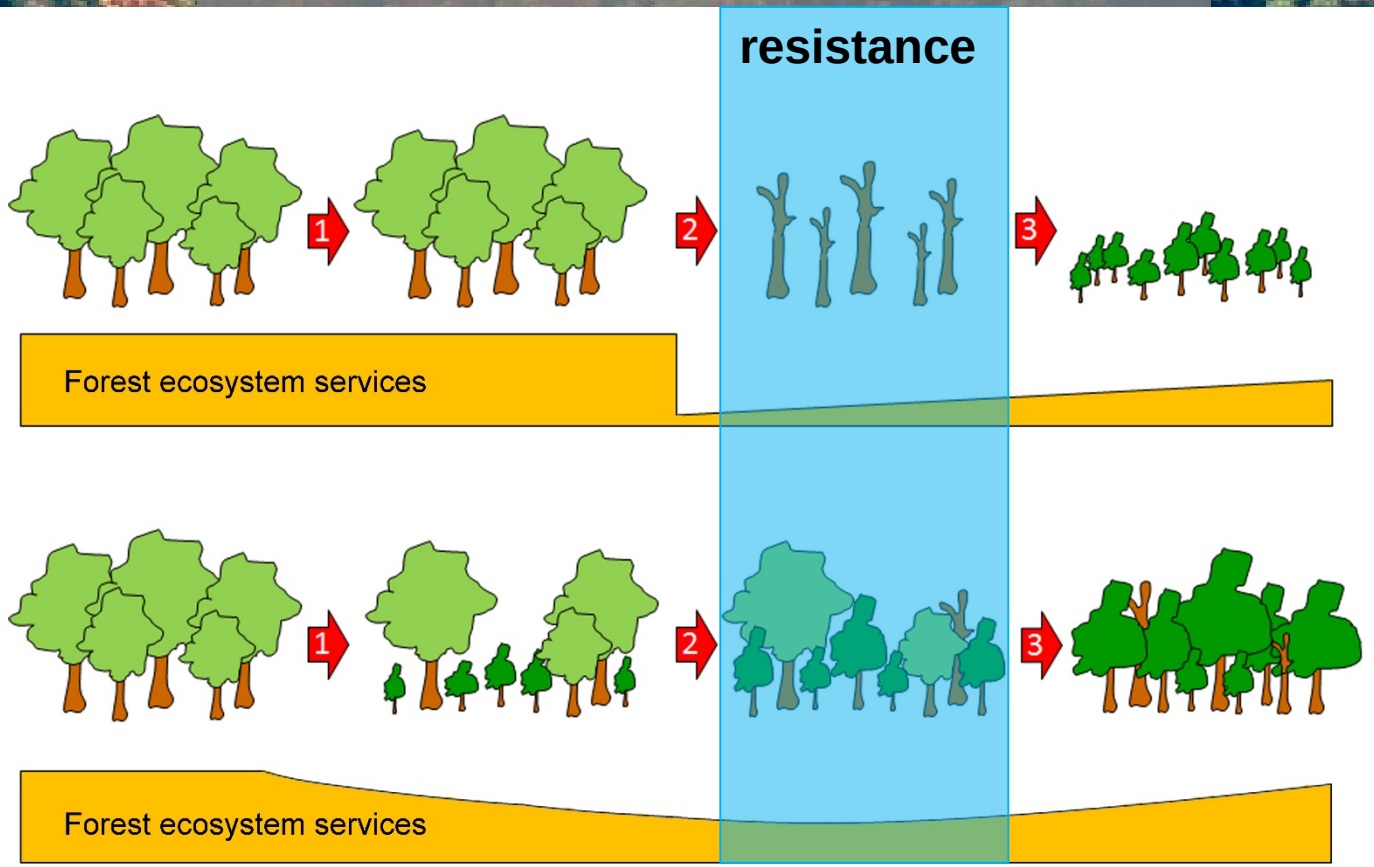

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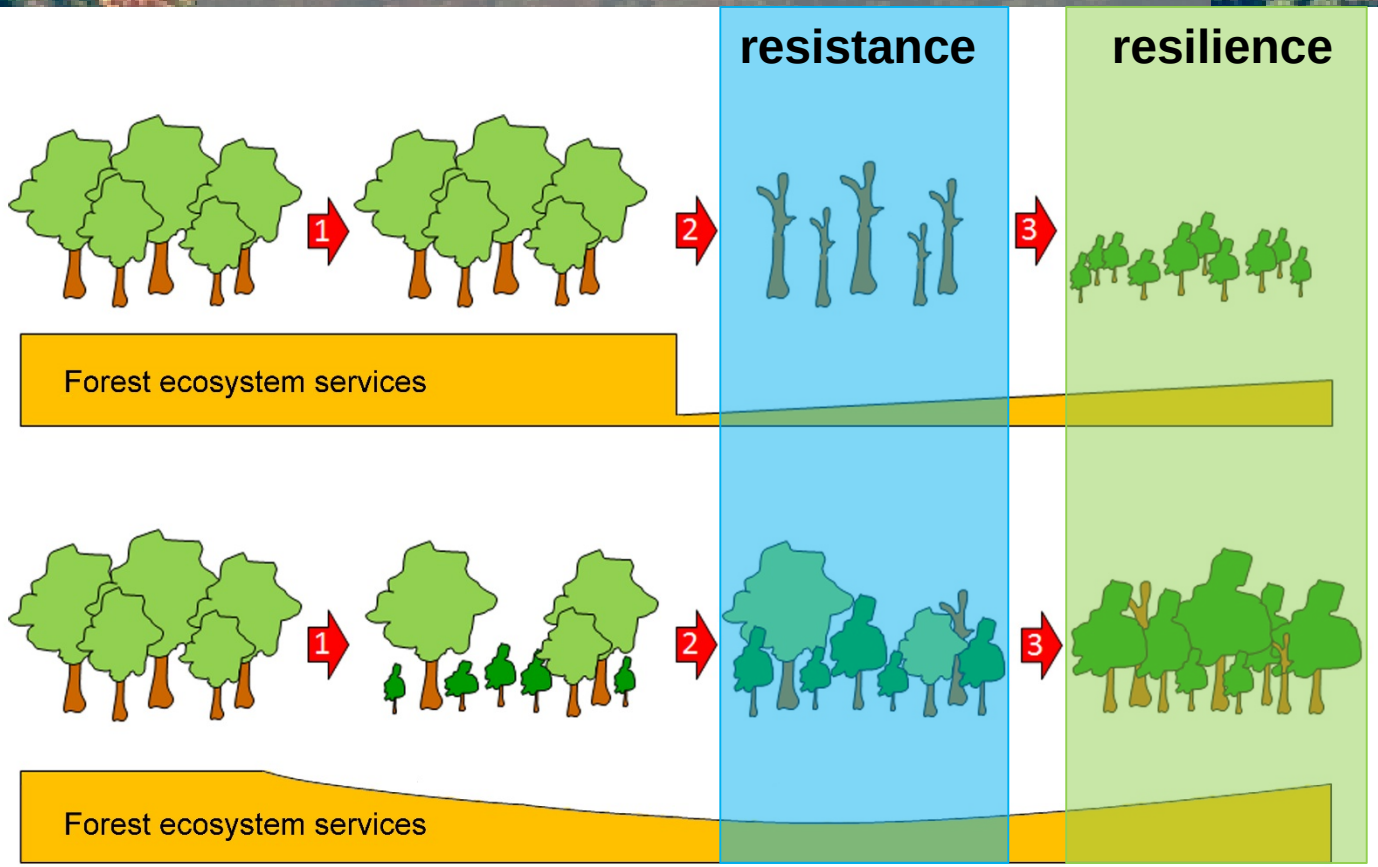

Millar and Stephenson, 2015 *Science*

USGS

Credit: N. Stephenson

Can prescribed fire increase forest **resistance** to drought?

Mechanical thinning at Lassen Volcanic NP

USGS

Credit: N. Stephenson

Second growth forest thinning at Redwood National Park

USGS

