Effectiveness and ecological effects of pre-fire fuel treatments in California yellow pine and mixed conifer forests

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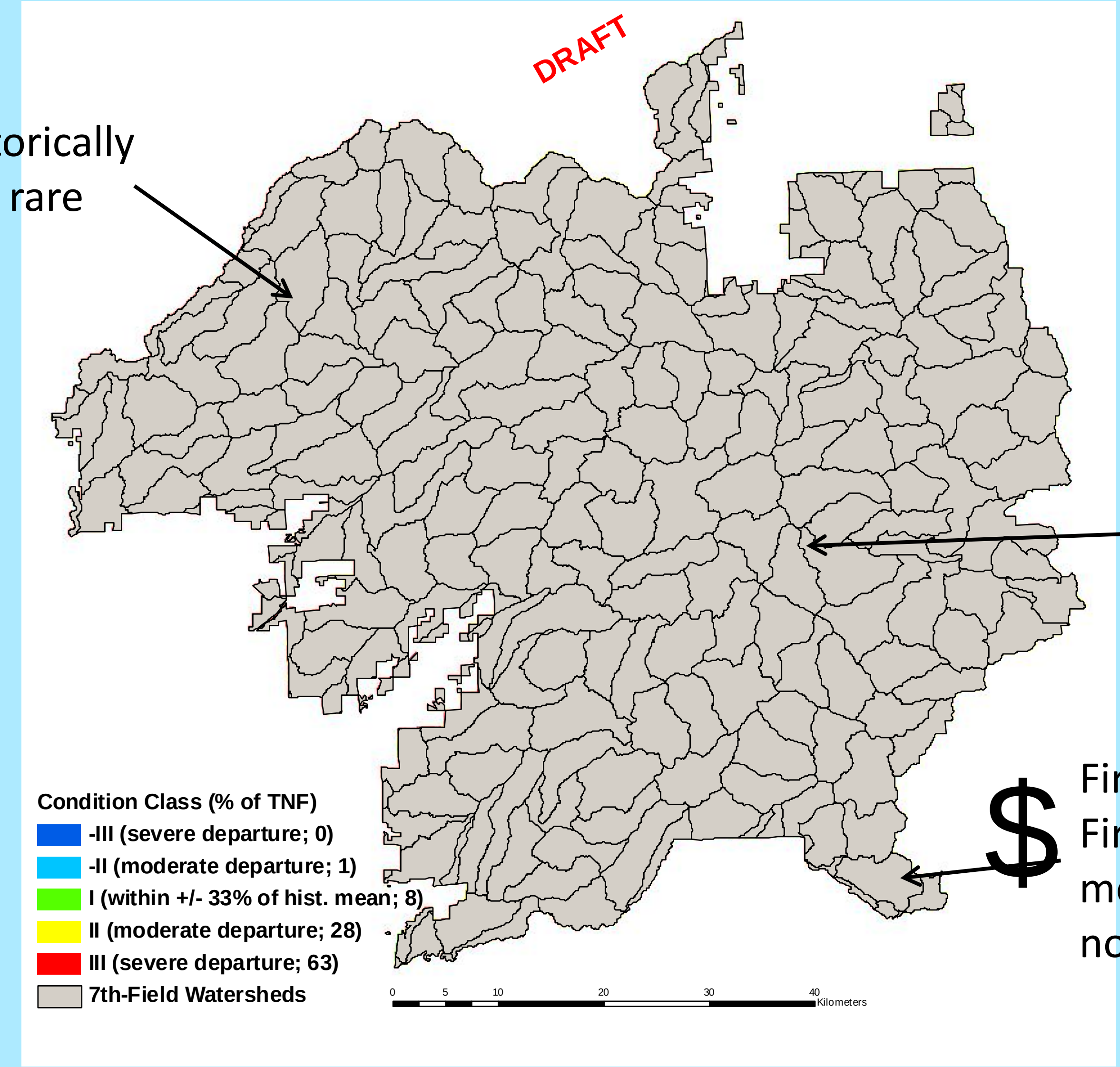
Outline

1. Background
   - Conditions and trends in fire, forests, and climate
2. Objectives
   - How effective are forest fuel treatments at reducing fire severity in Fire Regime I forests?
   - What are the ecological effects of fuel treatments?
   - Can fuel treatment/forest thinning in Fire Regime I forests approximate "restoration"?
3. Methods and Results
4. Some interpretive musings on ecological outcomes and restoration (if I have time)

Sierra Nevada: the lack of fire is changing the landscape

Tahoe National Forest

Fire Regime I:
Fires were historically frequent, now rare



Fire Regime IV/V:
Fires rare historically and today

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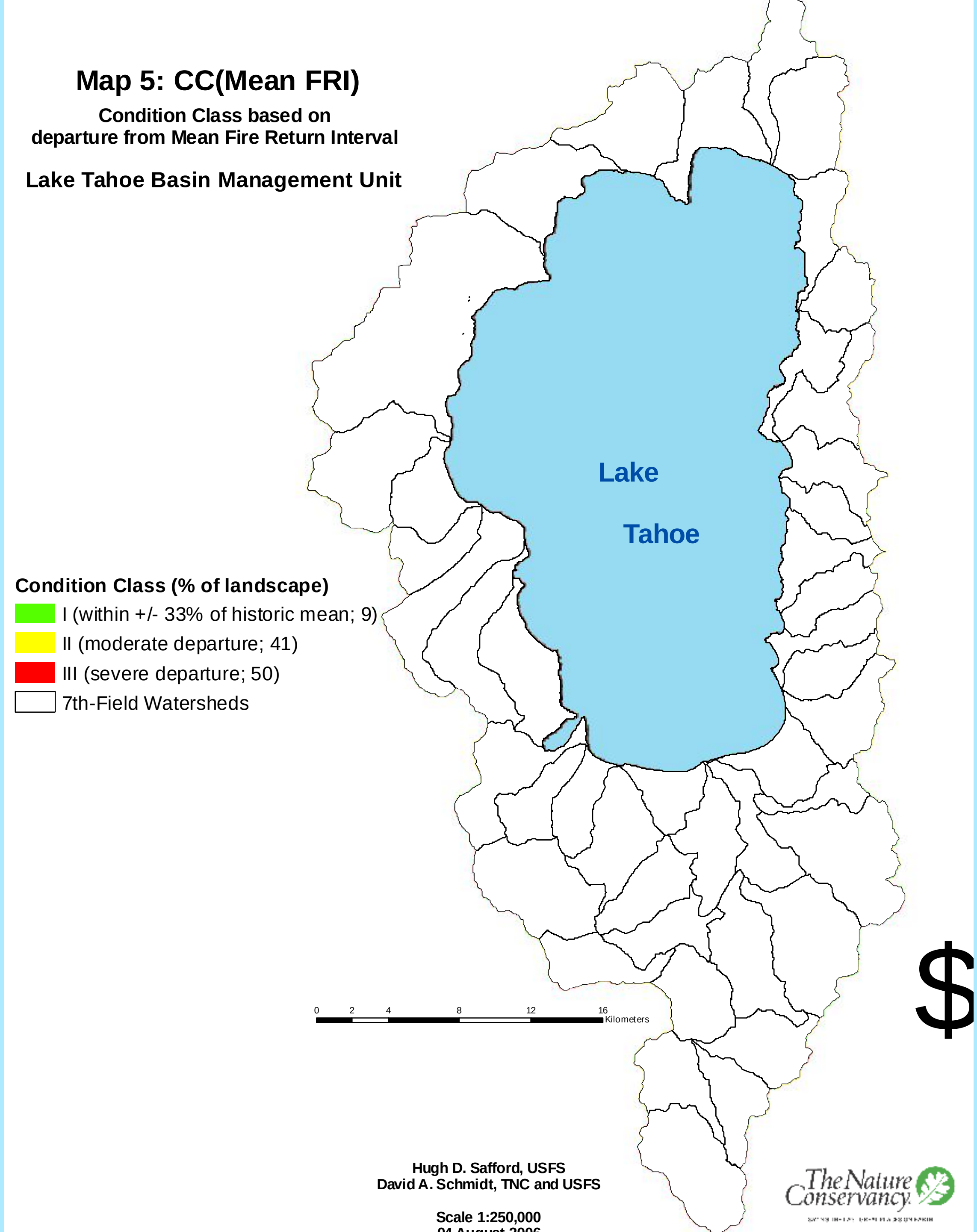
Fire Regime III:
Fires were of inter-mediate frequency, now rare



