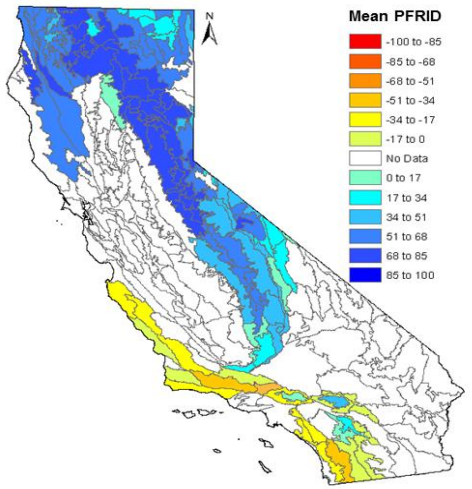
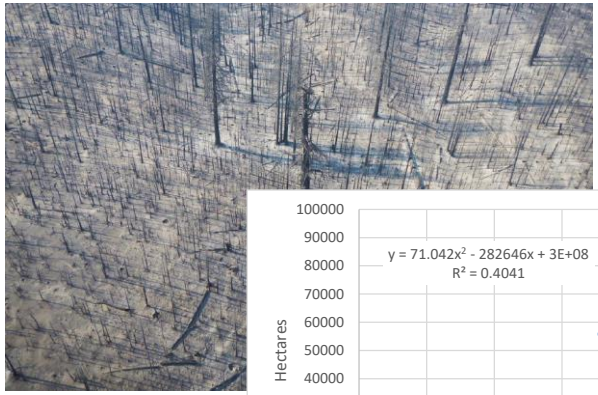
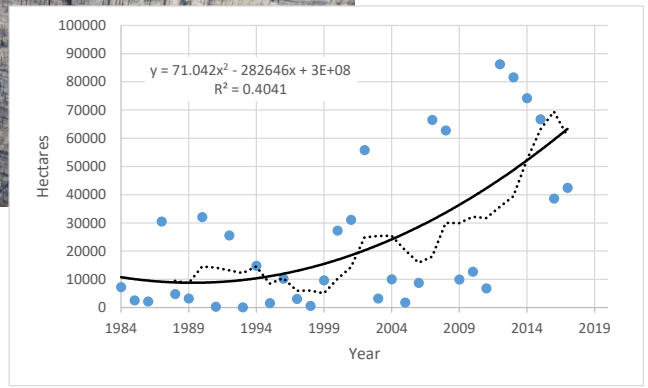
Fire and vegetation trends in California: Putting the big picture in context







Hugh Safford

USDA Forest Service, Pacific Southwest Region

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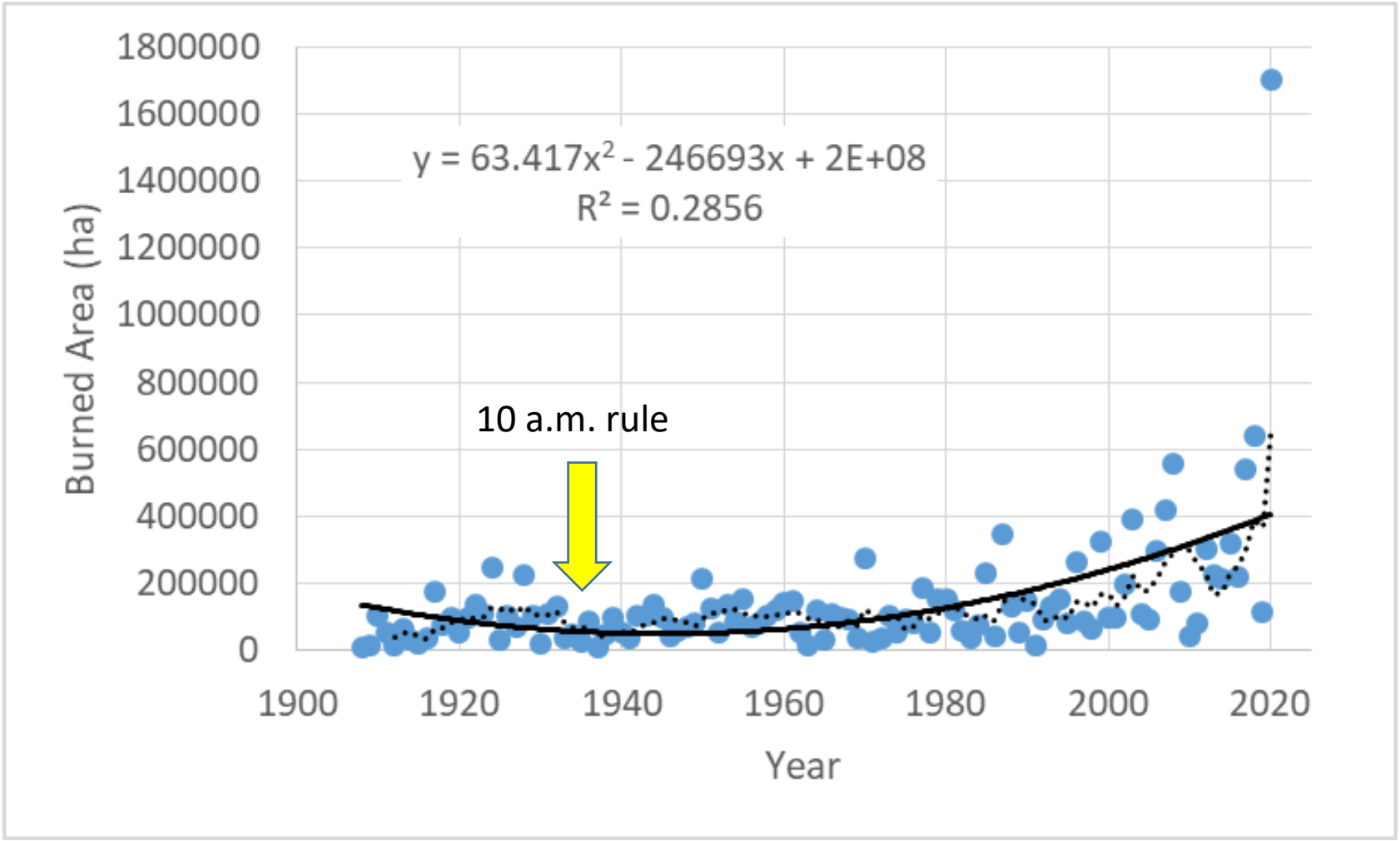
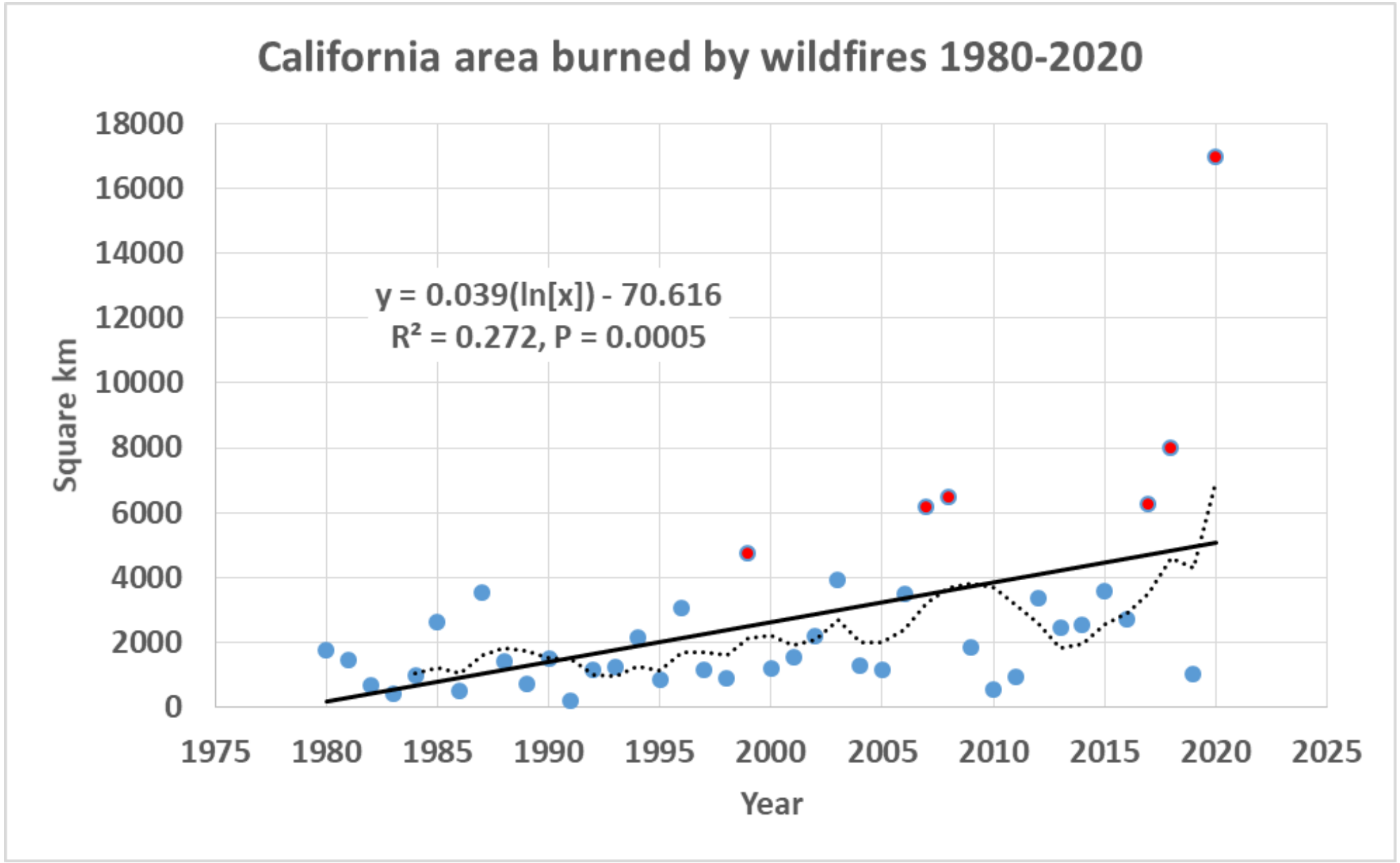
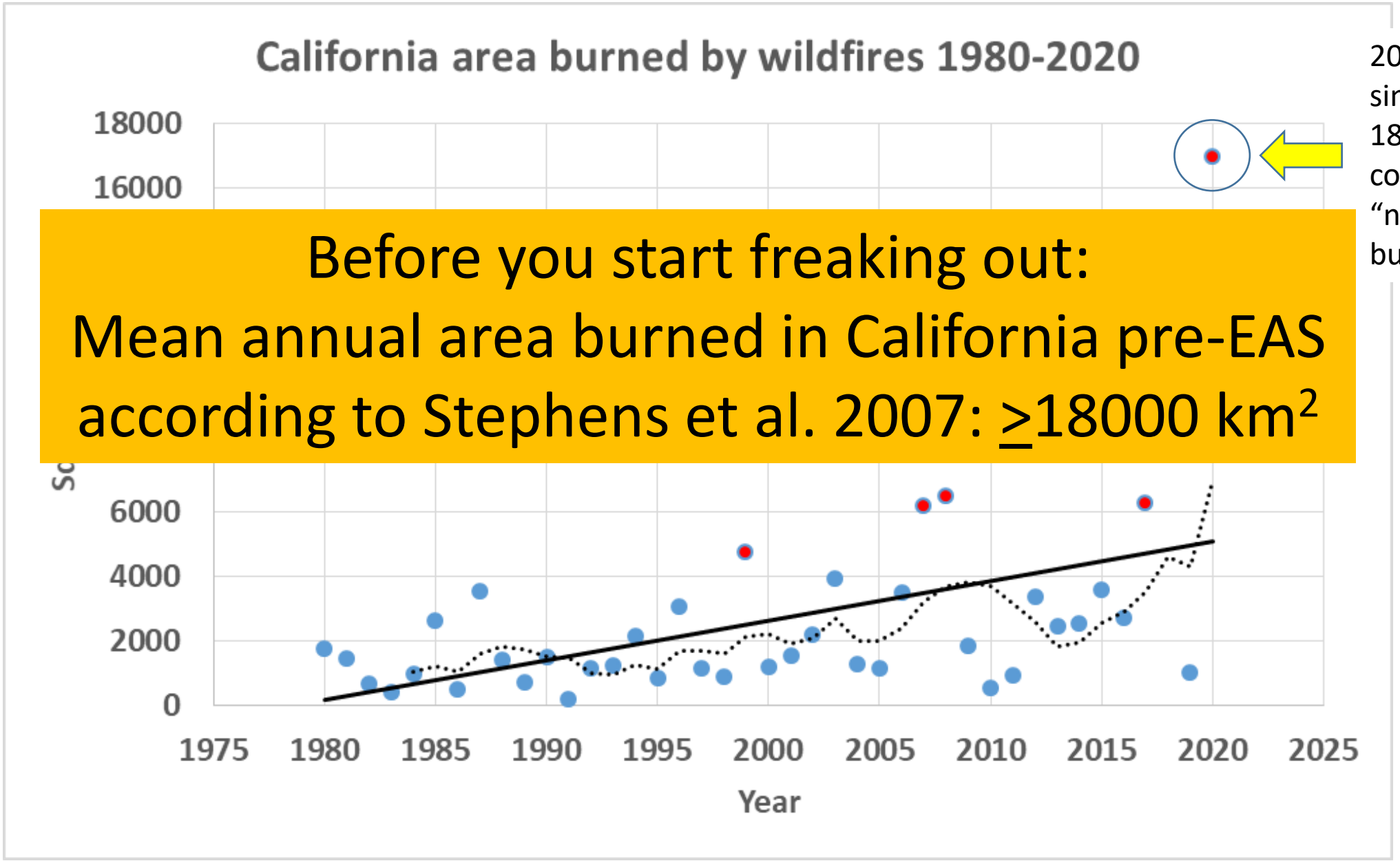
UC-Davis website: https://safford.faculty.ucdavis.edu/