Credit: J. Teraoka, NPS

Can prescribed fire increase forest resistance to drought?

Late season prescribed fire effects at Sequoia NP

Pre-fire

1 year post-fire

USGS

Credit: N. Stephenson

Can forest thinning be used as a climate change adaptation tool?

- Drought and changing patterns of tree mortality
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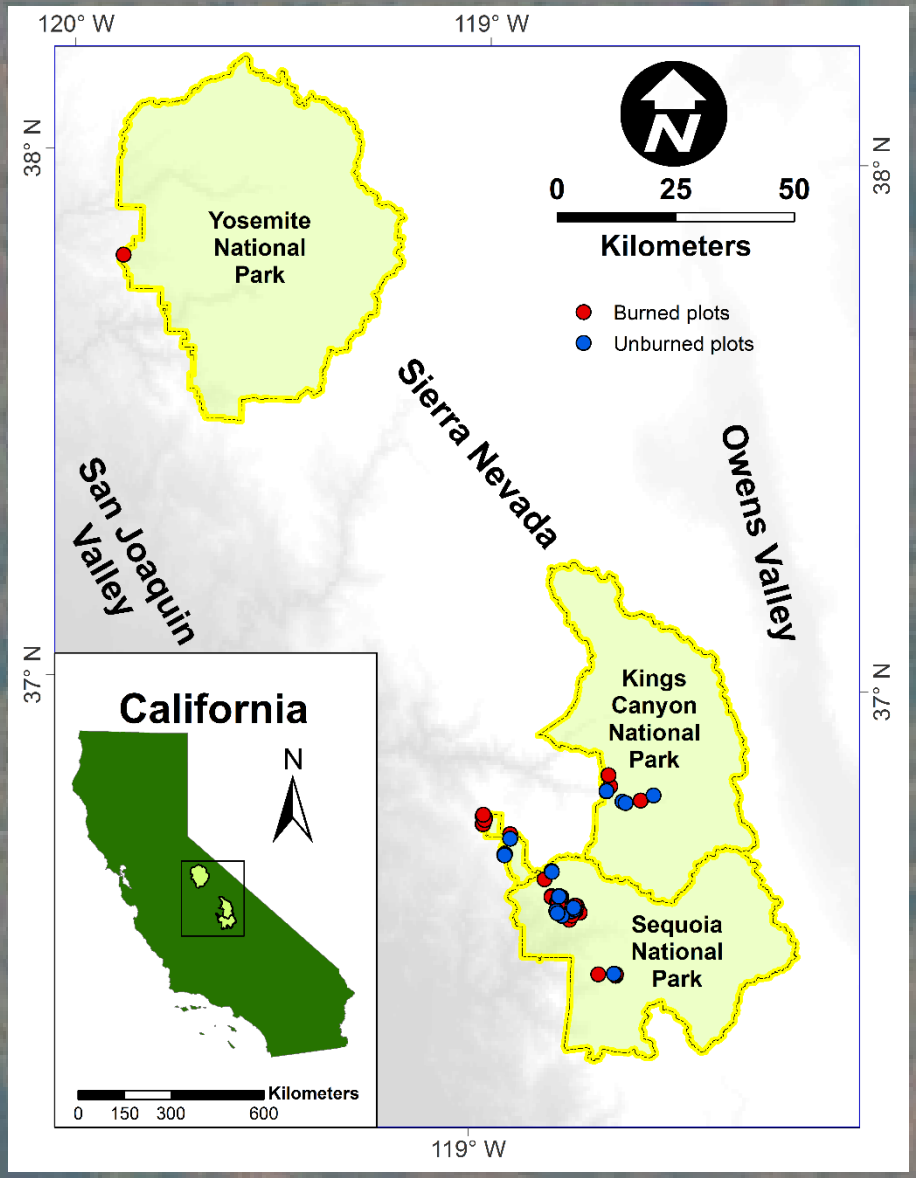
USGS