Lake
Tahoe
Basin

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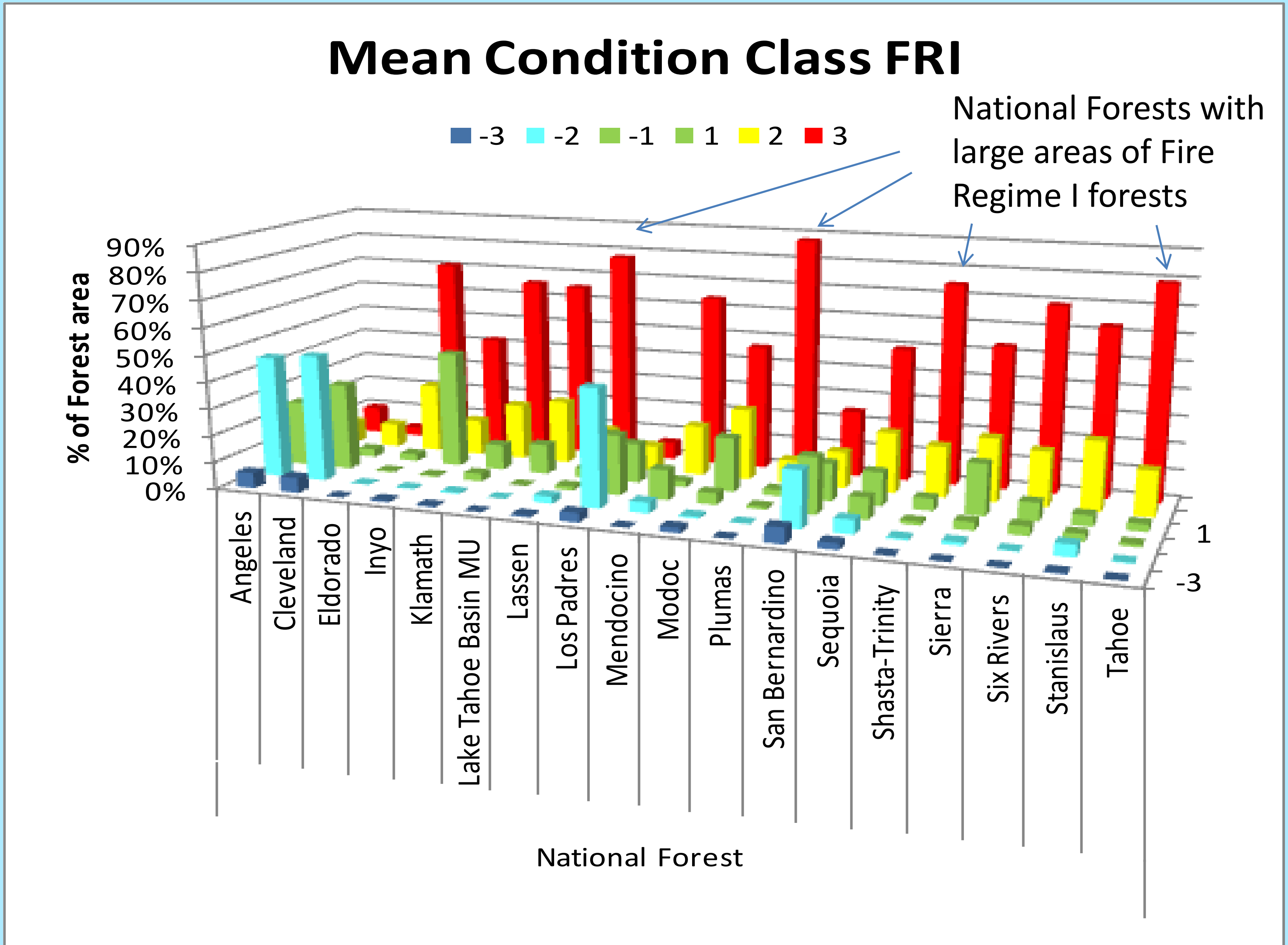
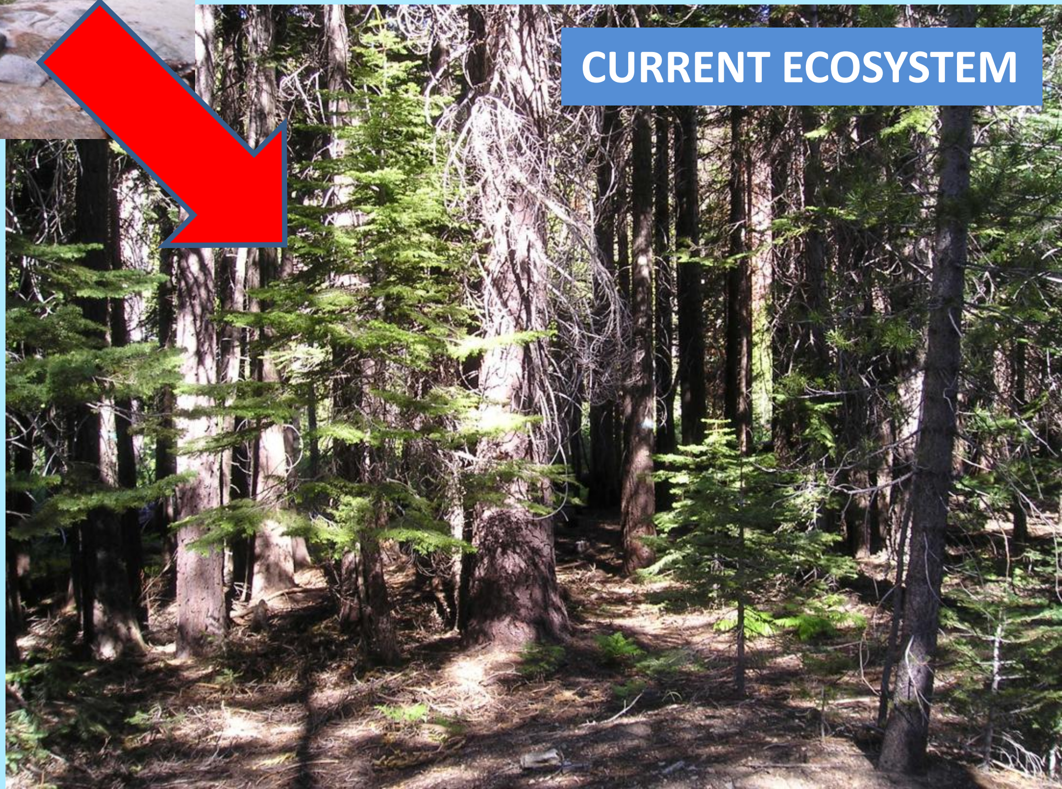
Fire departure patterns in the California Nat. Forests



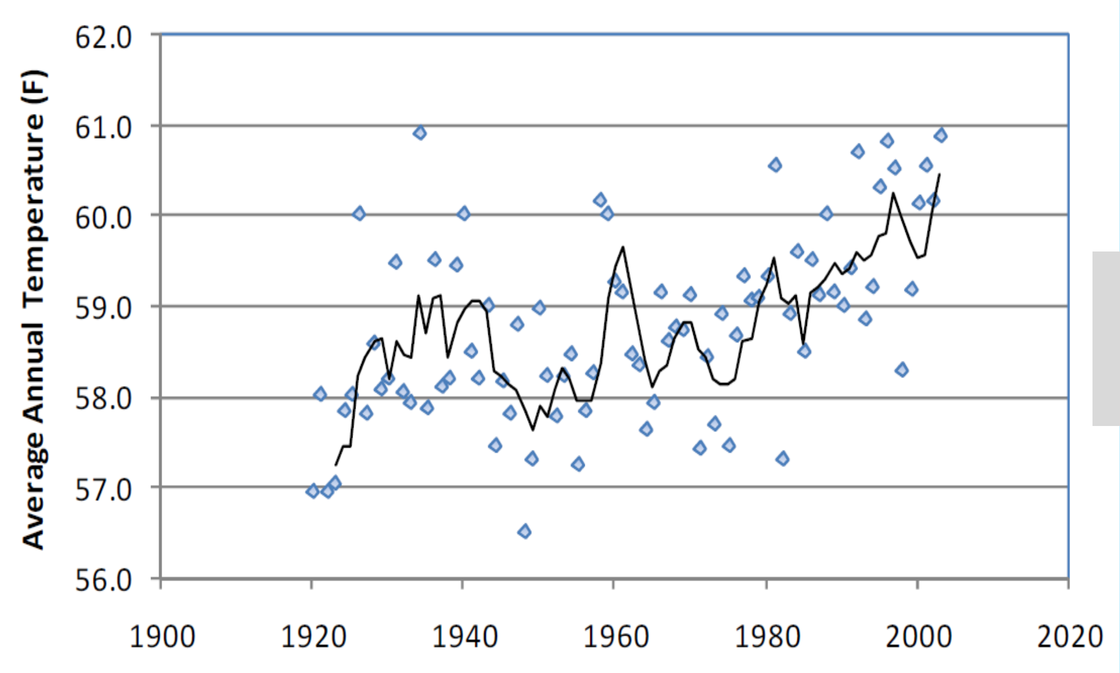
Human management has greatly changed montane forests in CA