California fire trends 1908-2020: Annual burned area rising rapidly since 1980s



From Cal Fire Perimeter Database: includes fires >40 ha (state & pvt lands) and >4 ha (Federal lands). This sums to c. 80-90% of overall annual burned area


California area burned by wildfires 1980-2020
y = 0.039(ln[x]) - 70.616
R² = 0.272, P = 0.0005
Square km
Year
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025

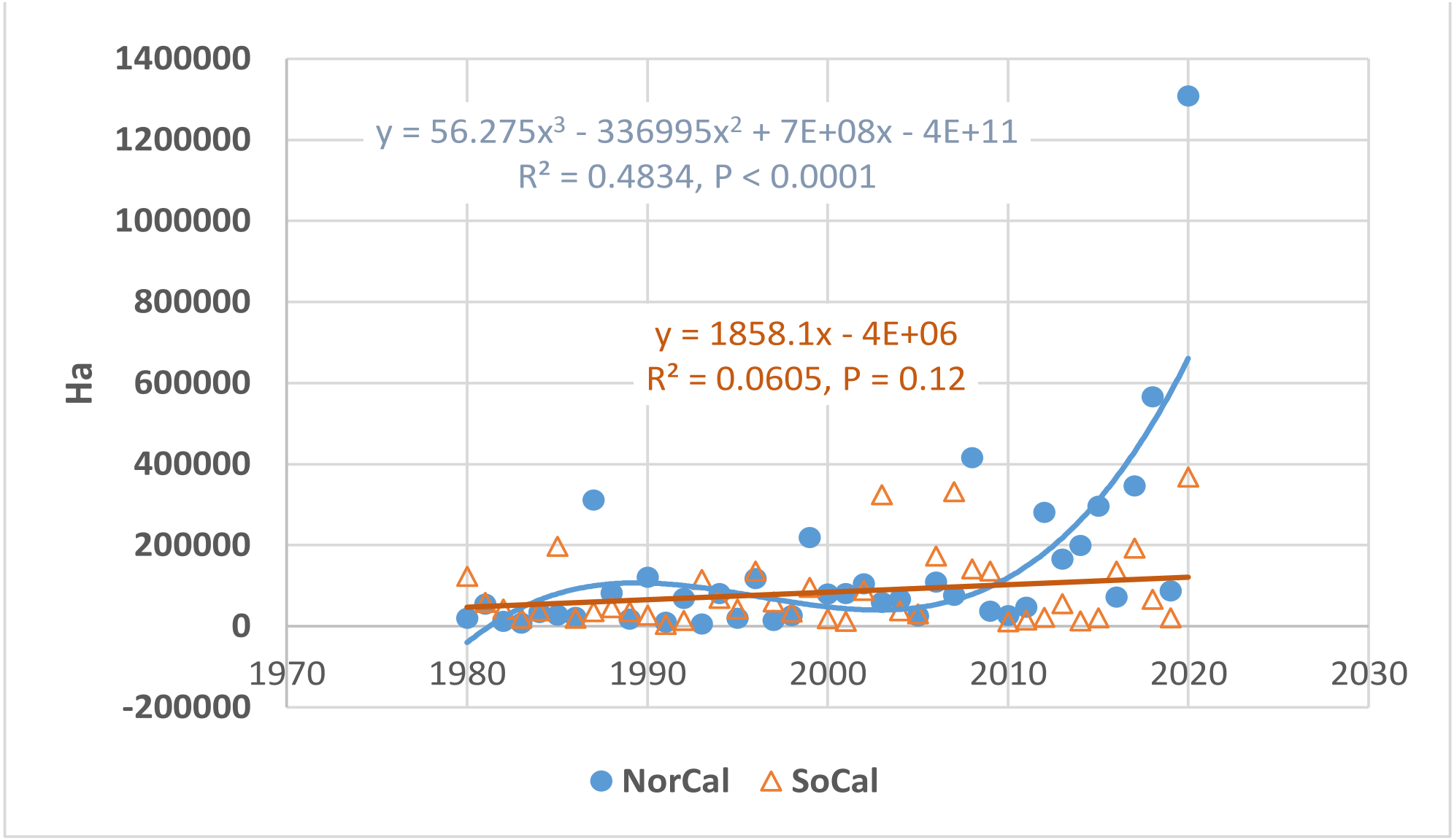


Before you start freaking out:
Mean annual area burned in California pre-EAS according to Stephens et al. 2007: ≥18000 km^2

2020: 1st year since late 1800s to come close to "normal" burning

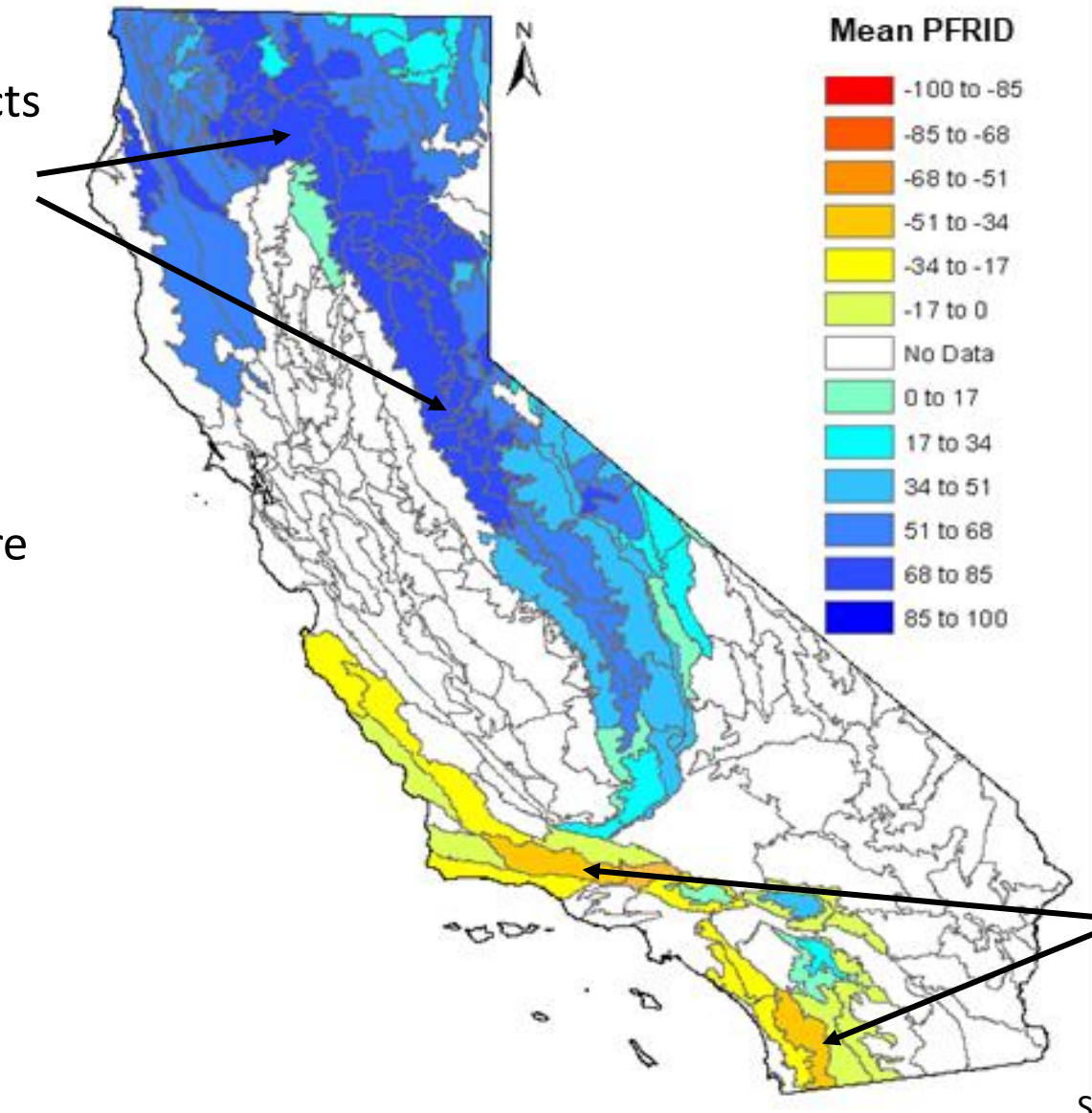
These values include all fires, data from Cal Fire

Burned area increases in California are nearly entirely in the north



Humans have greatly changed fire frequencies in California: reversed patterns in NorCal and SoCal

Fire suppression effects in formerly frequent-fire forests (F4)



Fire Return Interval Departure (FRID)

- Mean PFRID = mean % fire return interval departure
- Cool colors = missed fire cycles
- Warm colors = excessive fire

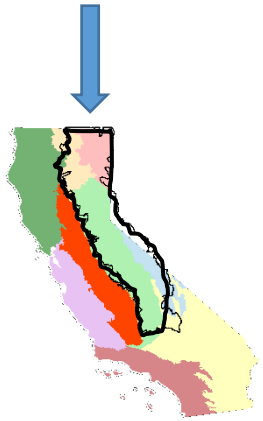
F4 ecosystems
- Oak woodland
- Yellow pine
- Mixed conifer
- Drier mixed evergreen