Credit: N. Stephenson

Can prescribed fire increase forest resistance to drought?

- Long-term forest plot data
- Surveys in 2014

- Ponderosa pine – mixed conifer forests (mostly *A. concolor*)
- 38 burned plots, 18 unburned plots
- ≥ 6 years post-fire
- ~10,000 trees

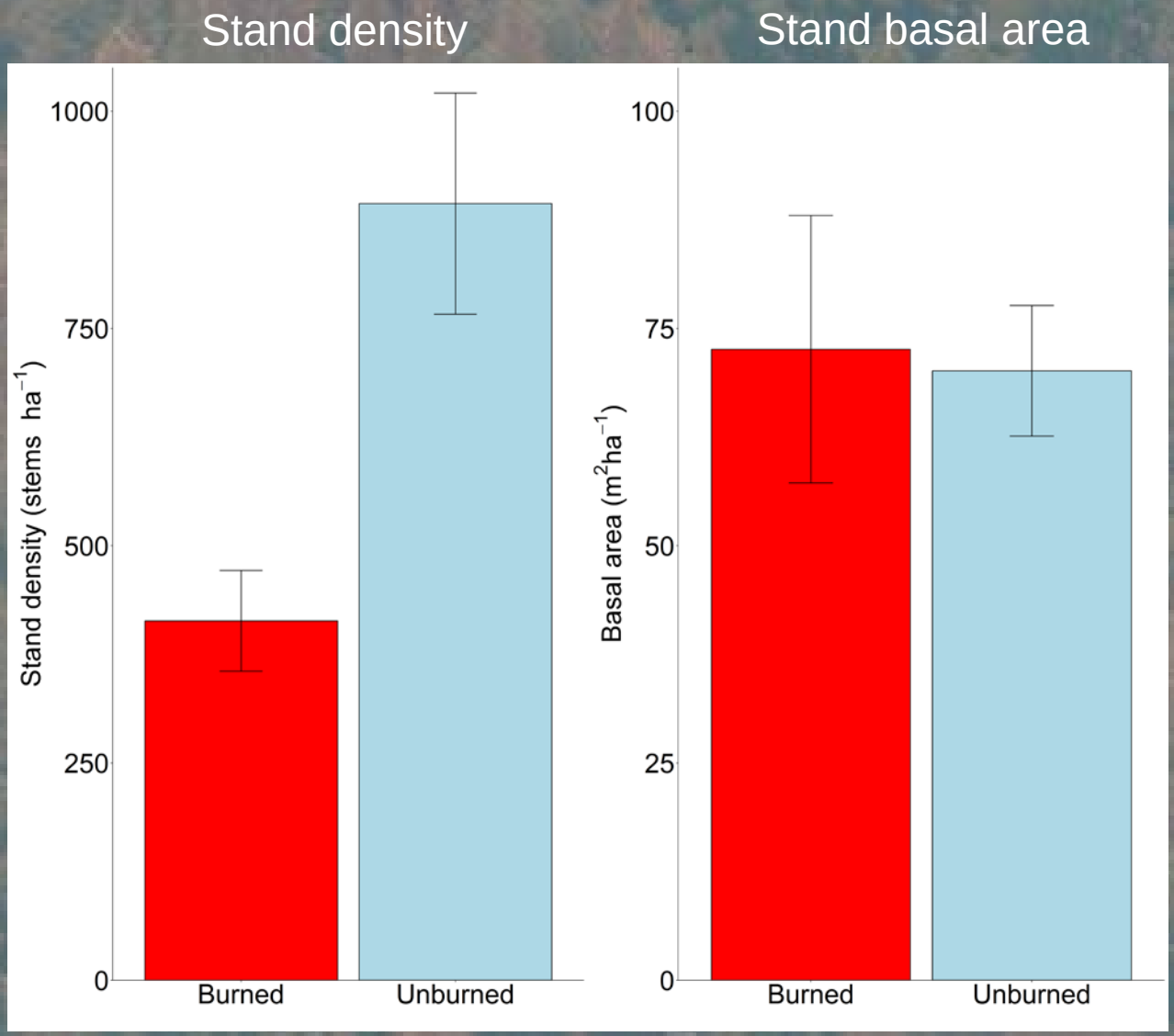


van Mantgem *et al.* in press *Fire Ecology*

USGS

Credit: N. Stephenson

Can prescribed fire increase forest resistance to drought?



van Mantgem *et al.* in press *Fire Ecology*

USGS

Credit: N. Stephenson

Can prescribed fire increase forest resistance to drought?