Reference forest: *Pinus* dominated, large canopy trees, open canopy, low stem density, low fuel loading (low litter levels, highly heterogeneous understory, fuel ladders rare), high diversity of understory species; fire frequent, low severity. Fire Regime I



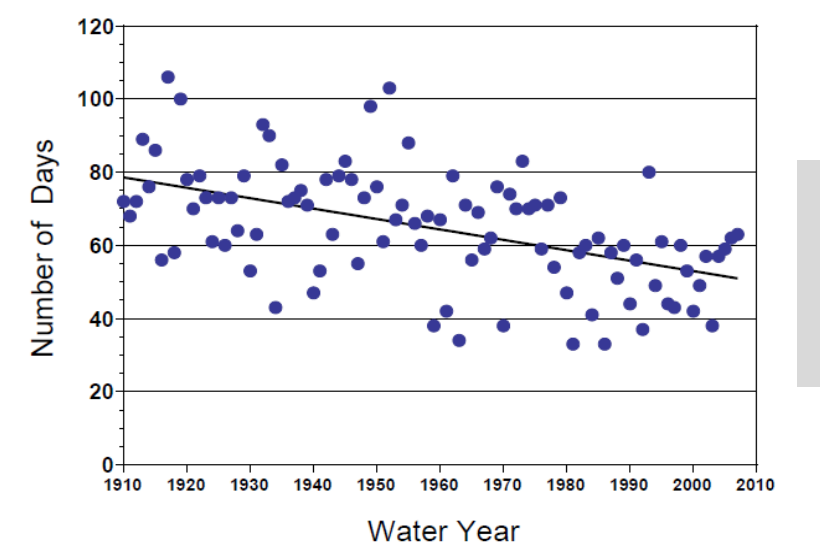
Current forest: *Abies* dominated, mostly small and mid-sized trees, high stem density, closed canopy, high fuel loading (very deep litter, high fuel continuity, fuel ladders common), low diversity of understory species; fire essentially absent, moderate to high severity when it occurs. Fire Regime III

The climate is changing



California: mean annual temps, 1920-2005

Moser et al. 2009



Tahoe City: number of days below freezing, 1910-2009

TERC 2009

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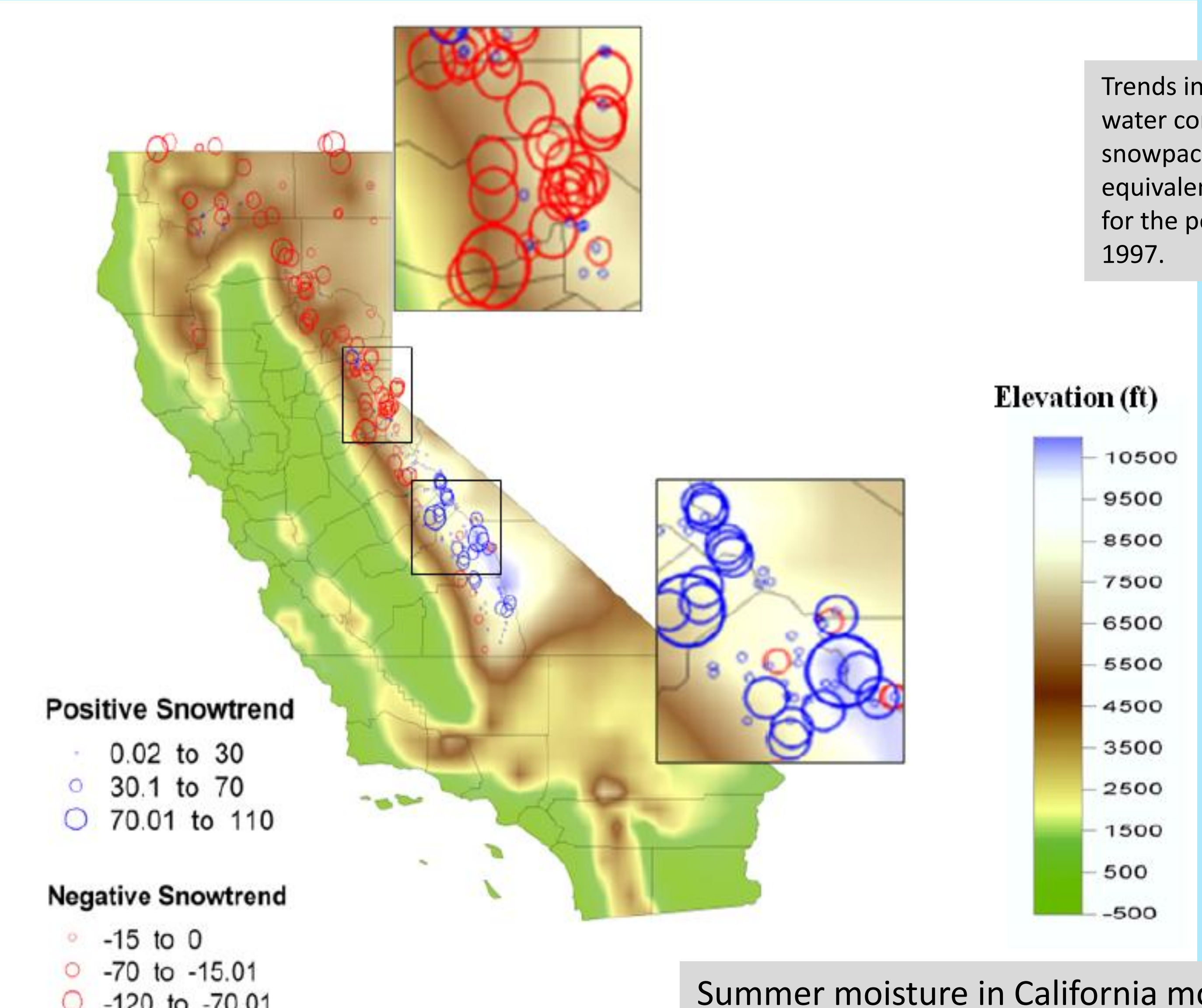
Winter snowpack is down across most of California