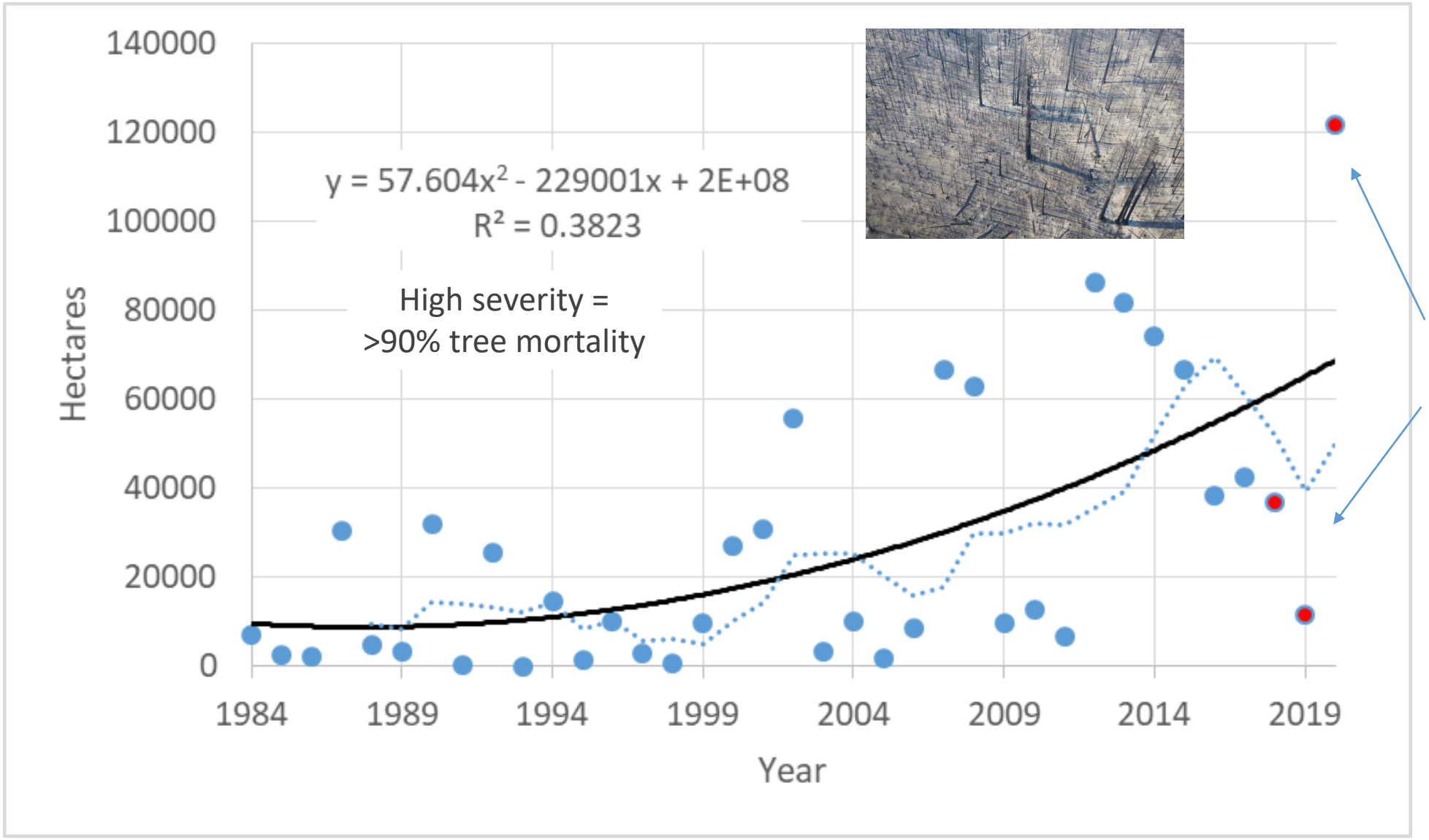
Ecosystems experiencing excessive fire
- Chaparral
- Sage scrub
- Desert mixed shrublands
- Sagebrush

Enhanced ignition effects in shrublands

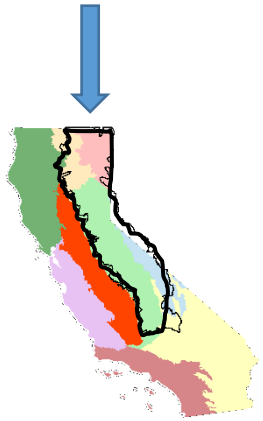
Safford & Van de Water 2014

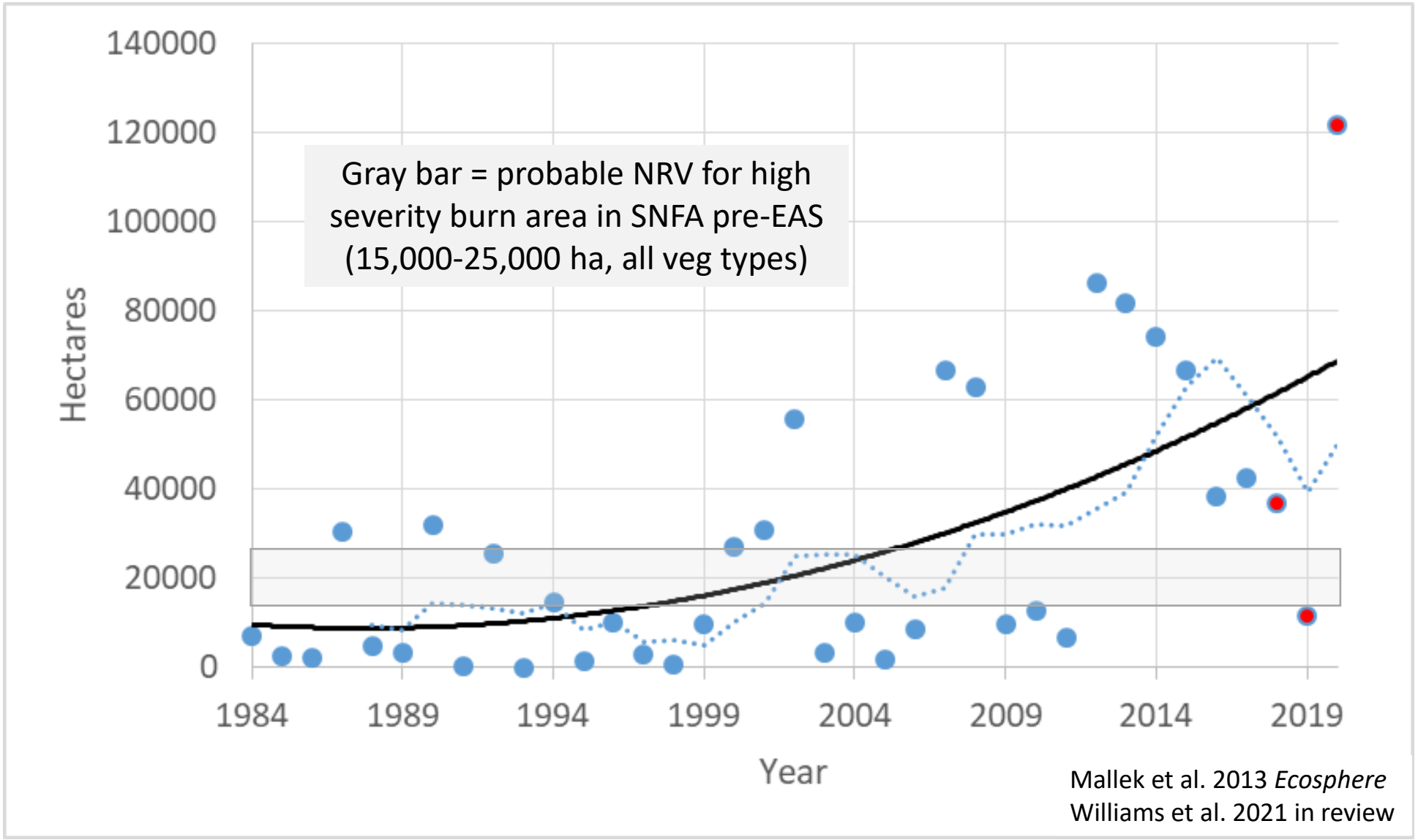
Sierra Nevada Framework Area: high severity burned area is increasing rapidly





Sierra Nevada Framework Area: high severity burned area is much greater than under EAS conditions