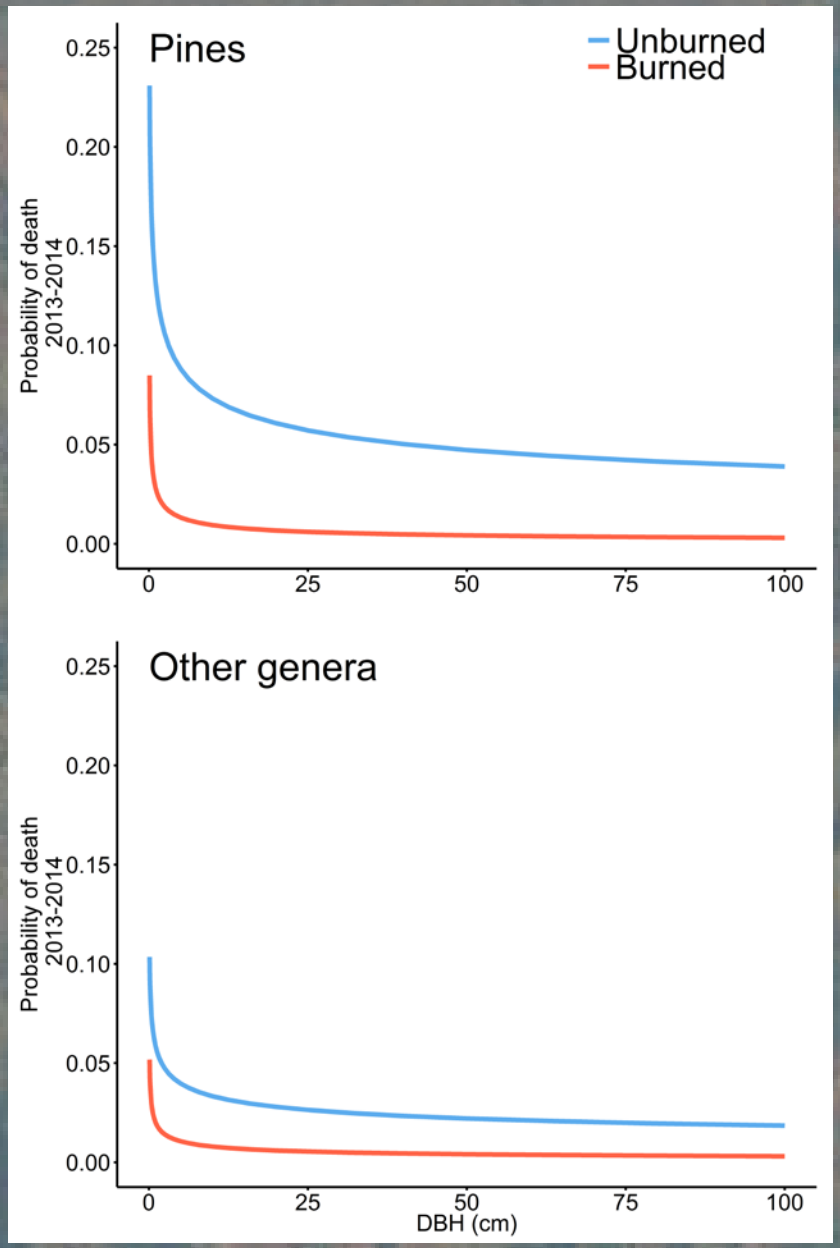
Findings

Probability of death lower in burned stands in 2013, 2014 (after accounting for tree size and taxonomic group).

What is the impact of continued drought in 2015?

Can we explicitly identify the mechanisms of tree mortality??
i.e., roles of competition, pathogens, insects?

Other species, other regions???



van Mantgem *et al.* in press *Fire Ecology*

Credit: N. Stephenson

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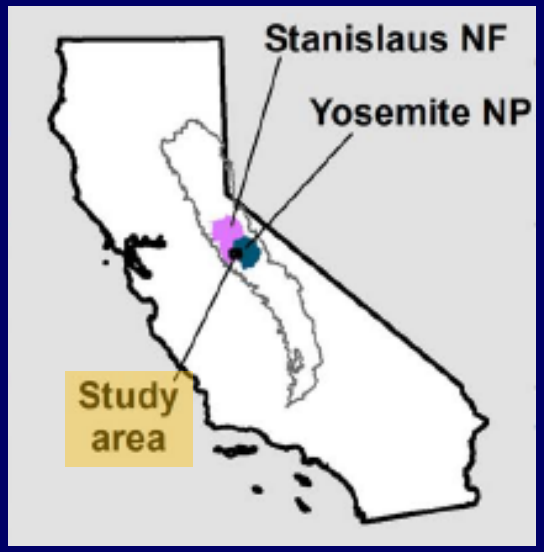
Can prescribed fire increase forest resistance to drought?