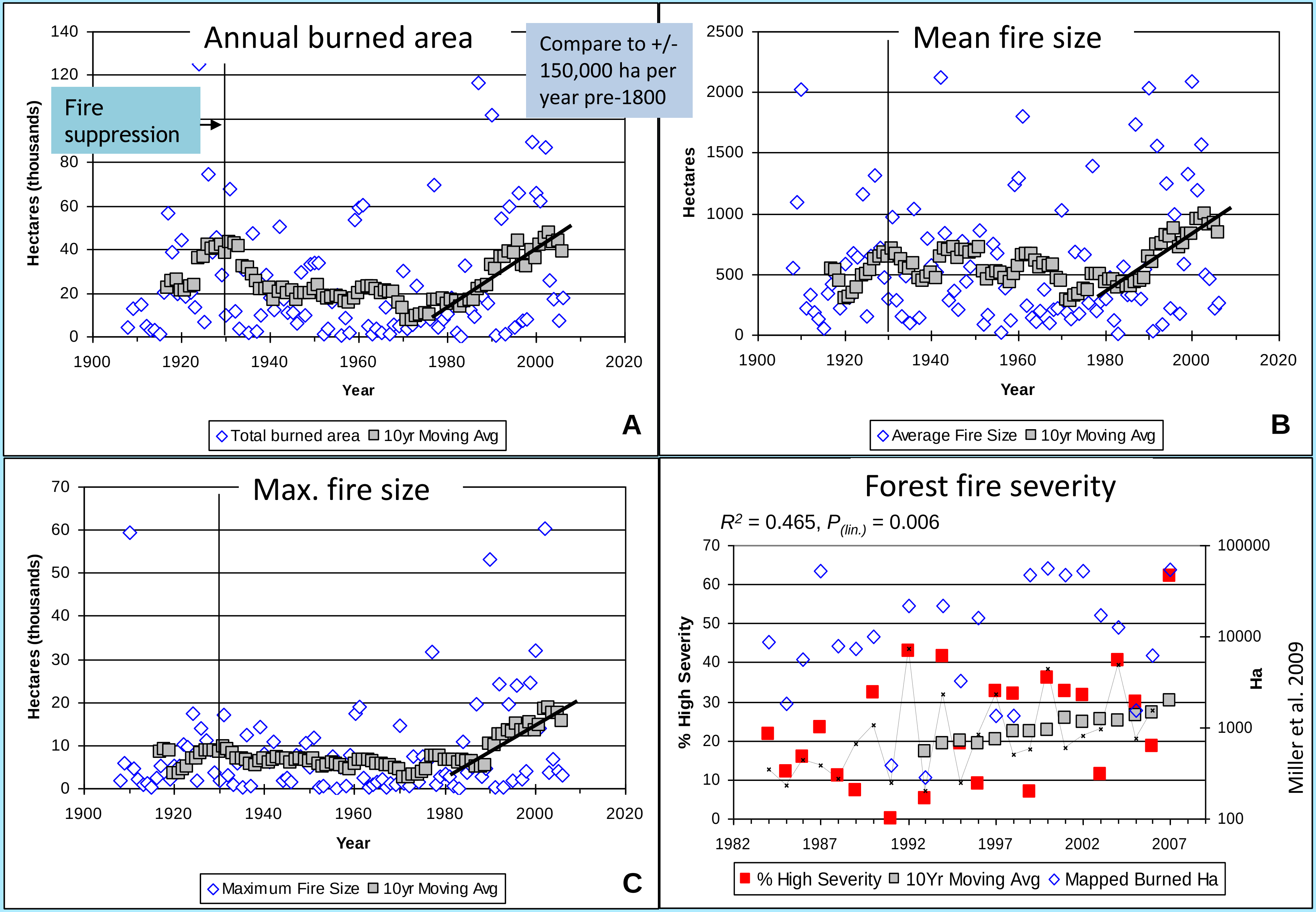


Moser et al. 2009

Trends in the amount of water contained in the snowpack ("snow water equivalent") on April 1, for the period 1950-1997.

Summer moisture in California montane forests is primarily snowpack-derived

Sierra Nevada: trends in fire area and severity



Future fire trends: Models project increases in fire activity in the Sierra Nevada

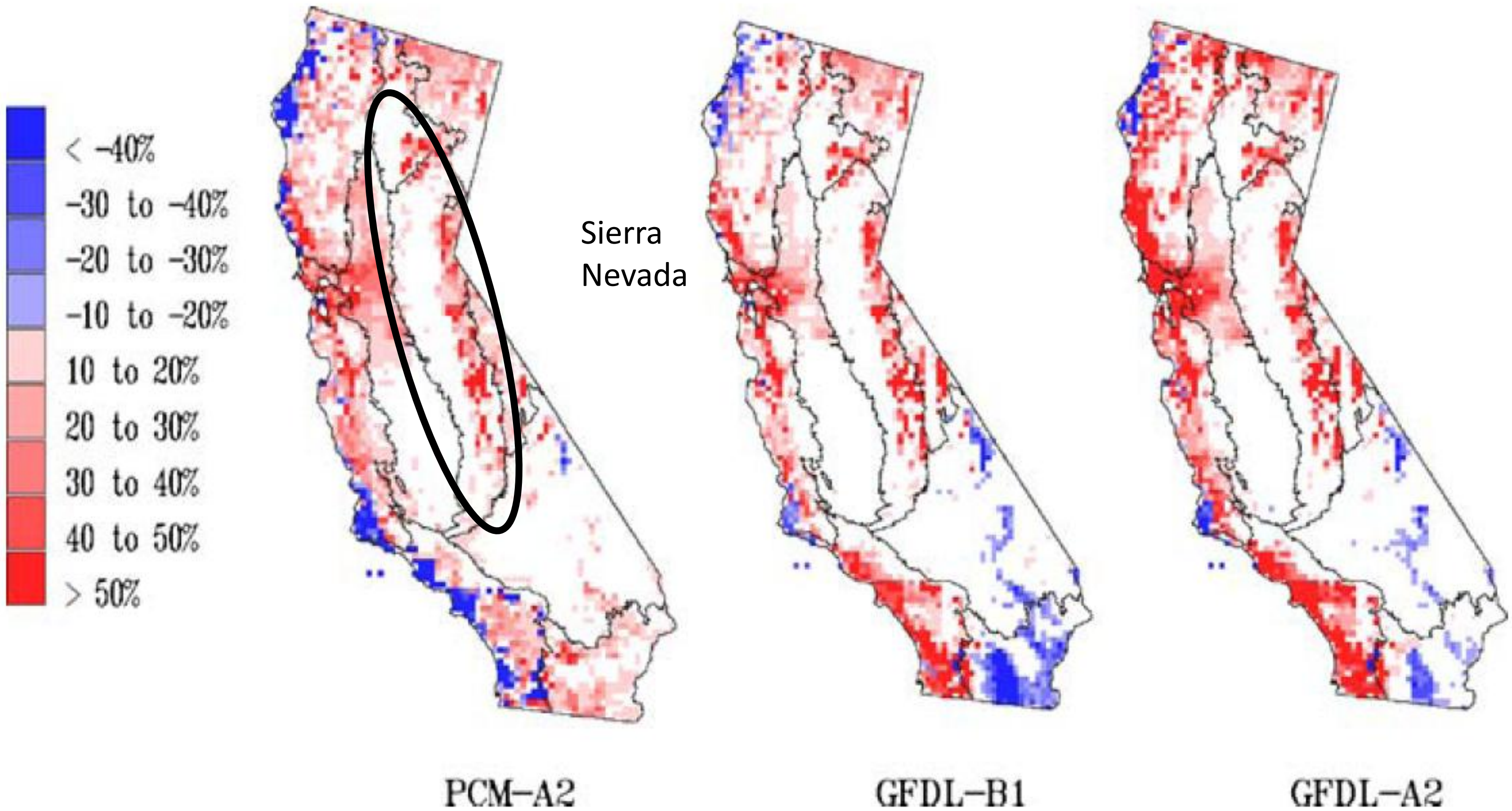
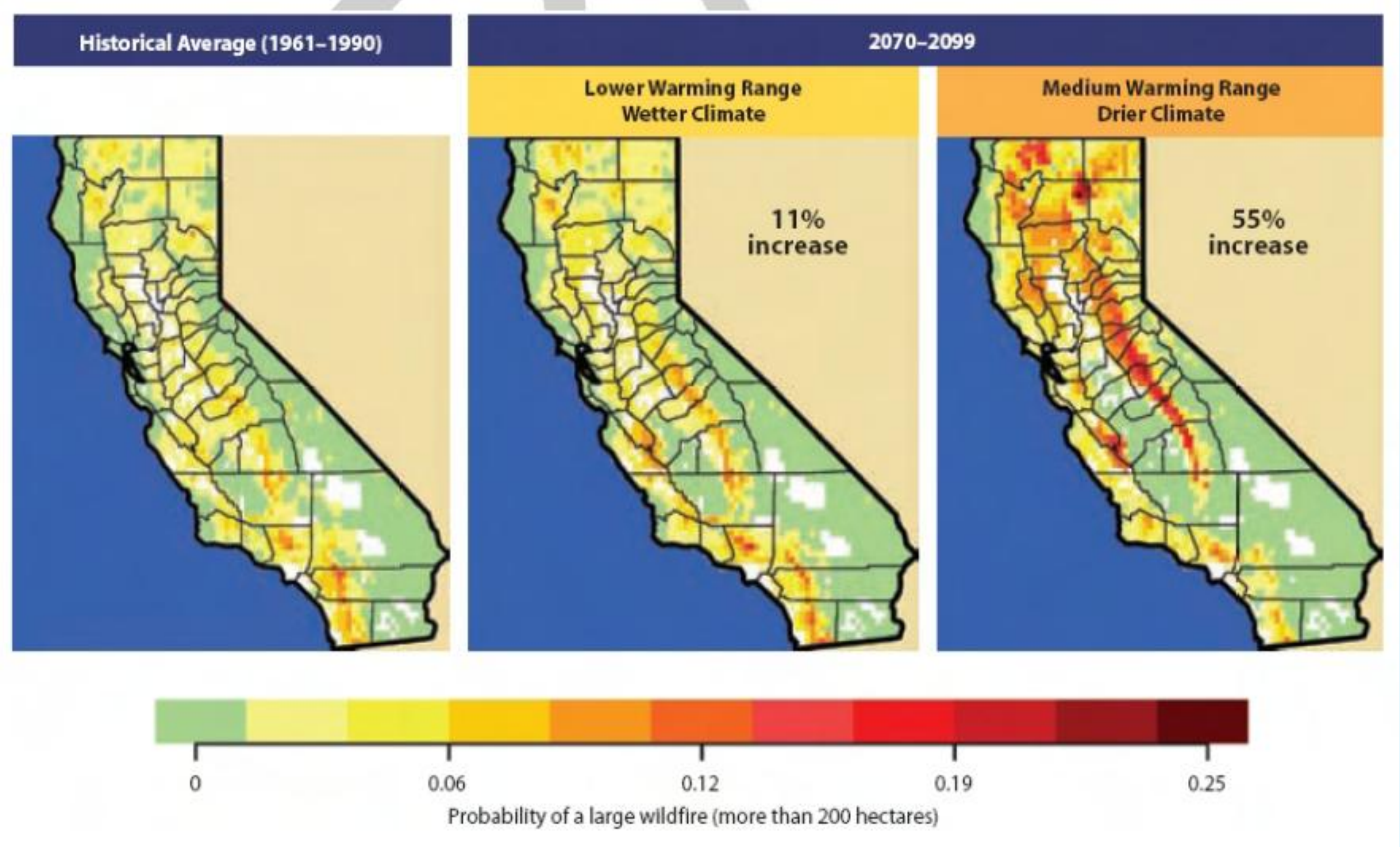