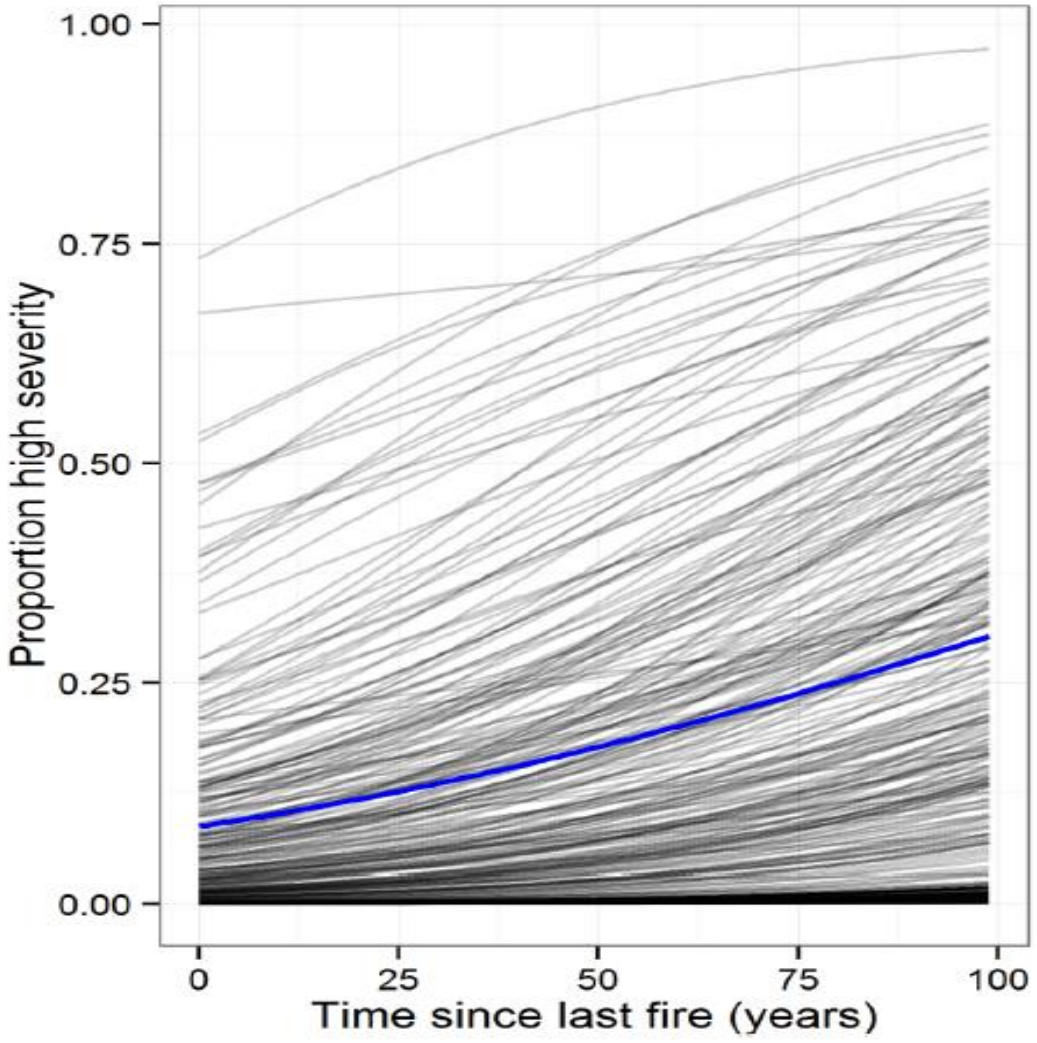


Mallek et al. 2013 *Ecosphere*
Williams et al. 2021 in review

The importance of time since last fire (TSLF): fire severity in YPMC forests

Forests densify and fuel accumulates in the years between fires

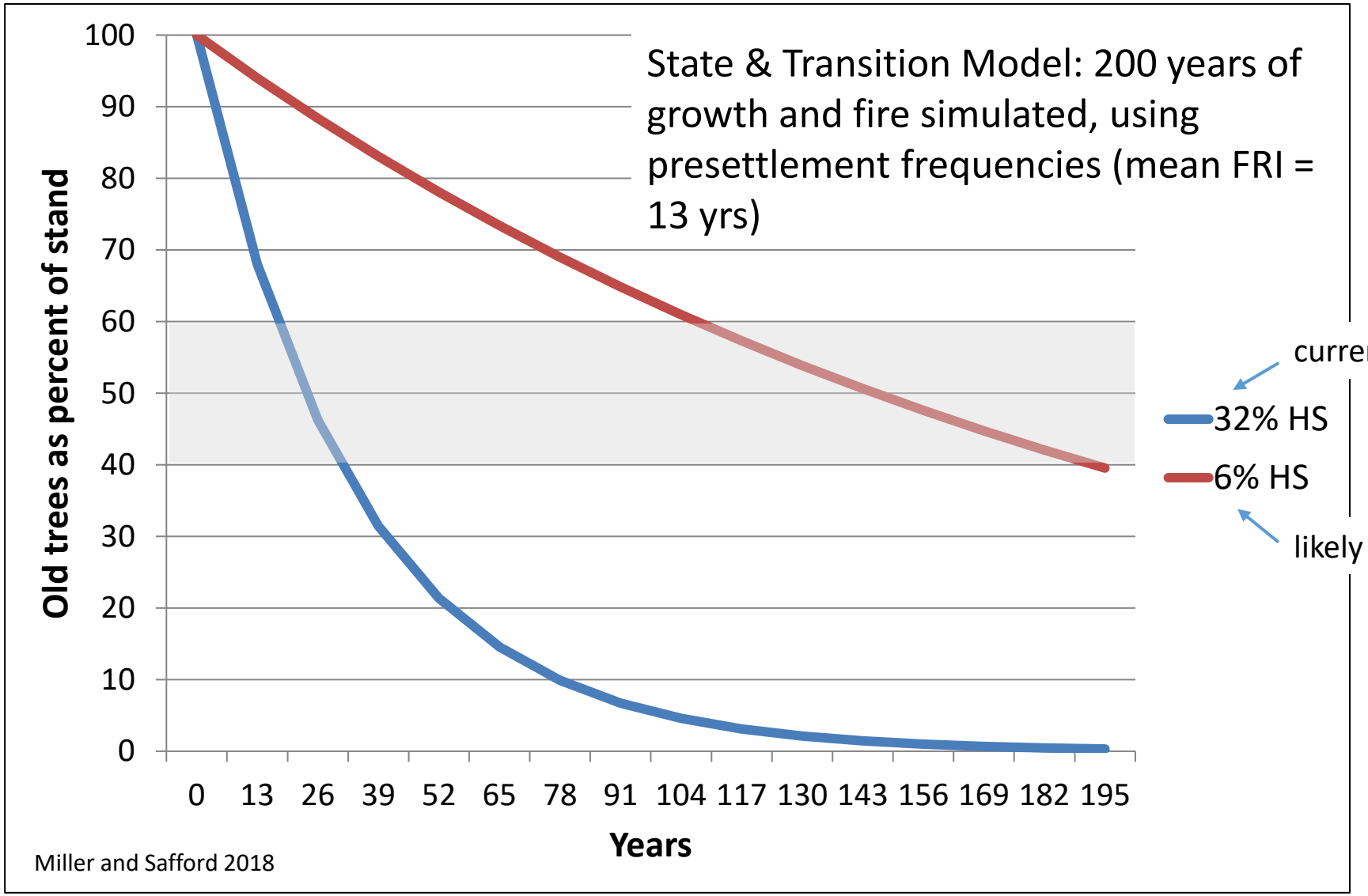
- >200 fires, 1984-2011
- Blue line = mean modeled function



Steel et al. 2015

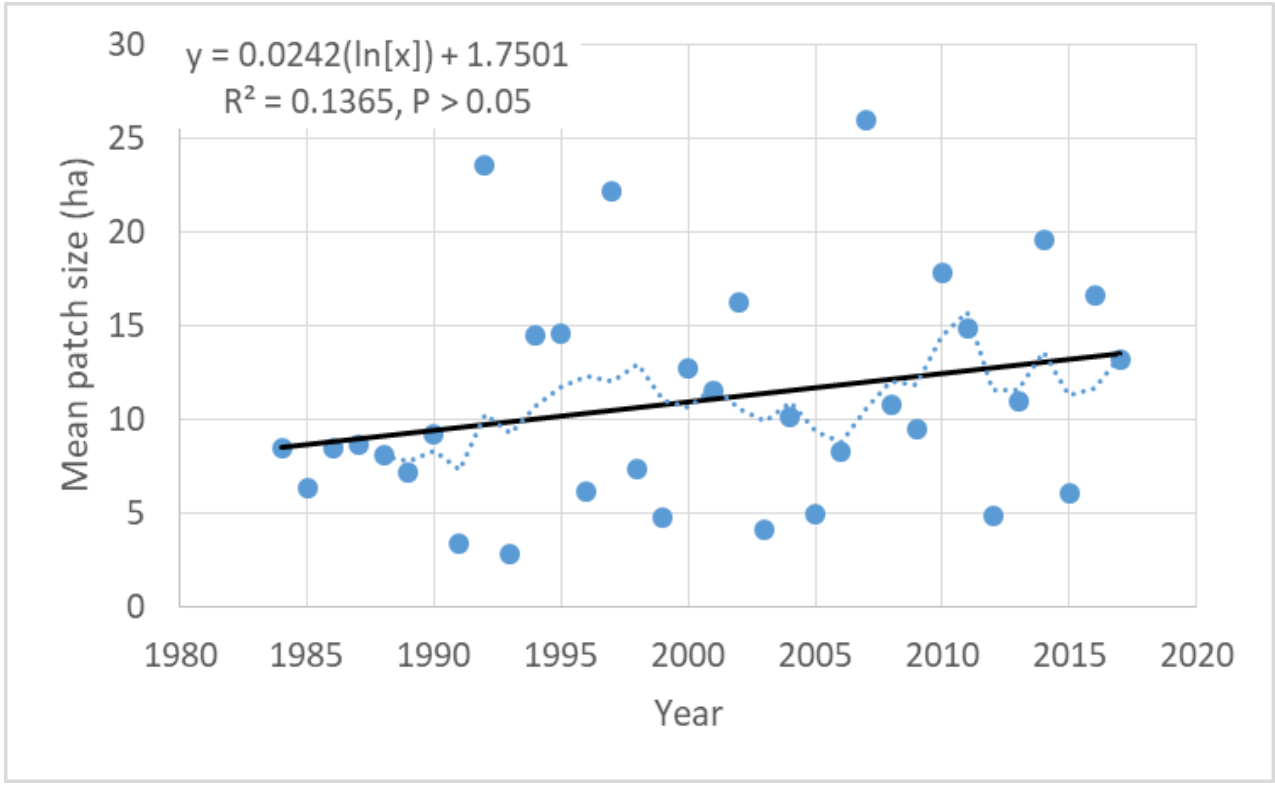
Impacts on old forest: under current fire severities, old-growth forest is an endangered species in the Sierra Nevada