ponderosa pine stand structure, central Sierra Nevada
Trees ≥15.2 cm DBH



1911 USFS inventories
Density: 72.7 trees ha^{-1}
Basal area: 21.5 m^2 ha^{-1}
(Collins *et al.* 2015 *Ecol. Appl.)*

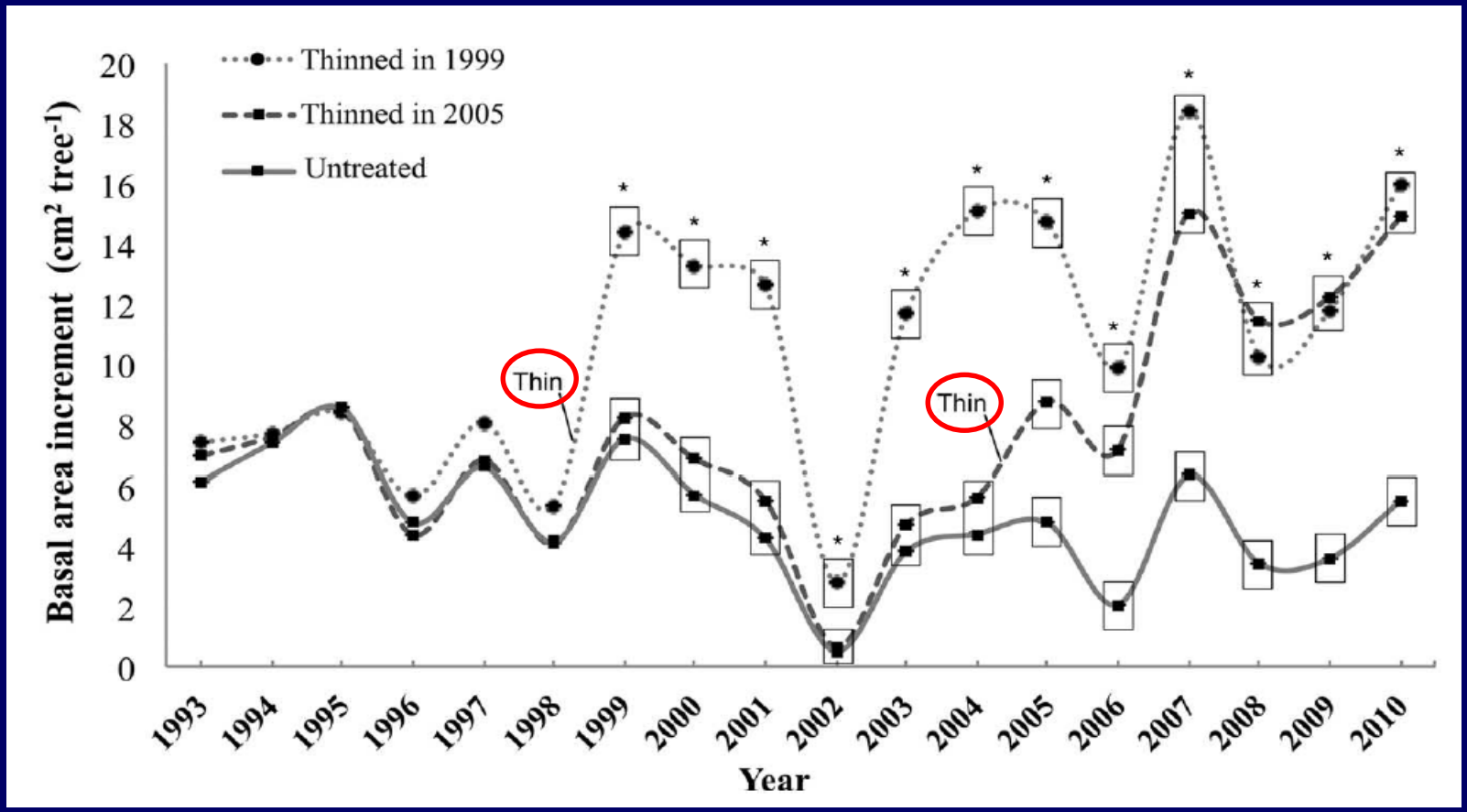
2013 Post-fire Yosemite, Kings Canyon and Sequoia NP
Density: 159 trees ha^{-1}
Basal area: 74.0 m^2 ha^{-1}
(van Mantgem *et al.* in press *Fire Ecology)*

USGS


Adaptation strategies
Resistance: ability to remain essentially unchanged following disturbance
Resilience: ability to recover quickly from disturbance
USGS
Credit: N. Stephenson

Resilience?