Fig. 8 Percent change in mean annual area burned for the 2050–2099 future period relative to the mean annual area burned for the historical period (1895–2003)

Lenihan et al. 2008

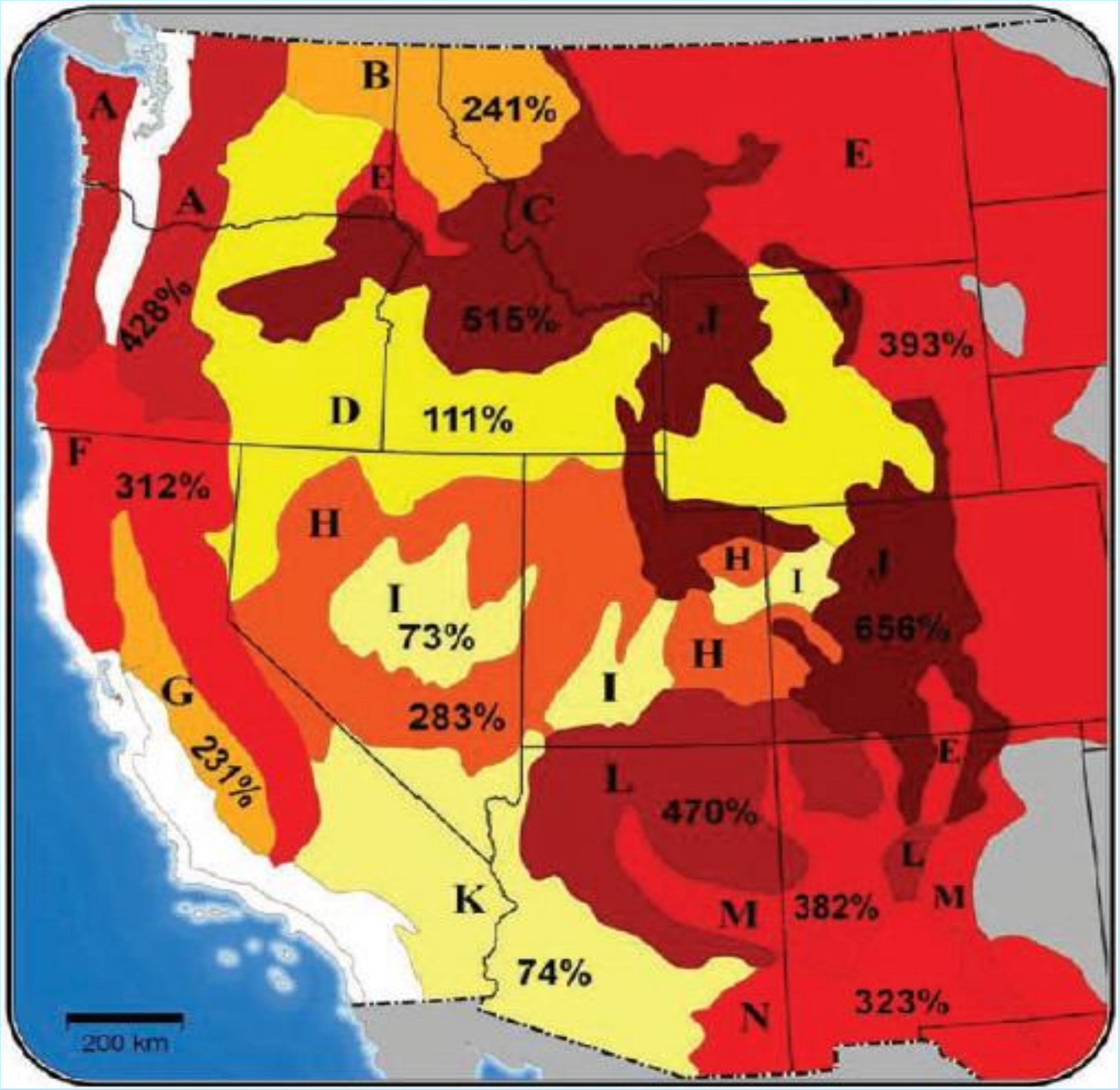
PCM-A2: no change in ppt., +2.5 to 3° C; GFDL-B1 scenario: slightly drier, +2.5 to 3° C; GFDL-A2: much drier, +4 to 5° C

Future fire trends: Increasing probabilities of large wildfires in most of the Sierra Nevada



State of California 2009

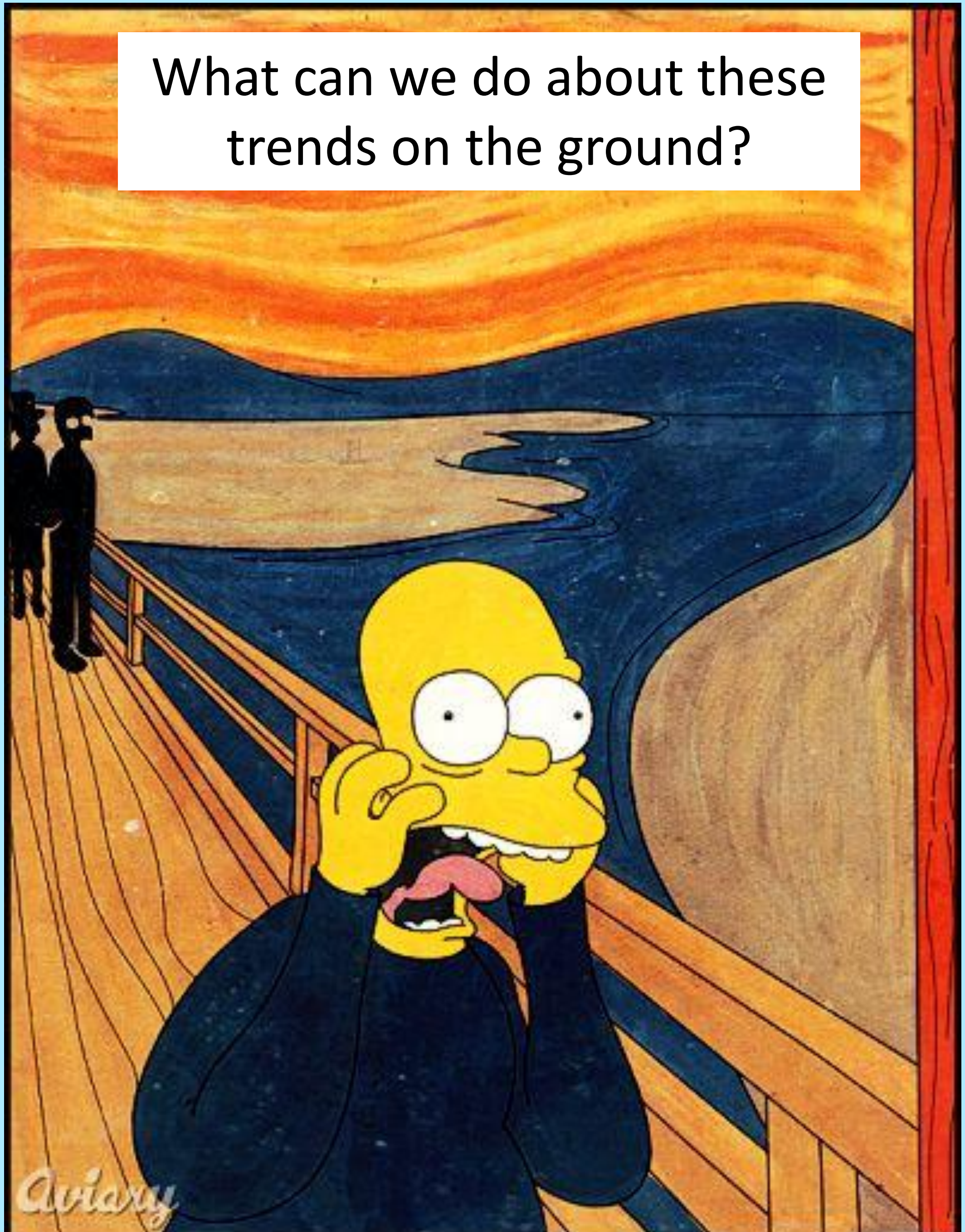
Modeled increase in median annual area burned under 1°C increase in temperature



National Research Council 2011

By 2100 temperatures in California are expected to rise by 2-5°

What can we do about these trends on the ground?