Range of old-growth forest from early assessments

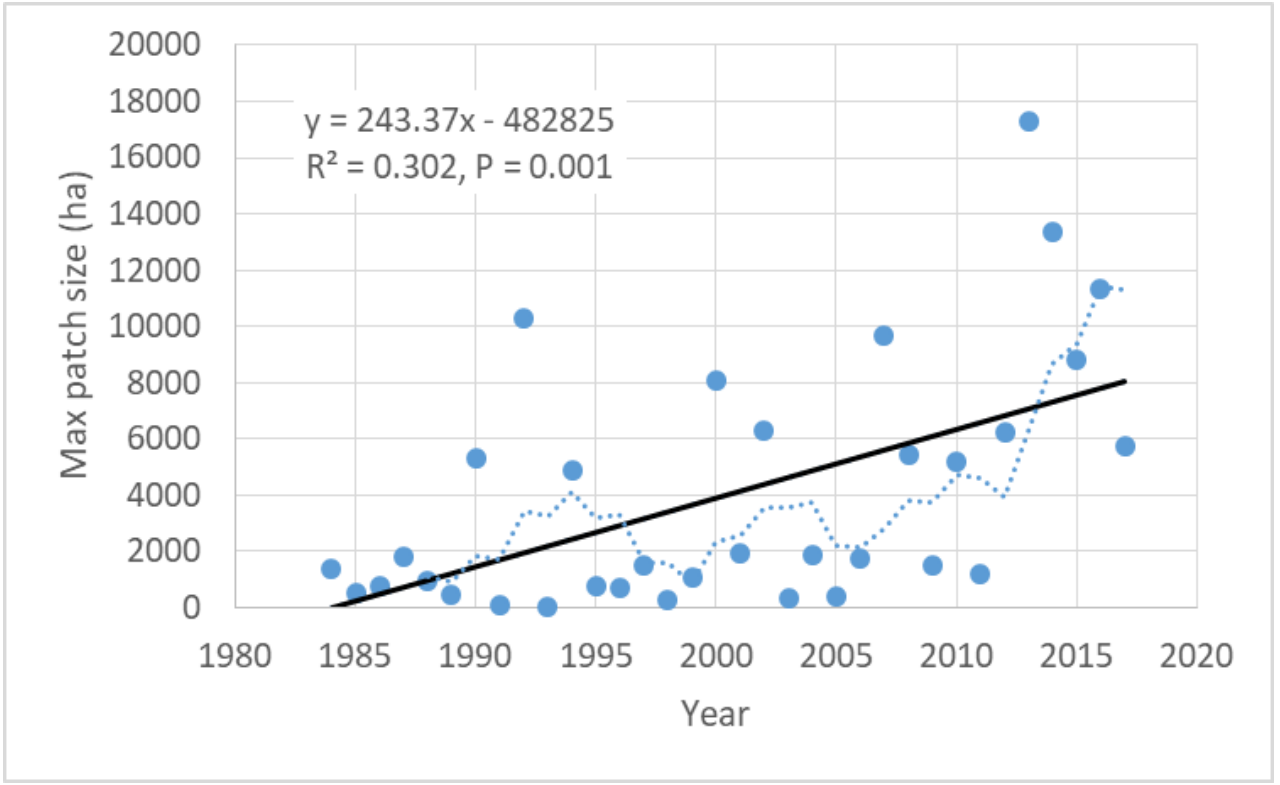


Impacts on young trees:
High severity patch sizes are increasing

Mean HS patch size

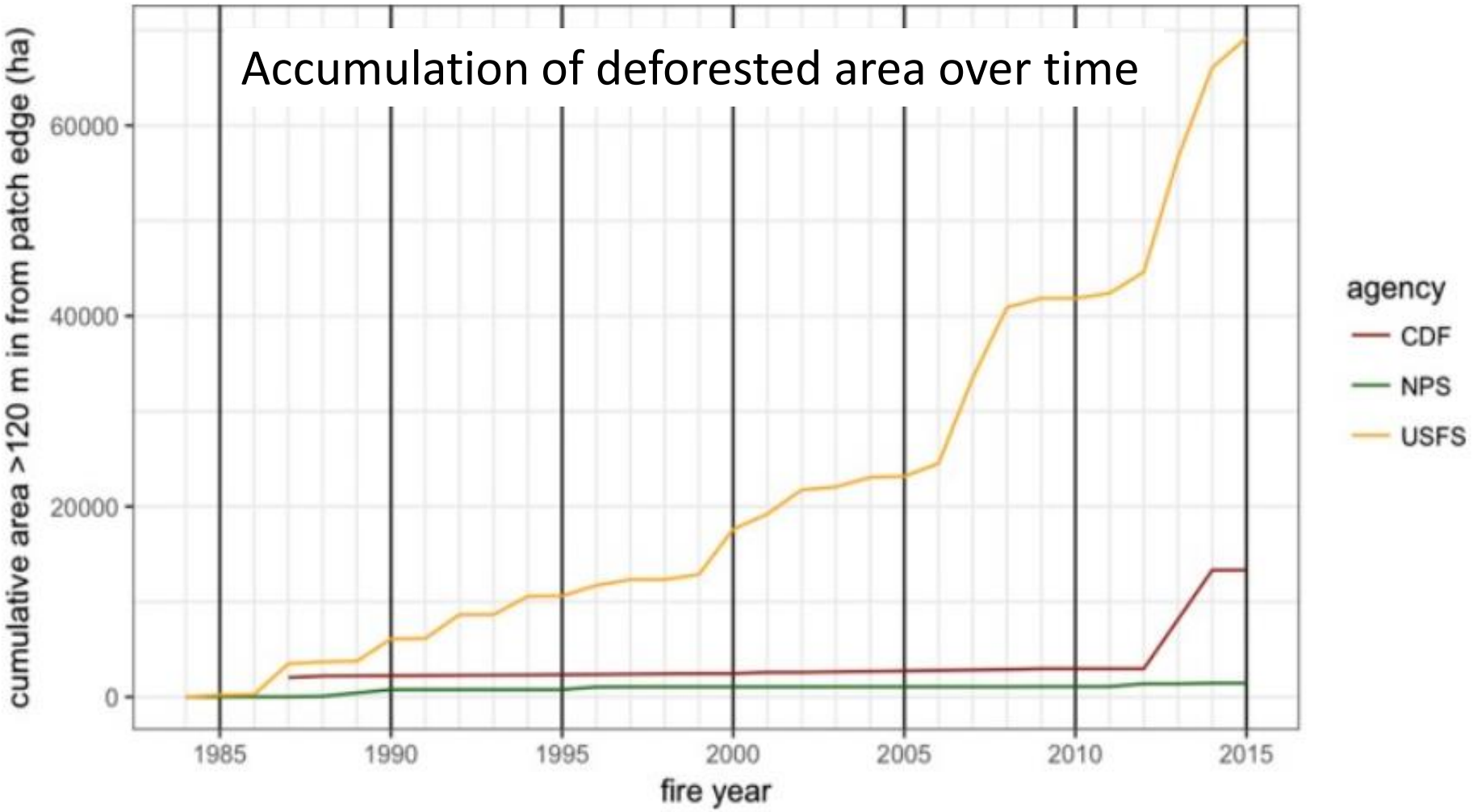


Maximum HS patch size



Trends in high severity patch complexity and distance to edge

120 m = general dispersal threshold for Sierra Nevada conifers



Stevens et al. 2017 *For Ecol Mgt*
Steel et al. 2017 *Landscape Ecol*

The future looks pretty smoky

Annual area burned, 2050-2009 vs 20th century

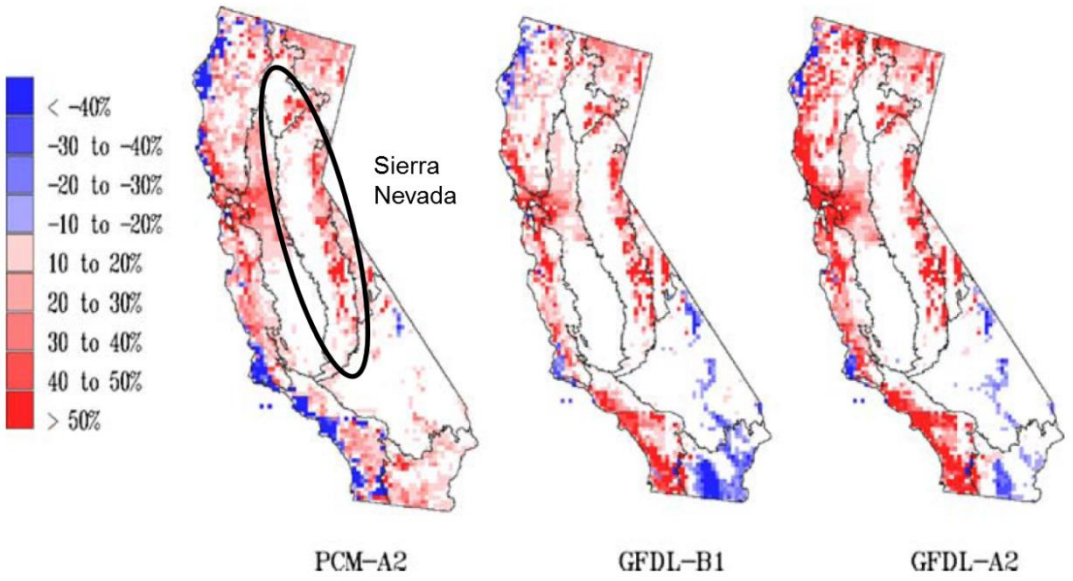
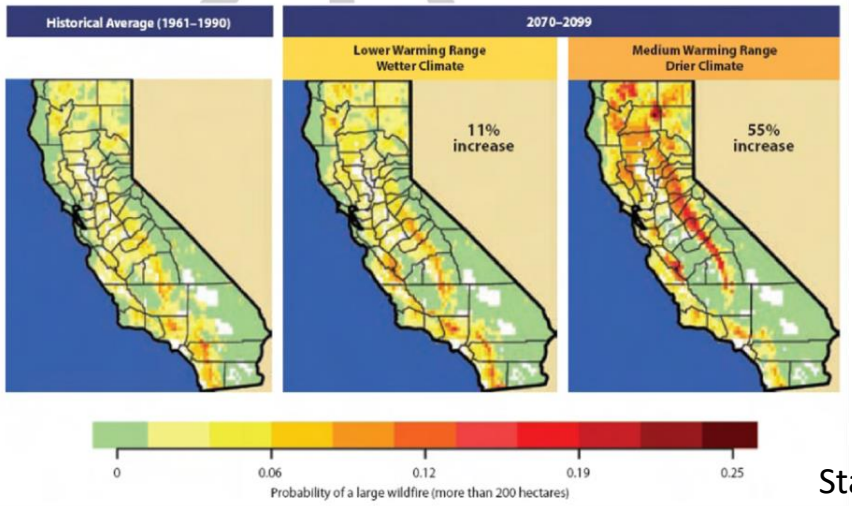


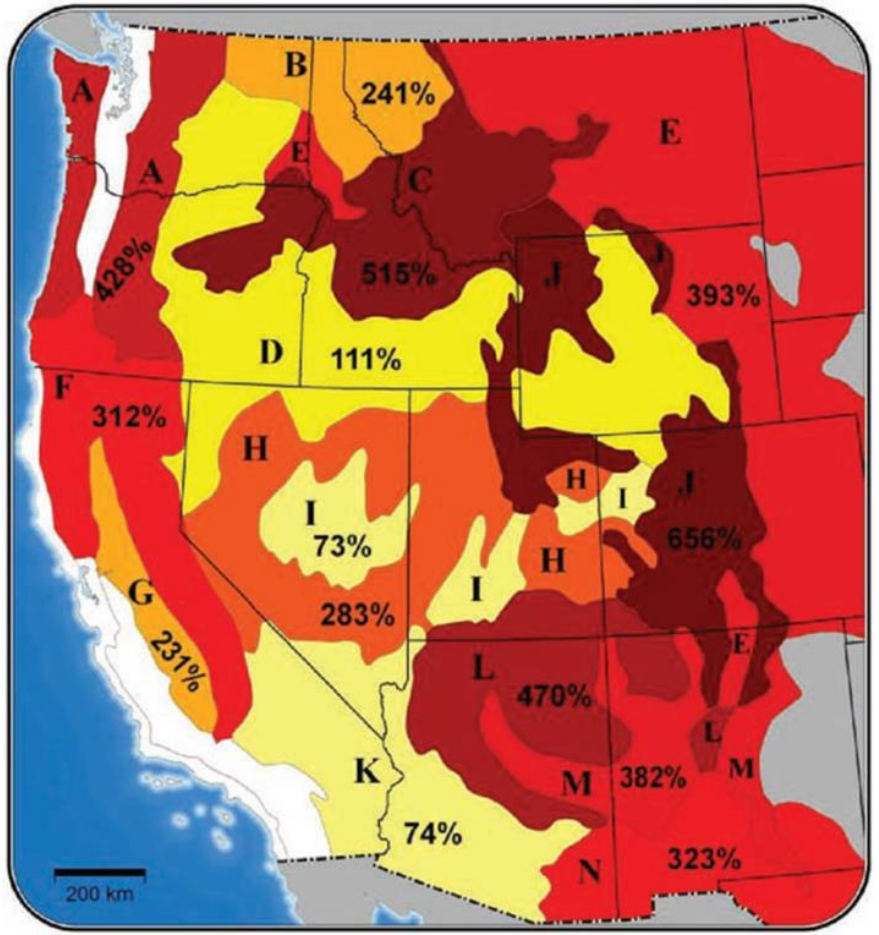
Fig. 8 Percent change in mean annual area burned for the 2050–2099 future period relative to the mean annual area burned for the historical period (1895–2003)

Lenihan et al. 2008

Large wildfire probability



State of California 2009



NRC 2011

Projected increase in burned area by 2100 with 1°C warming

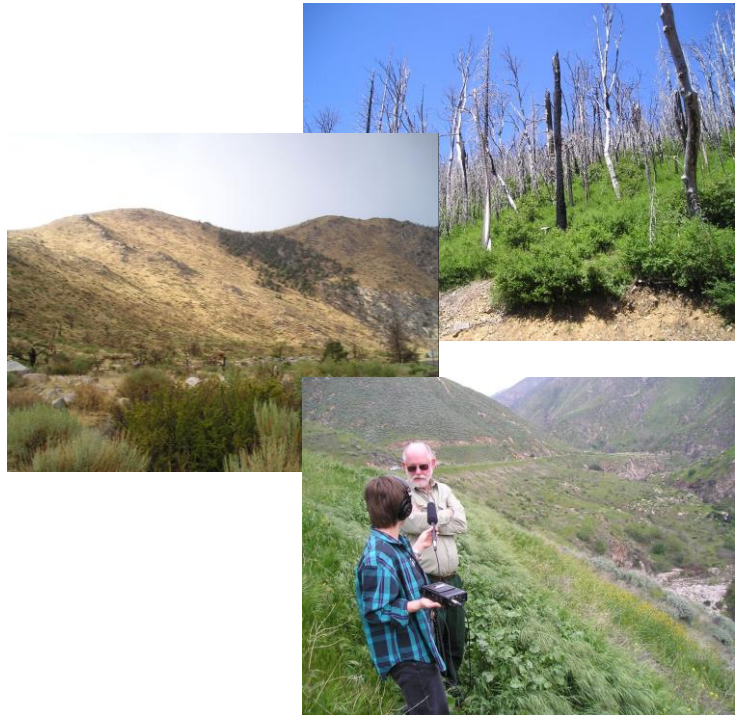
Fire trend summary

- Overall burned area is still well below pre-EAS levels, but it is rising quickly
  - Problem is centered in montane forests and oak woodlands
  - Ecologically, California needs *more* fire, but of the right type!
- Fire regimes have been changed drastically by Euroamericans
  - F4 ecosystems (oak woodlands, yellow pine, mixed conifer) have experienced a long-term lack of burning due to fire exclusion
  - Formerly infrequent-fire ecosystems at lower elevations (chaparral, sage scrub) have experienced increased fire frequencies
- Fire severity is high and rising in F4 ecosystems
  - Modern % of burned area c. 35% vs 5-15% pre-EAS
  - Modern HS burned area c. 3x greater than under pre-EAS fire regime, even with less overall burning!