- 30 *P. ponderosa* stands in northern NM
- History of high grading logging and grazing
- Thinned and Rx fire in 1999 (n=11) or in 2004 (n=7)
  Treatments lowered stand density and BA



Thomas and Waring 2014, *For. Sci.*

USGS

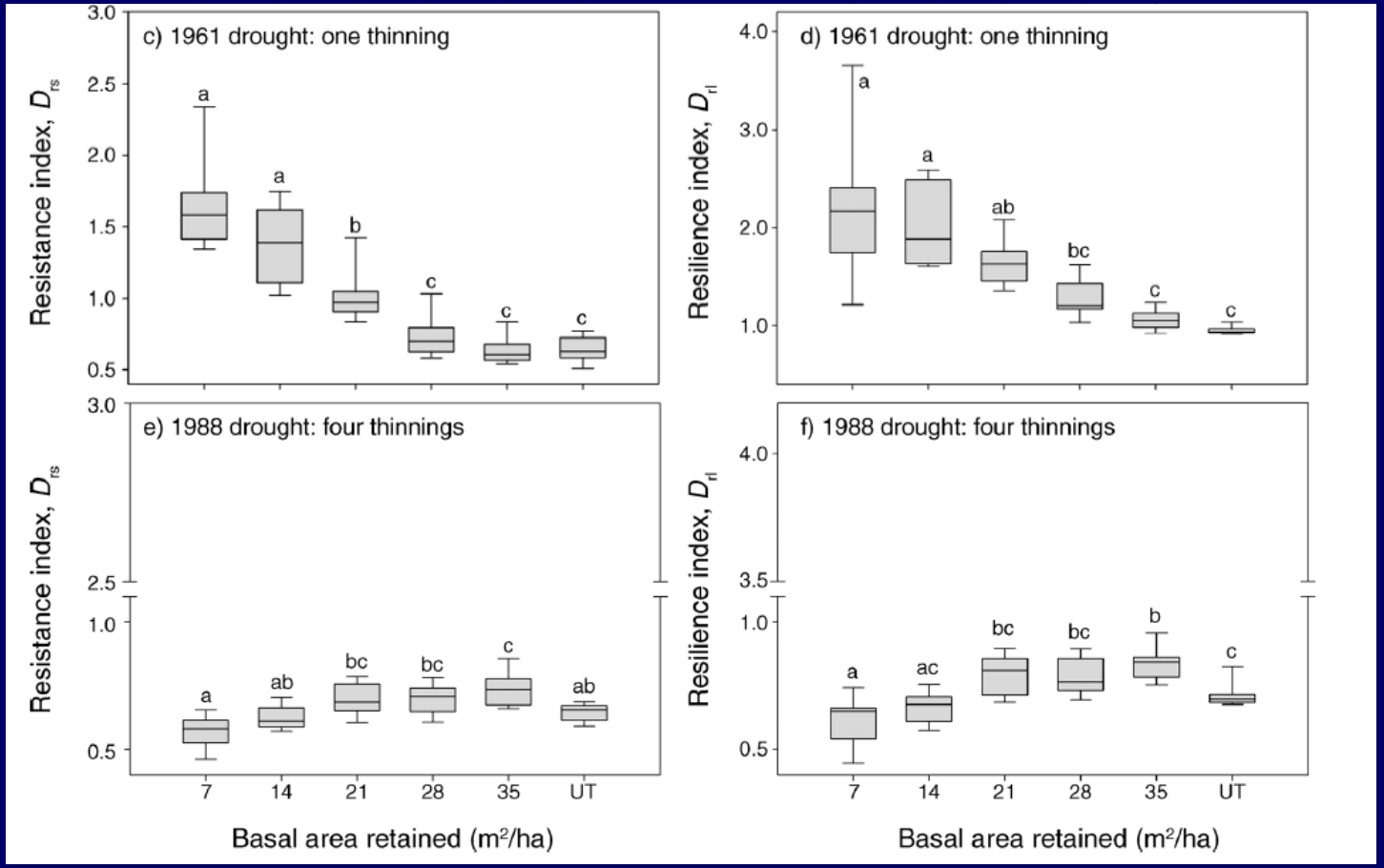
Resilience?

D'Amato et al. 2013 *Ecol. Appl.*

- Long-term thinning experiment on *P. resinosa* (red pine) in MN
- Varied levels of BA retention (7 to 35 m^2 ha^{-1})