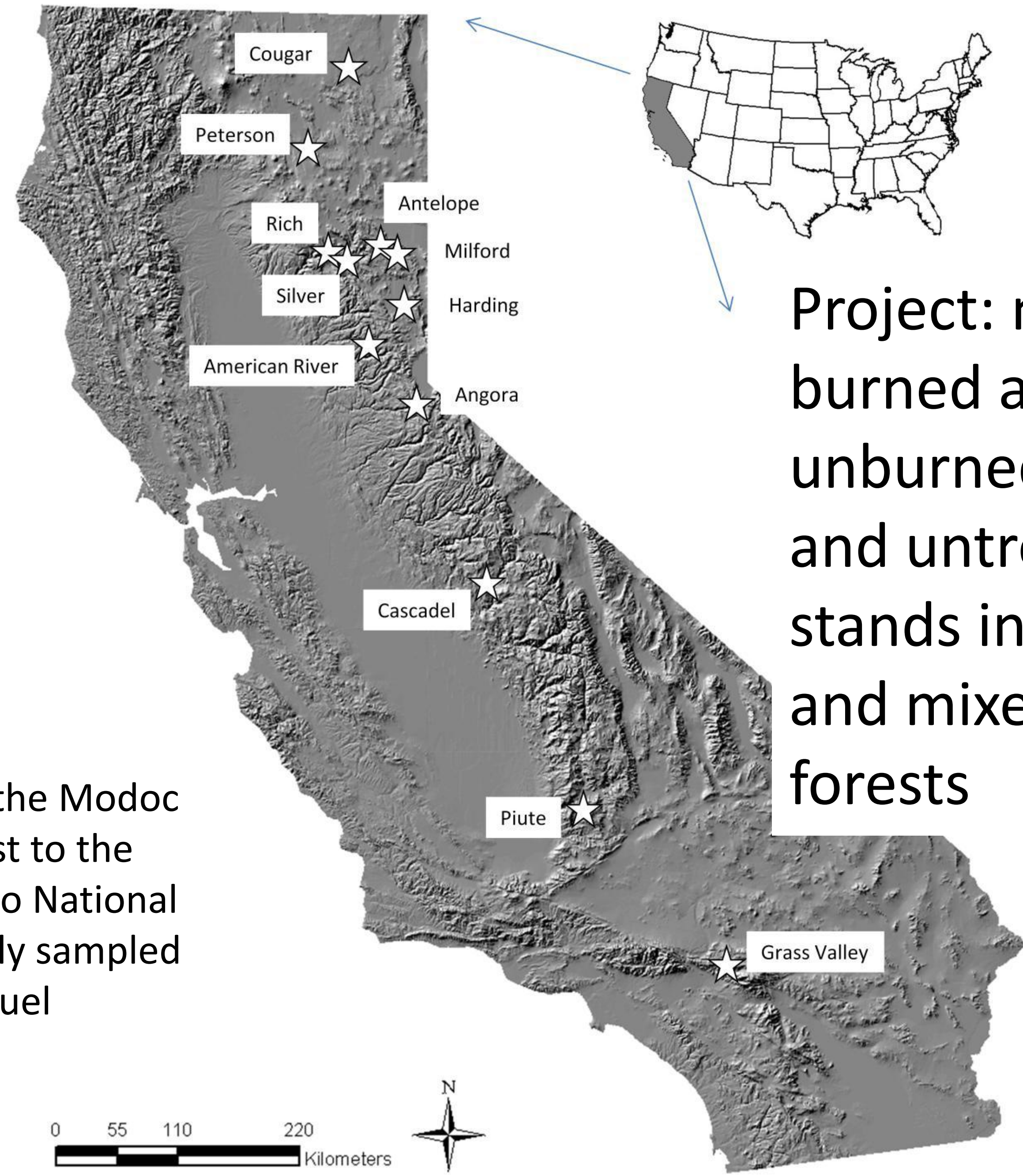


Forest Service answer

- Thin the forest and reintroduce (mostly prescribed) fire, but:
  1. Does it work?
  2. What are the ecological effects?
  3. And is it restoration?

We are trying to answer all of these questions, today I'll primarily focus on #1

Methods

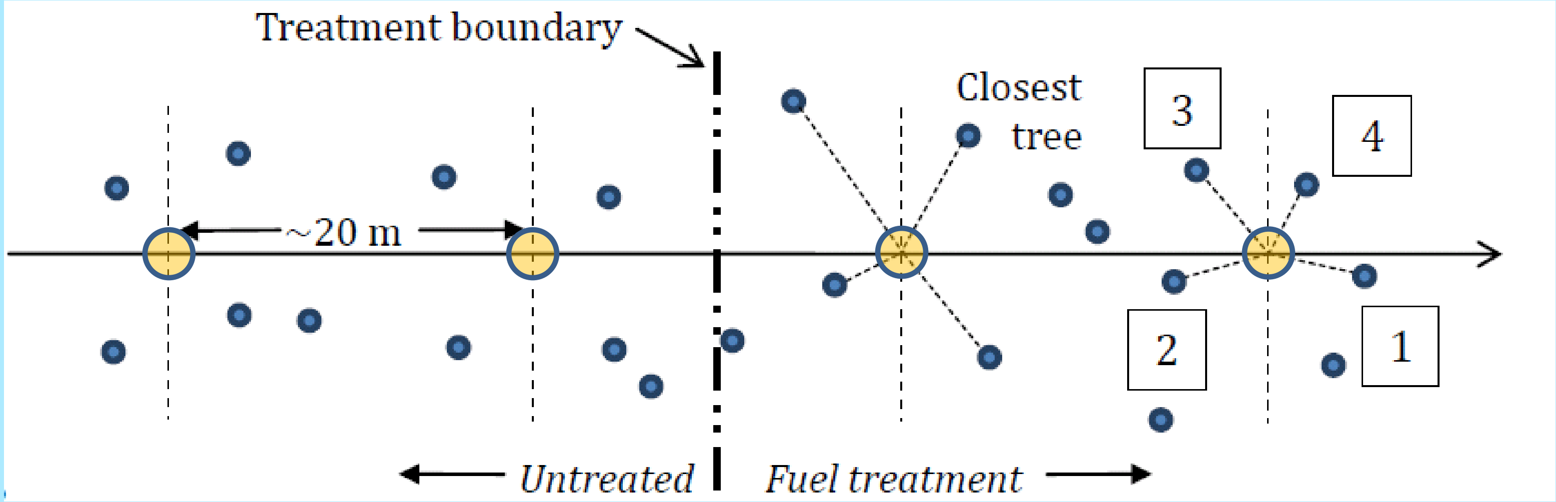


Project: monitor burned and unburned/treated and untreated forest stands in yellow pine and mixed conifer forests

12 sites from the Modoc National Forest to the San Bernardino National Forest. We only sampled “completed” fuel treatments

Simple protocol

Tree data from transects, plot data from points at 20 m intervals, mean = 3 transects and 35 points per fire



See Safford et al. (2009, 2012) *Forest Ecology and Management* for details

High variation in fires and landscapes

Table 1
General information for the 12 sampled fires.