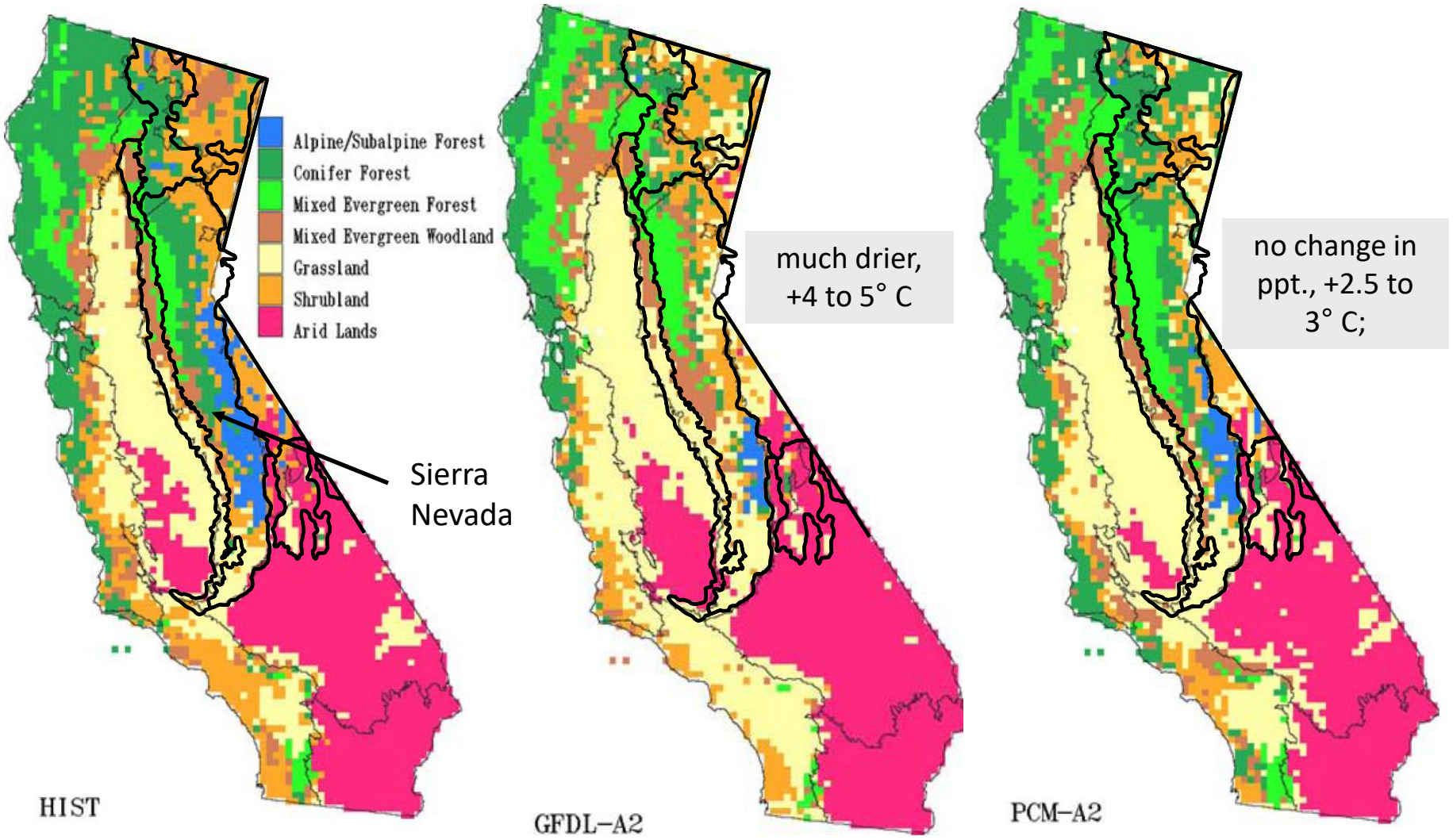
Ecosystem impacts of altered fire regimes

Acute changes in the factors that influence fire and fire behavior can have major consequences for ecosystems and biota

- Altered stem density and fuels
- Changes in structural heterogeneity
- Increased biological invasion
- Amplified drought stress
- Impacts to species life cycles
- Altered rates of nutrient cycling
- Streamflow and groundwater changes
- Increased erosion
- Soil structure and chemistry effects…



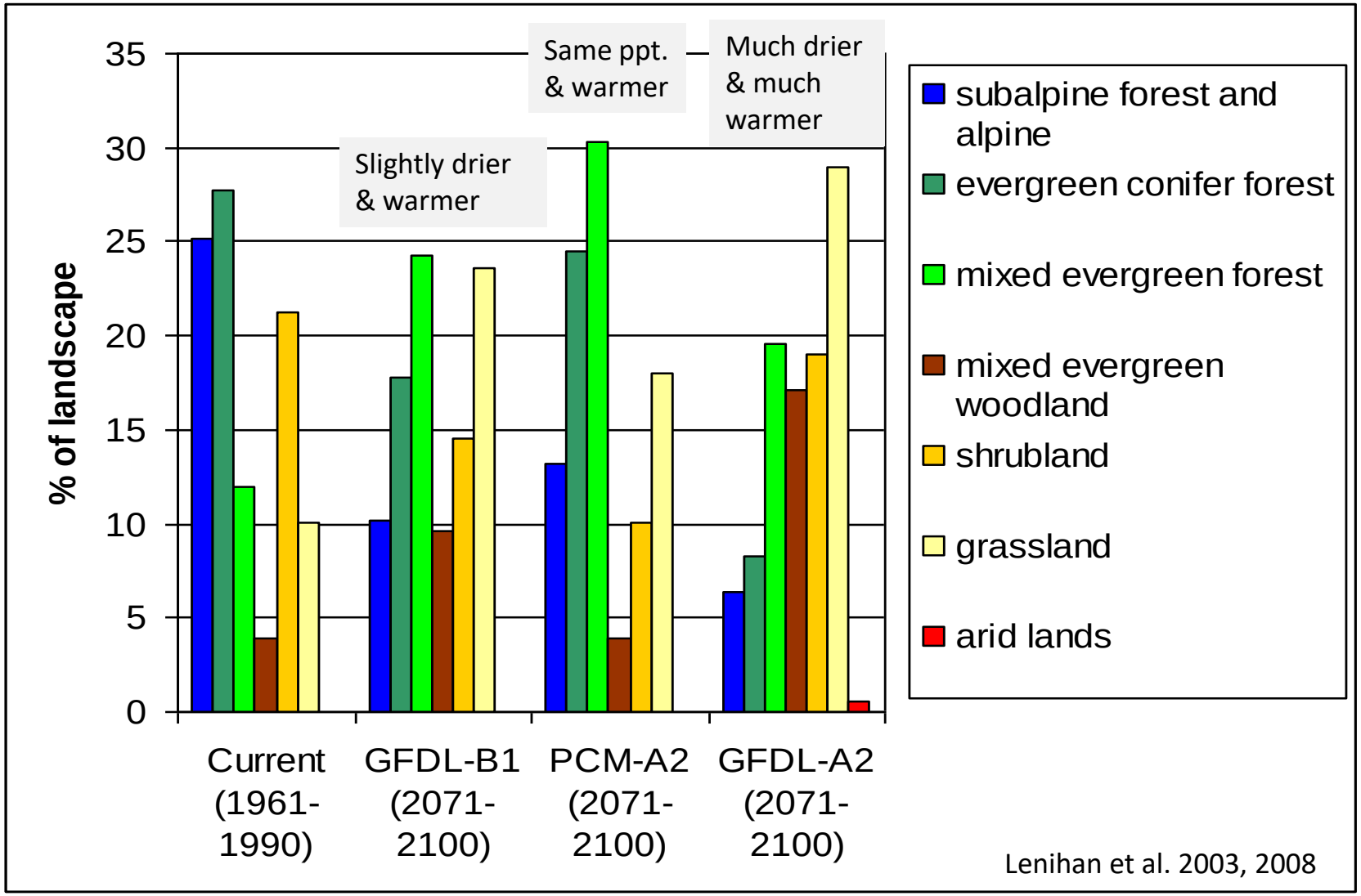
Implications of altered fire regimes for vegetation



Interactions between climate change and fire are projected to have major effects on California vegetation

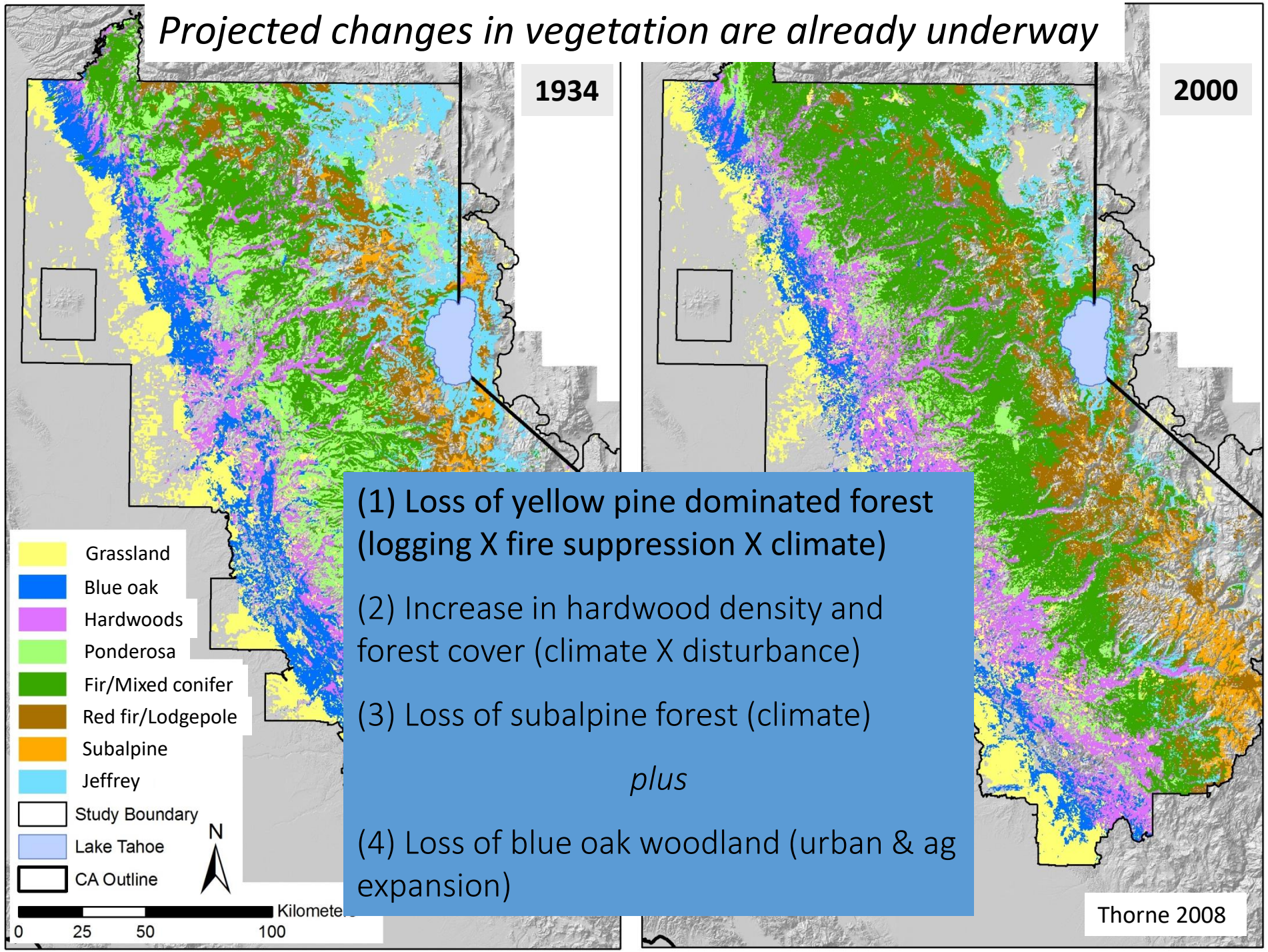
Lenihan et al. 2003, 2008

Sierra Nevada Ecoregion: expect loss of conifers, success of hardwoods, major expansion of exotic grassland