1961 Drought
+ thinning effects

1988 Drought
- thinning effects



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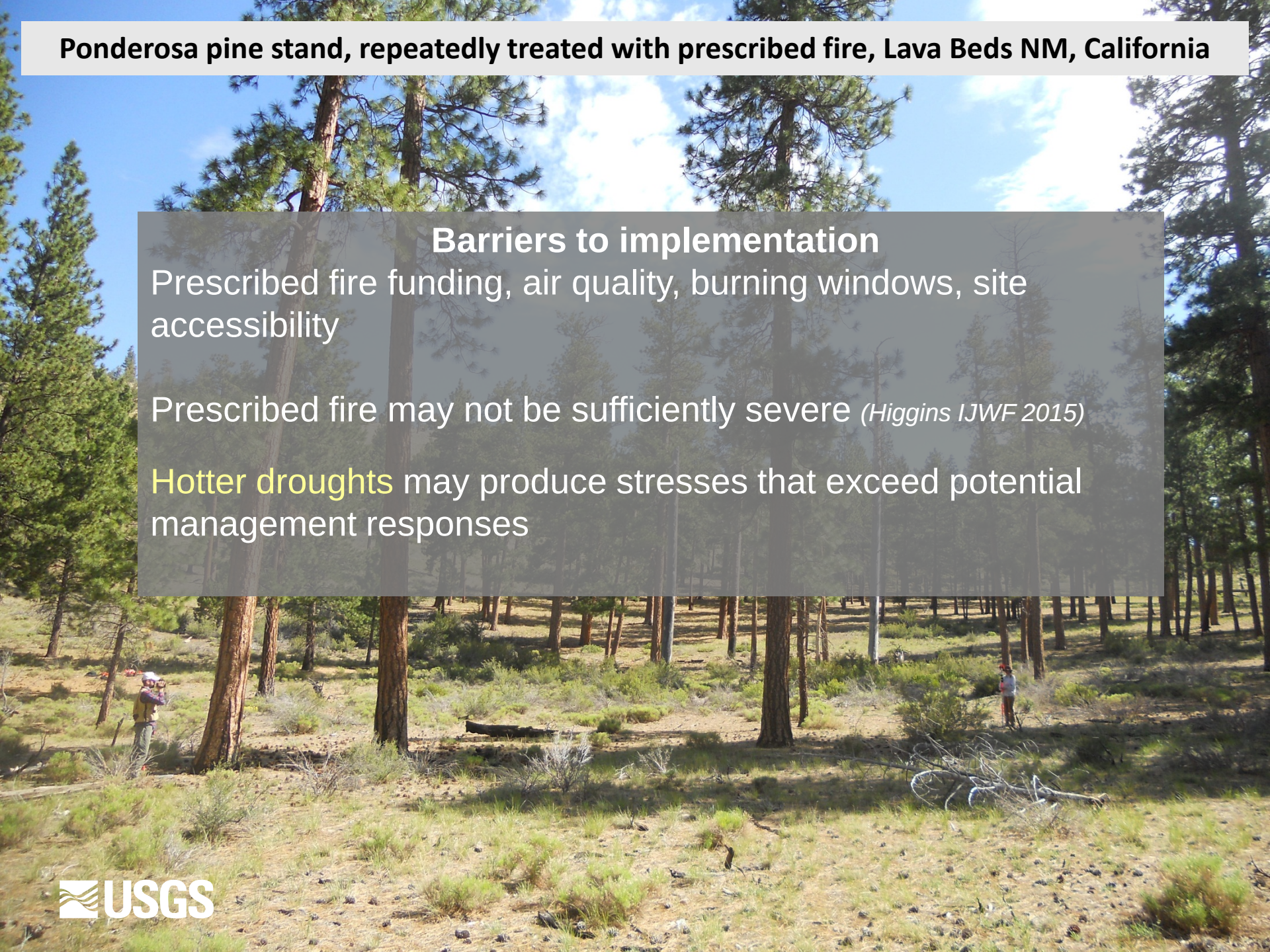

Ponderosa pine stand, repeatedly treated with prescribed fire, Lava Beds NM, California

Barriers to implementation

Prescribed fire funding, air quality, burning windows, site accessibility

Prescribed fire may not be sufficiently severe *(Higgins IJWF 2015)*

Hotter droughts may produce stresses that exceed potential management responses

USGS


USGS

The take home!

- The 2012-2015 drought may be a “sneak peak” of future conditions.
- Thinning treatments (mechanical, prescribed fire, or both) have the potential to increase forest resistance and resilience to drought.
- Thinning treatments may represent “no regrets” management options, though barriers exist to implementation.

USGS

Thanks!

Countless field crews and data managers…

National Park Service, USGS,
Southwest Climate Science Center

www.werc.usgs.gov/DroughtForestFire

USGS

Can forest thinning be used as a climate change adaptation tool?

- Drought and changing patterns of tree mortality
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Summarize current study plan – are we measuring the right things at the right places?

Discuss how best to make this work useful to you – translational ecology?