Fire name	National forest	Ignition date	Cause[a]	Size (ha)	Lat.[b]	Long.[b]	Mean annual ppt. (mm)[c]	Mean annual temp. (°)[c]	Jan. mean min. temp. (°)[c]	July mean max. temp. (°)[c]	First sample year[d]
American River Complex	Tahoe	21-Jun-08	L	8190	39.211°	120.588°	1700	10.2	−1.2	26.7	2009
Angora	Lake Tahoe Basin	24-Jun-07	H	1243	38.887°	120.039°	974	6.3	−7.8	25.9	2007/2008
Antelope Complex	Plumas	5-Jul-07	L	9004	40.14°	120.582°	814	7.4	−6.5	26.9	2009
Cascadel	Sierra	11-Sep-08	H	112	37.249°	119.444°	1065	10.8	−0.9	27.7	2010
Cougar	Modoc	8-Jun-11	L	716	41.65°	121.43°	392	8.8	−4.9	28.5	2011
Grass Valley	San Bernardino	22-Oct-07	H	501	34.265°	117.187°	697	11.0	−1.5	27.8	2010
Harding	Tahoe[e]	24-Aug-05	H	914	39.635°	120.314°	641	7.2	−6.8	26.4	2010
Milford Grade	Plumas	4-Apr-09	L	131	40.109°	120.389°	669	7.5	−5.7	26.5	2009/2010
Peterson	Lassen	21-Jun-08	L	3235	40.917°	121.335°	559	9.6	−6.0	30.7	2009
Piute	Sequoia	28-Jun-08	H	15059	35.502°	118.337°	369	8.1	−4.5	25.5	2009
Rich	Plumas	29-Jul-08	H	2464	40.041°	121.135°	1099	10.5	−1.2	28.2	2009
Silver	Plumas	19-Sep-09	H	125	39.949°	121.09°	1321	9.5	−2.1	26.5	2010

[a] L – lightning, H – human.
[b] Of the center of the fire.
[c] 1970–2004 data, from the PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 4 Feb 2004.
[d] Where there are two years listed, the first year pertains to measures of severity, the second year to mortality.
[e] Treatments were on California Department of Fish and Game land adjoining the Tahoe National Forest.

Fuel loading, fire weather, etc.

Table 2b
General information from sampled fuel treatments, continued: measures of fuel loading, fire weather and fire danger, and published and unpublished reference sources with further information.

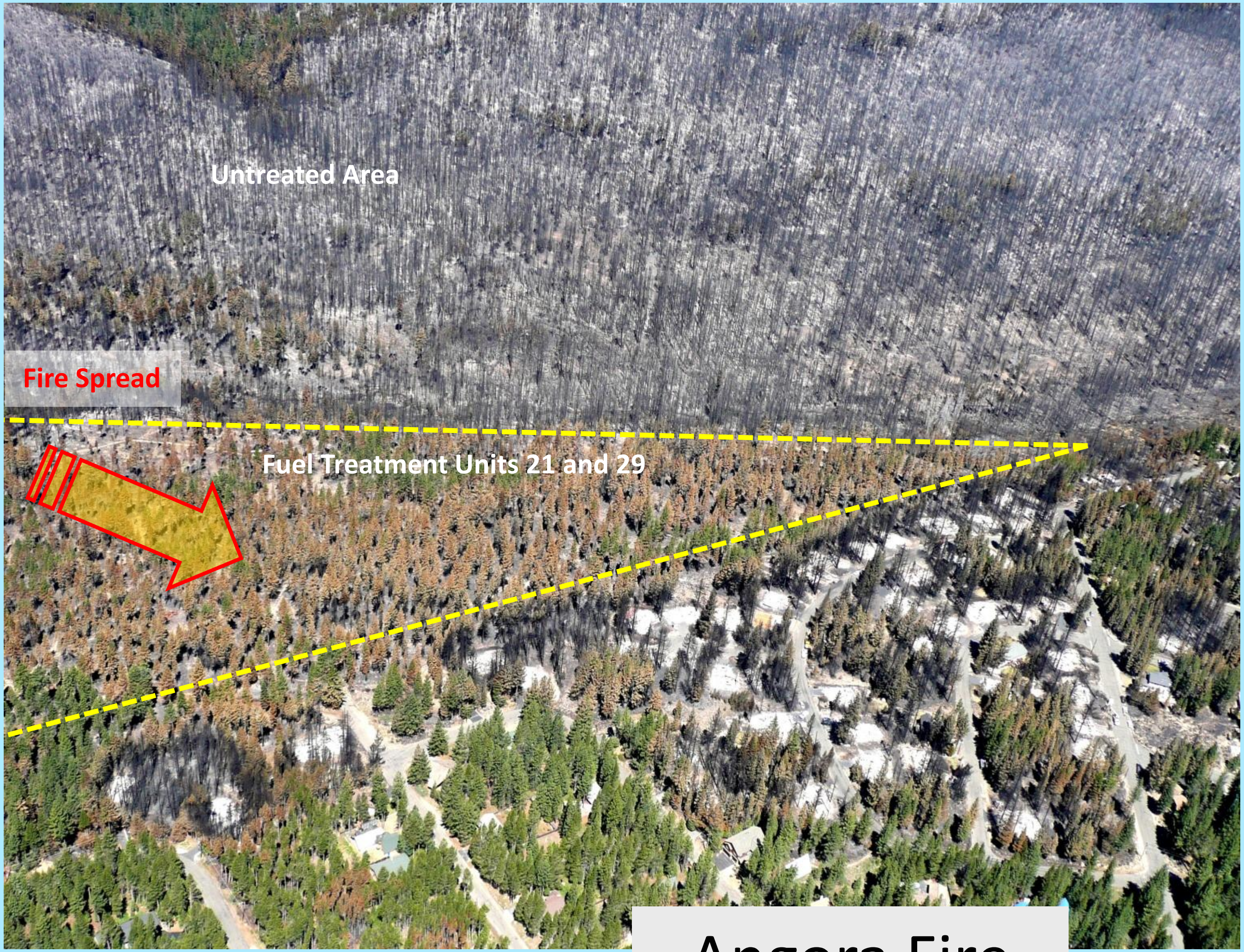
Fire	Fuel loading[a]		Fire weather/fire danger measures					References
	Treated fuel load (t/ha)	Untreated fuel load (t/ha)	ERC (%ile)[b,c]	10-h fuel moisture (%)[c]	Max. temp. (°C)[c]	Min. rel. Humidity (%)[c]	Wind speed (gust) (km/hr)[c]	
American River Complex		49.1	81/81 (89/89)	5.2/5.3	26	16	0–8 (8)	Safford, 2008
Angora	11.8	57.9	44 (90)	5	23	11	15–30 (65)	Murphy et al., 2007; Safford et al., 2009
Antelope Complex	18.7	48.5	90 (87)	3.7	33	19	10–35 (>60)	Fites et al., 2007; Murphy et al., 2010
Cascadel		58.4	60 (90)	6.4	28	27	0–16 (25)	
Cougar	4.7	10.0	46 (>90)	8	20	32	0–5 (13)	USFS, 2011
Grass Valley			70 (64)	5.2	16	8	15–30 (65)	Rogers et al., 2008
Harding		18.2	51 (62)	6.8	29	18	0–5 (20)	
Milford Grade	8.7	15.5	55 (90)	8.0	22	14	4–30 (53)	USFS, 2010a; Murphy et al., 2010
Peterson			72/71 (91/90)	7.4/7.8	24	17	5–17 (35)	Merriam, 2008; Murphy et al., 2010
Piute	7.9	25.0	97/86 (90/85)	5.8/6.0	29	7	0–11 (37)	Meyer and Safford, 2010
Rich	26.8	56.0	82 (87)	5	32	15	6–10 (30)	USFS, 2009; Murphy et al., 2010
Silver	29.7	36.5	84 (92)	6.5	31	14	9–16 (30)	USFS, 2010b; Murphy et al., 2010

[a] Tons/ha calculated as sum of all surface fuels (1–1000 h[+]). Mean of all measures available for sampled treatments and adjacent untreated stands, data obtained from National Forest staff (field measurements and/or photo series estimates) and/or direct field measurement by our crews in unburned sites. Where both data sources were available, we averaged the two.

[b] Energy Release Component, from the National Fire Danger Rating system. ERC is the 24-h, potential worst case, total available energy (BTUs) per unit area (in feet^2) within the flaming front at the head of a fire. "% ile" is percent of times over a period of many years that ERC falls below (i.e. fire danger is lower than) the measurement given for the given day.

[c] Calculated from the nearest weather station at similar elevation for the day the fuel treatments in question burned. ERC and fuel moisture data courtesy of Larry Hood, US Forest Service Region 5.