Projected changes in vegetation are already underway

Comparison of Forest Service vegetation mapping from 1930s vs 2000s



(1) Loss of yellow pine dominated forest (logging X fire suppression X climate)

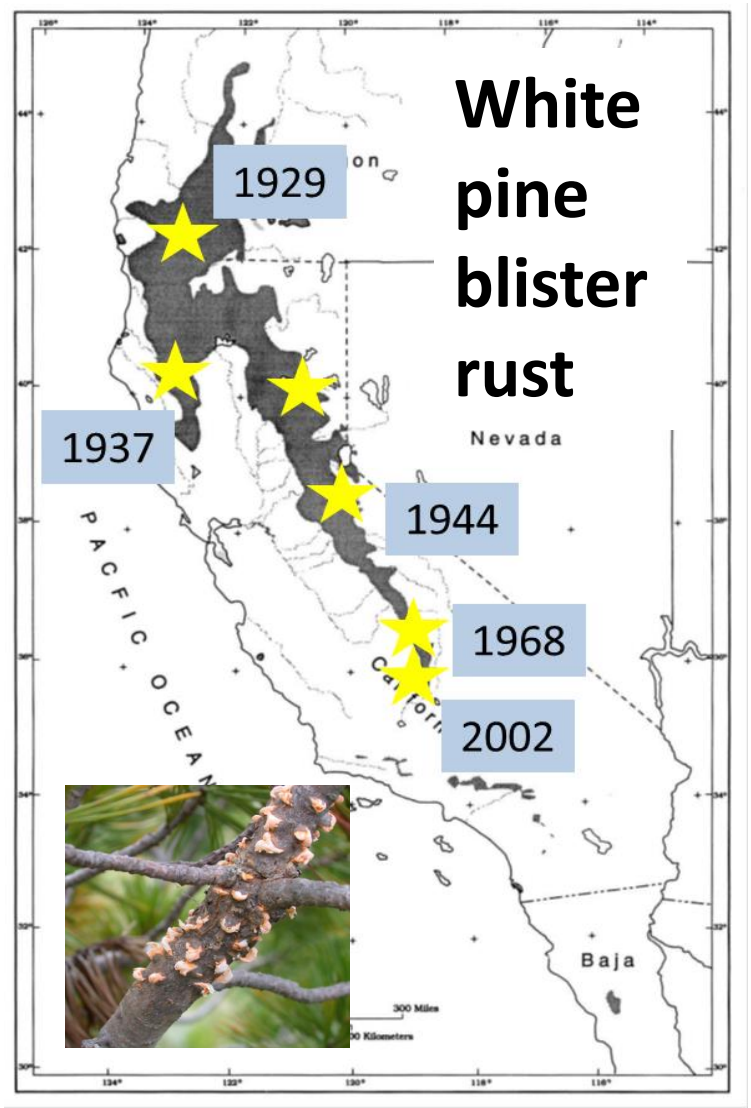
(2) Increase in hardwood density and forest cover (climate X disturbance)

(3) Loss of subalpine forest (climate)

plus

(4) Loss of blue oak woodland (urban & ag expansion)

Other stressors…



Drought

Ozone

N depo-sition

etc.

Interactions among fire and other stressors are provoking vegetation changes across California

Forestland to shrubland and grassland

Shrubland to grassland

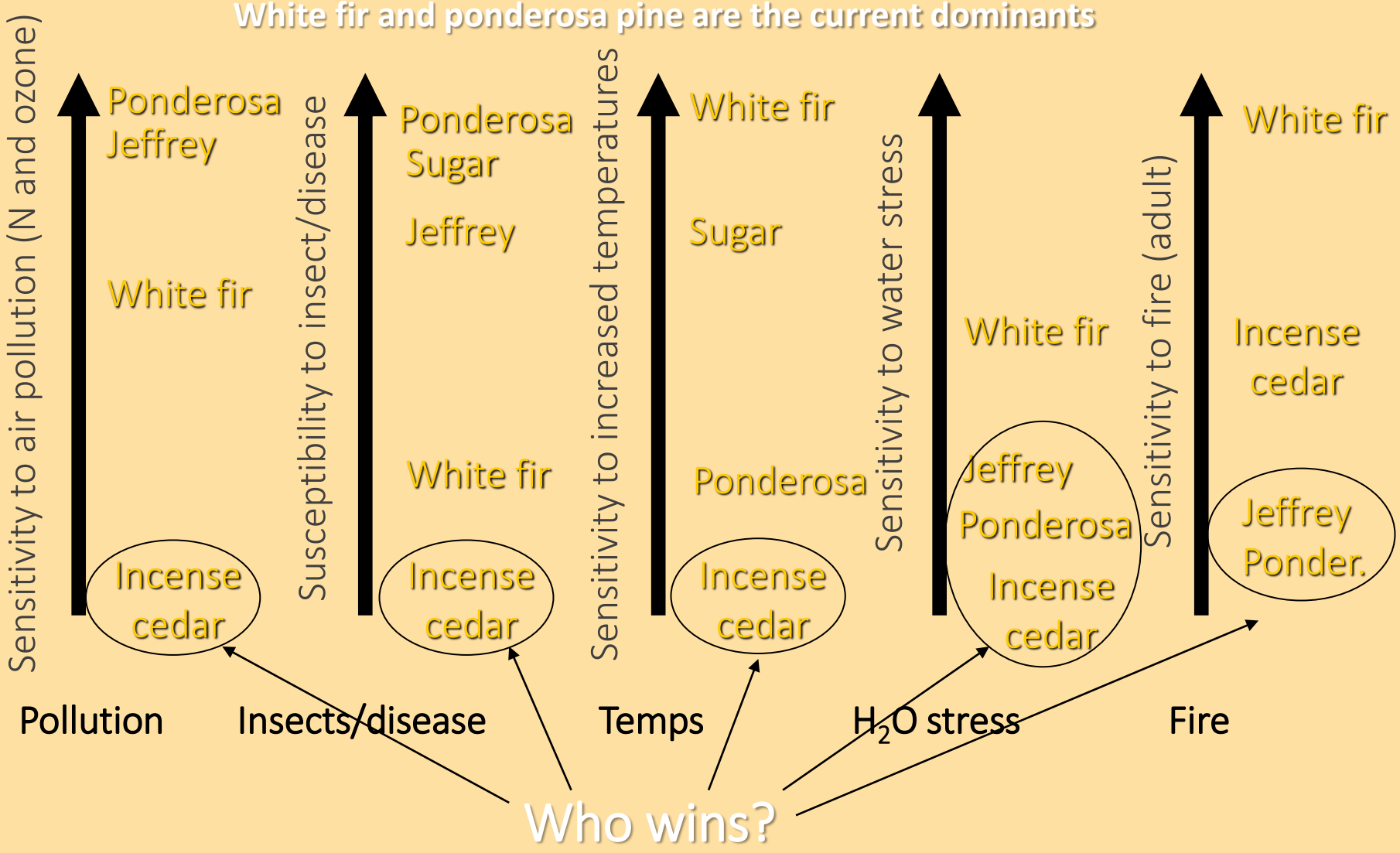
Fire exclusion: in many ecosystems, lack of fire is just as serious an ecosystem disturbance as uncharacteristically severe fire

Open pine forest to dense fir forest

Meadow to forestland

California forests are under major ecological stress: California forest conifer trees

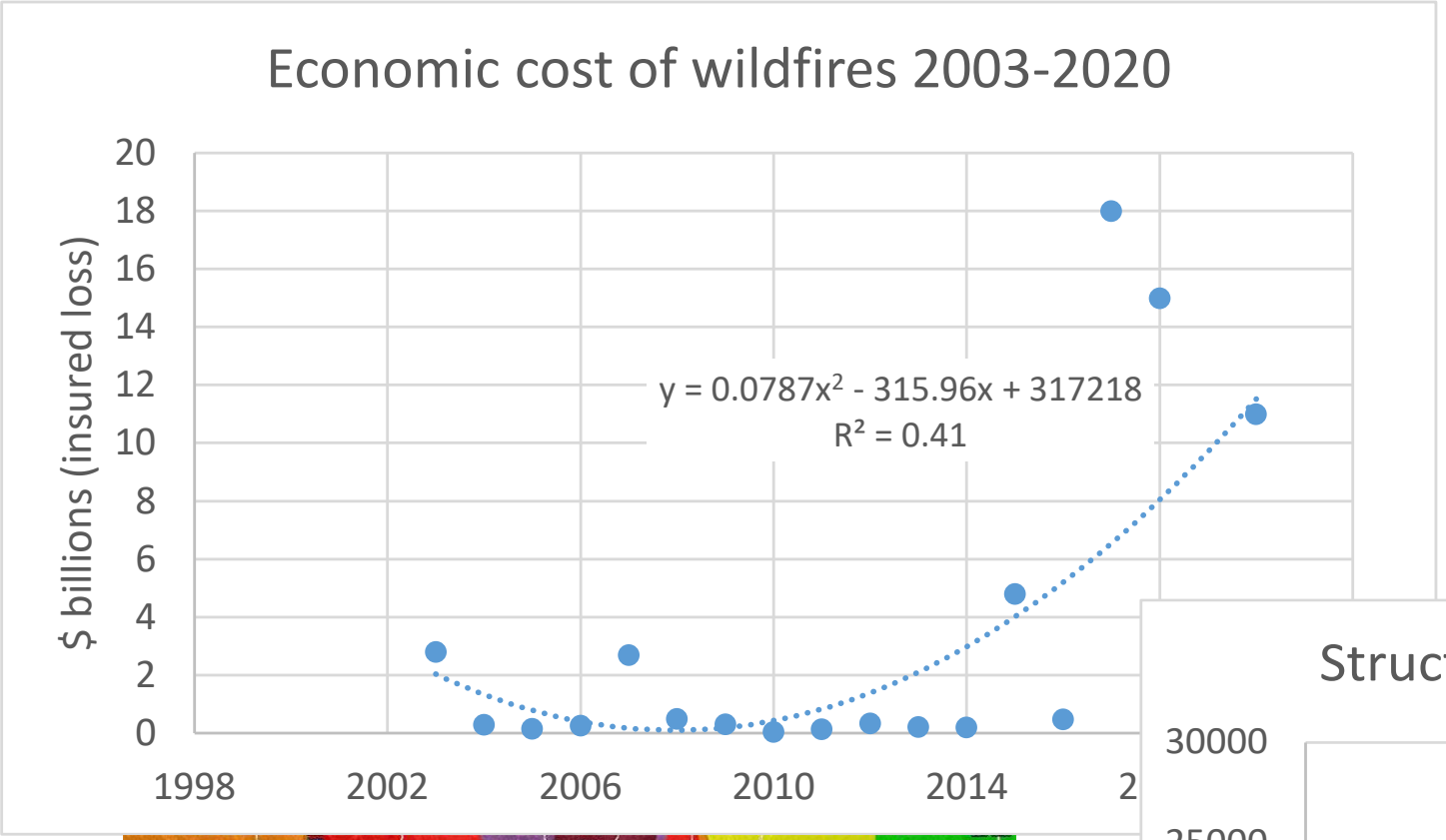
White fir and ponderosa pine are the current dominants