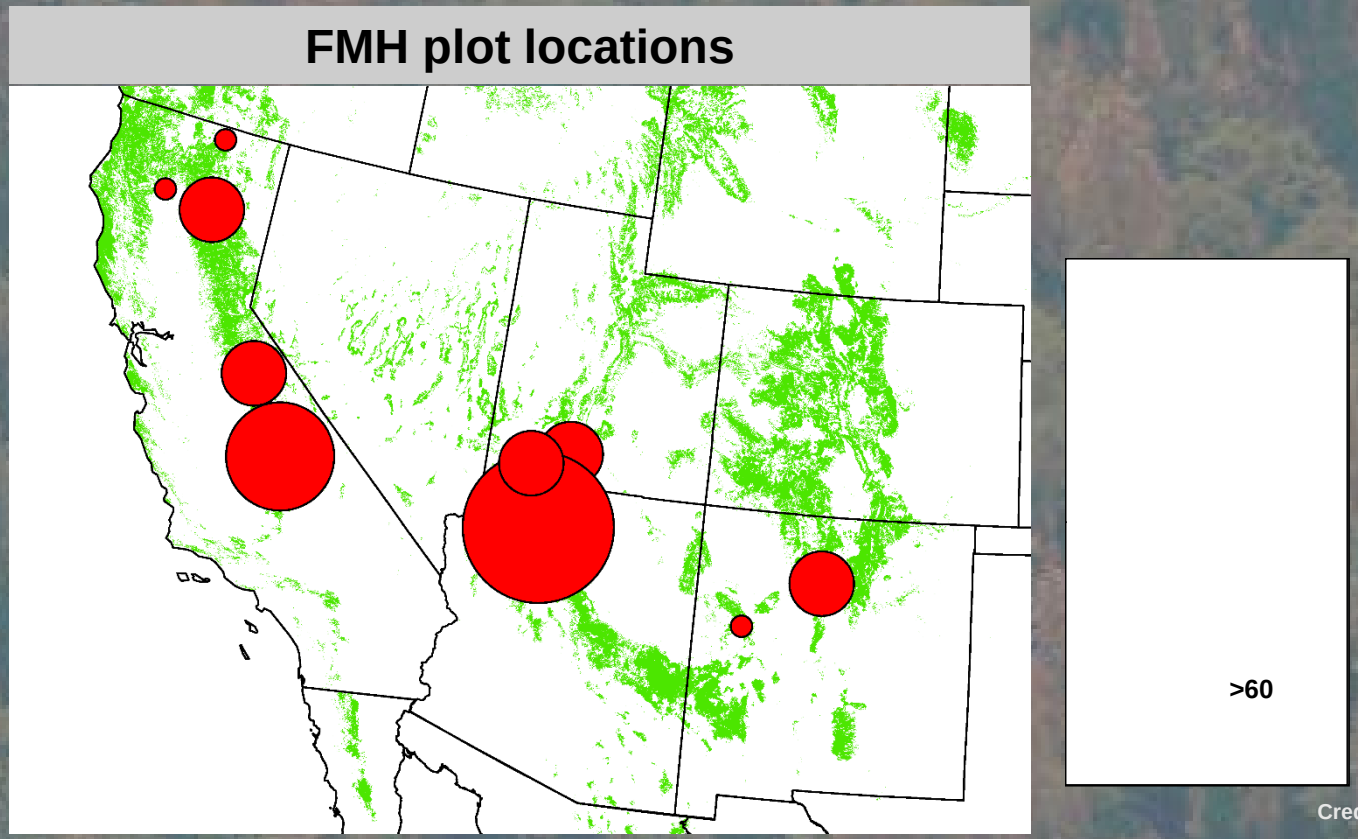
USGS

Credit: N. Stephenson

Can prescribed fire increase forest resistance to drought?

www.werc.usgs.gov/DroughtForestFire

1) Survey tree mortality in burned and unburned areas.
2) Construct mortality models in burned and unburned stands (using tree rings).



USGS

Credit: N. Stephenson

Can prescribed fire increase forest resistance to drought?

www.werc.usgs.gov/DroughtForestFire

Potential study sites

California

- FMH plots
- Fire & Fire Surrogate sites (Goosenest, Blodgett, Sequoia NP)
- USGS Forest Dynamics plot network (YOSE, SEKI only)
- Teakettle Experimental Forest

Colorado Plateau

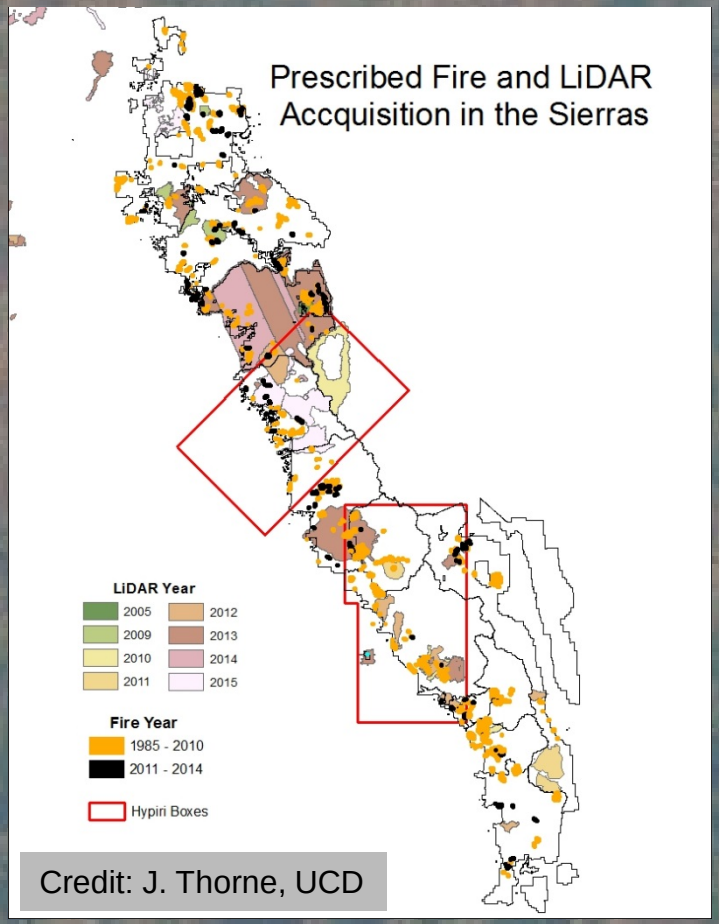
- FMH plots
- Fire & Fire Surrogate sites (Jemez Mountains, N. Arizona)

USGS

Credit: N. Stephenson

Can prescribed fire increase forest resistance to drought?
Next steps…

Remotely sensed indices of drought response (e.g., aerial mapping of forest dieback, NDVI, hyperspectral data) modified by management history (thinning, prescribed burning)?



Credit: J. Thorne, UCD

USGS

Credit: N. Stephenson