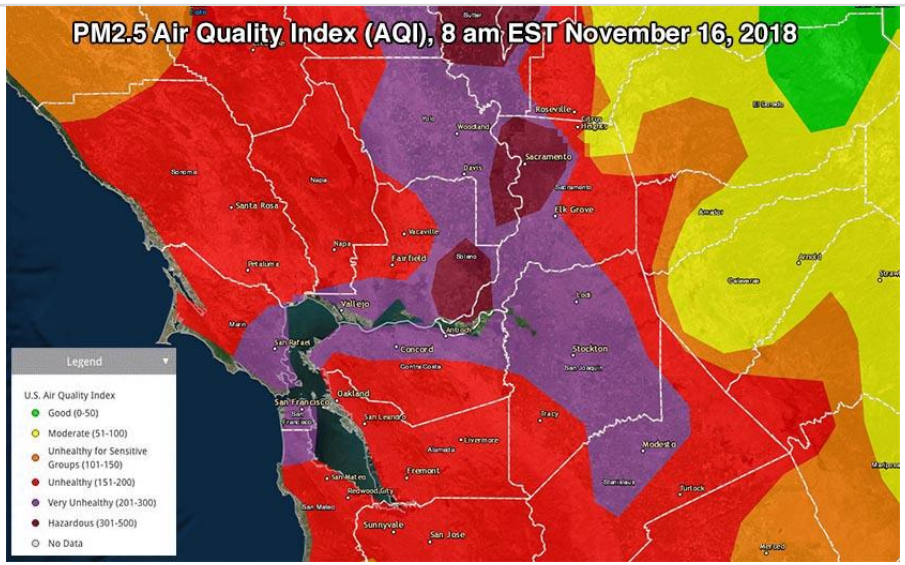


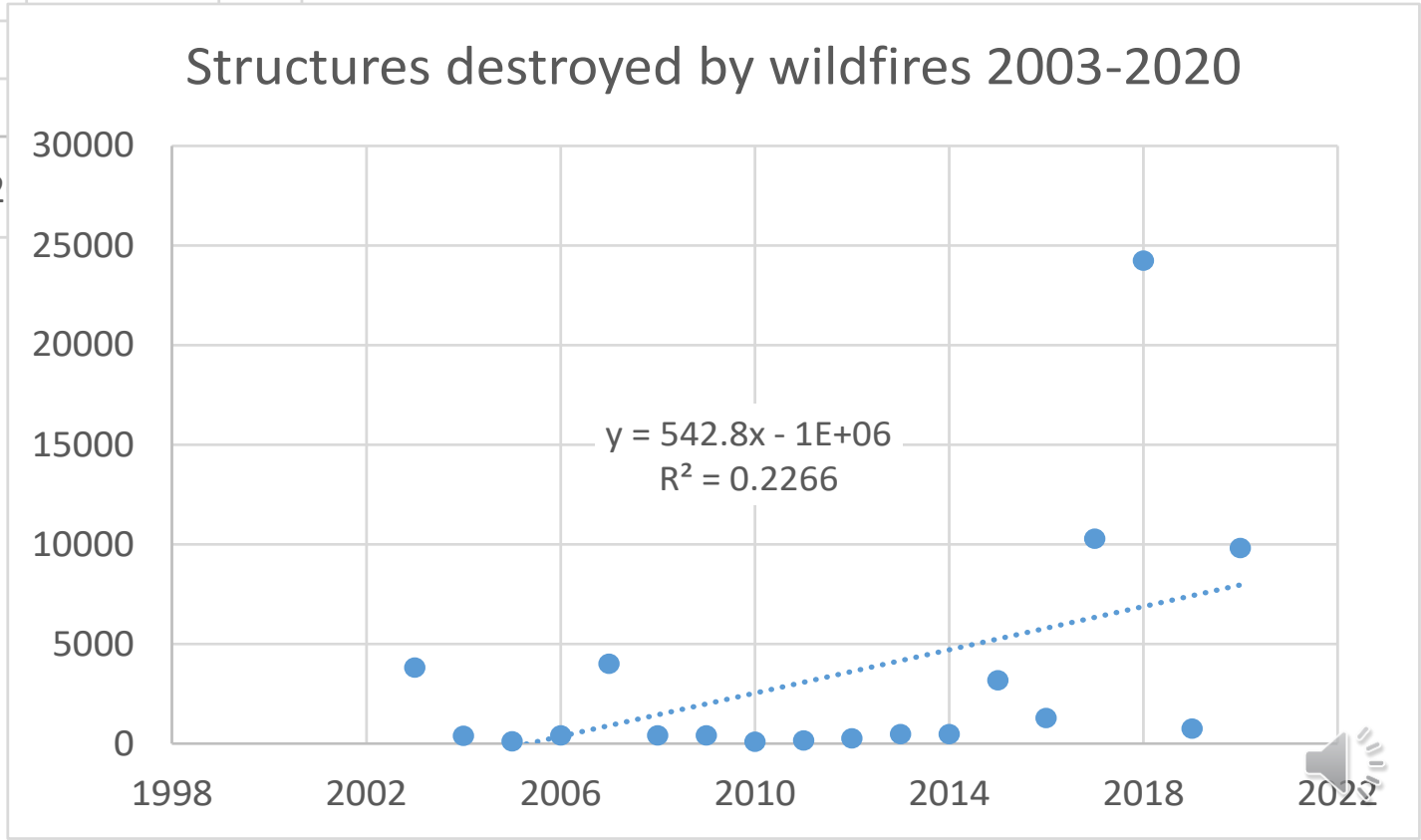
Pinus ponderosa, P. Jeffreyi, P. lambertiana (sugar pine), *Abies concolor* (white fir), *Calocedrus decurrens* (incense cedar)

Vegetation trend summary

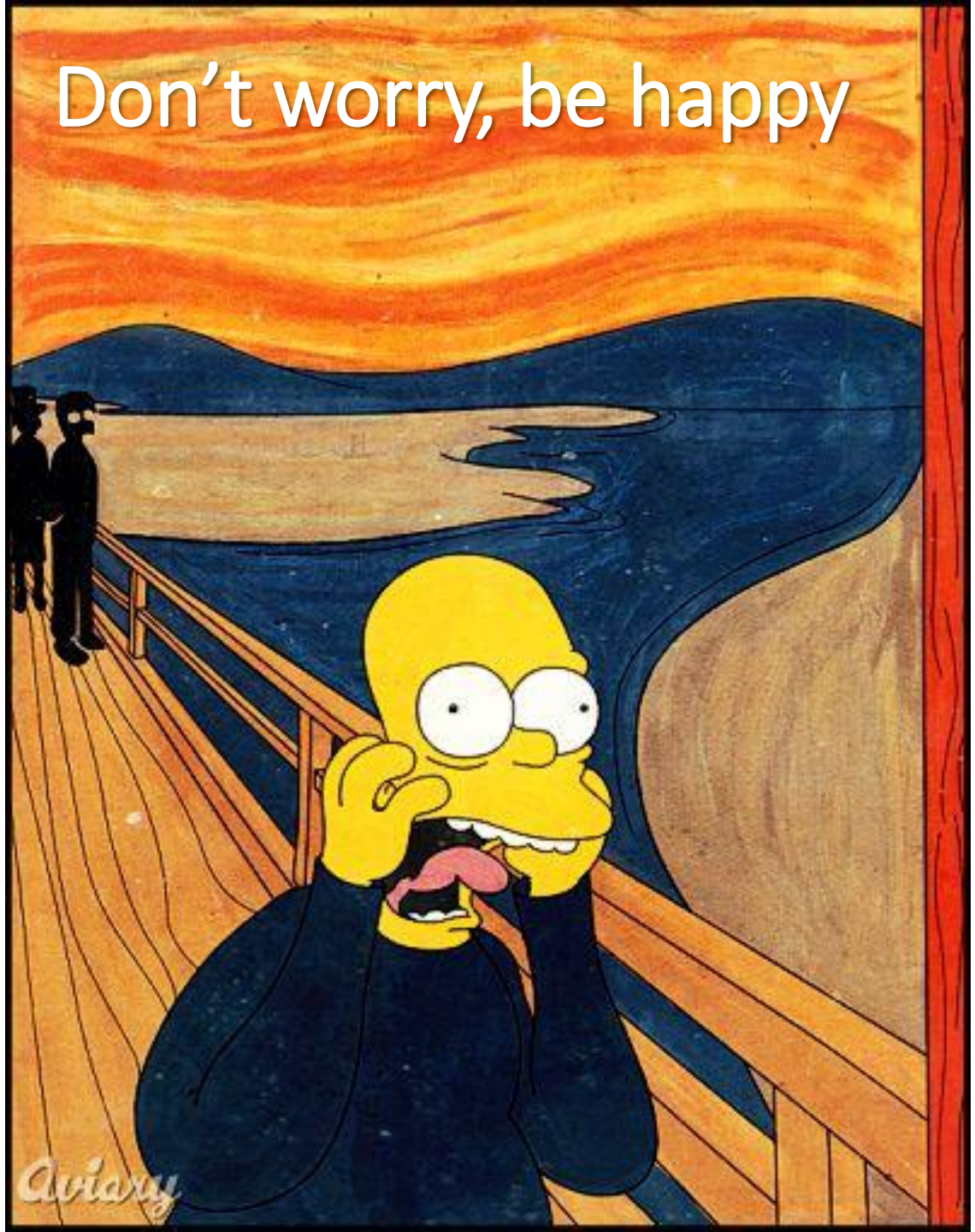
- Fire will interact with climate & other factors to provoke major veg changes
  - Projected changes are already occurring
- As high severity area and patch size increase, and as summer droughts deepen, regeneration of conifers will become progressively more difficult
  - Given sufficient precip., hardwood species will replace many lower elevation conifer forests after disturbance
- Major structural and compositional changes to montane and subalpine forest are inevitable (and already occurring)
- Many areas of persistent shrubland that succeeded to conifers under fire suppression may return to shrubs
- Major expansion of grassland is projected for much of California due to frequent fires in forests and shrublands


Economic cost of wildfires 2003-2020
$ billions (insured loss)
20
18
16
14
12
10
8
6
4
2
0
1998
2002
2006
2010
2014
2
y = 0.0787x² - 315.96x + 317218
R² = 0.41


PM2.5 Air Quality Index (AQI), 8 am EST November 16, 2018
Legend
U.S. Air Quality Index
Good (0-50)
Moderate (51-100)
Unhealthy for Sensitive Groups (101-150)
Unhealthy (151-200)
Very Unhealthy (201-300)
Hazardous (301-500)
No Data
Sacramento
Oakland
San Jose
Stockton
Concord
Fremont
Vallejo
Fairfield
Santa Rosa
Roseville
Elk Grove
Modesto
Sunnyvale


Structures destroyed by wildfires 2003-2020
30000
25000
20000
15000
10000
5000
0
1998
2002
2006
2010
2014
2018
2022
y = 542.8x - 1E+06
R² = 0.2266

Don’t worry, be happy



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