Results: Fire severity - typical scenes, untreated vs. treated, one year postfire

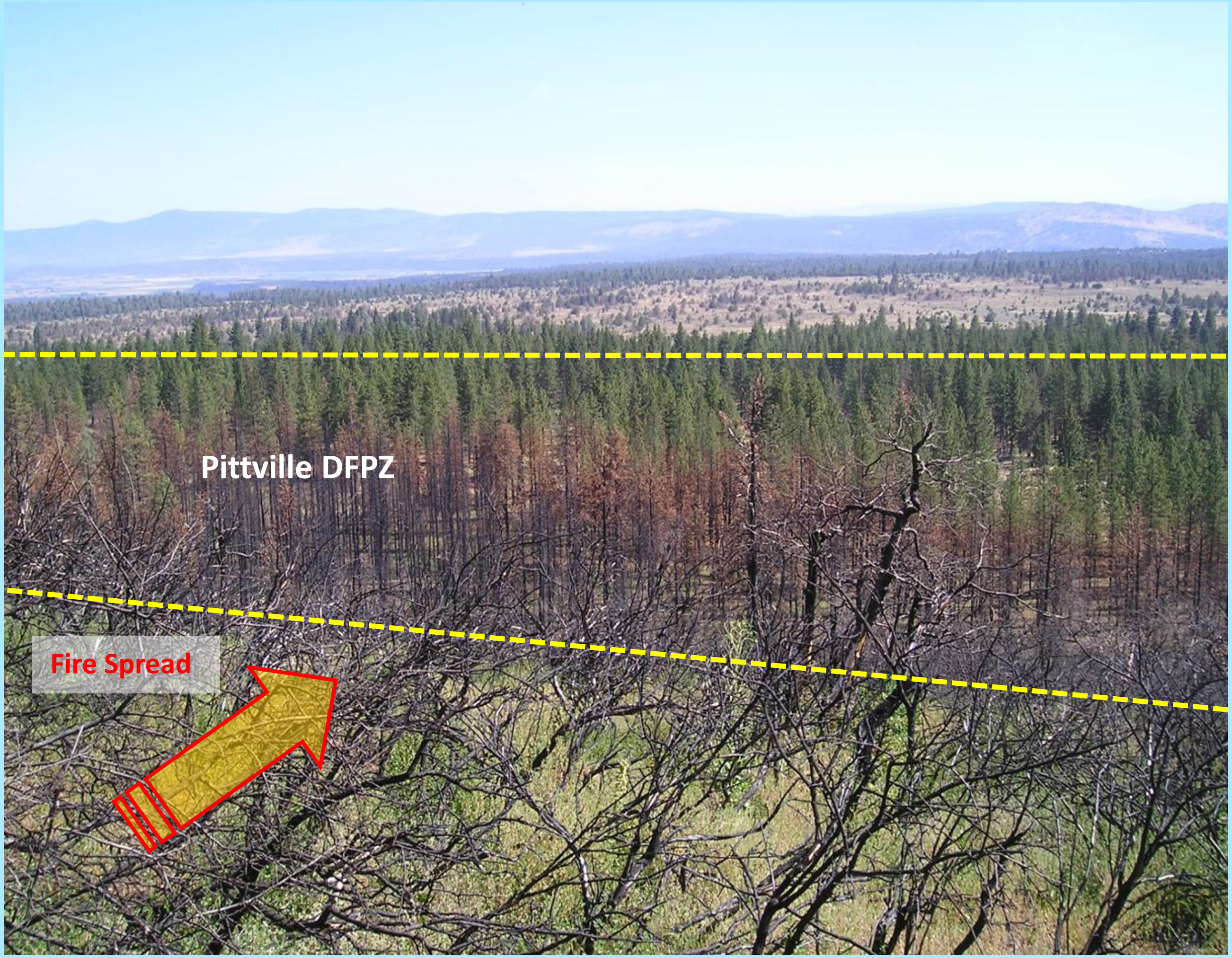


Angora Fire

UNTREATED

TREATED

Peterson Fire, Lassen NF



TREATED

UNTREATED

American River Complex, Tahoe NF

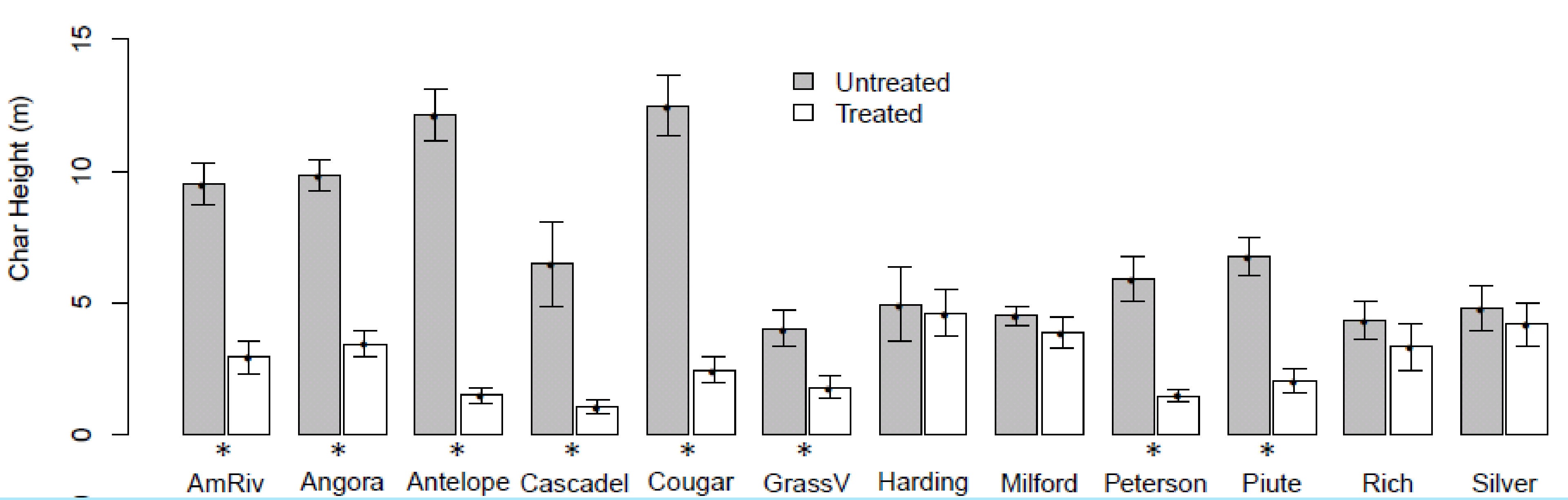
TREATED

UNTREATED

Results: data

<u>Mean fuel loadings</u> – 37.5 tons/ha untreated vs 15.5 tons/ha treated

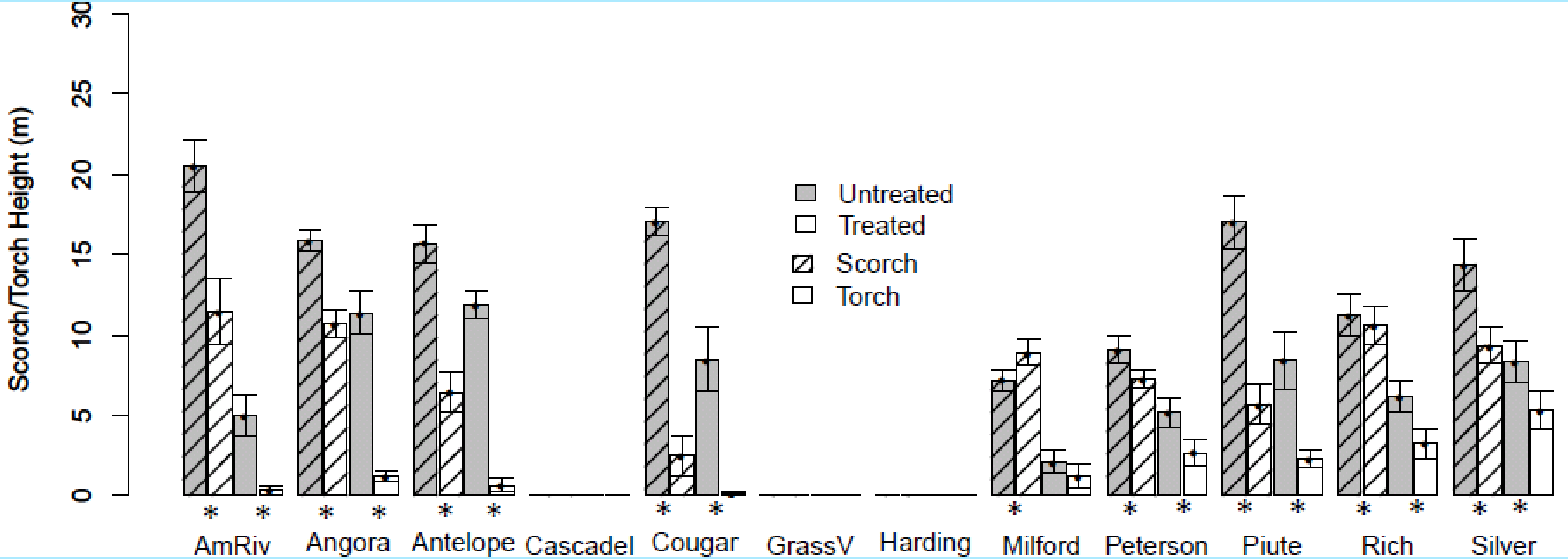
<u>Bole char height</u>



Always higher in untreated stands, statistically significant differences in 8/12 fires.
Average difference = 5.8 m

Results

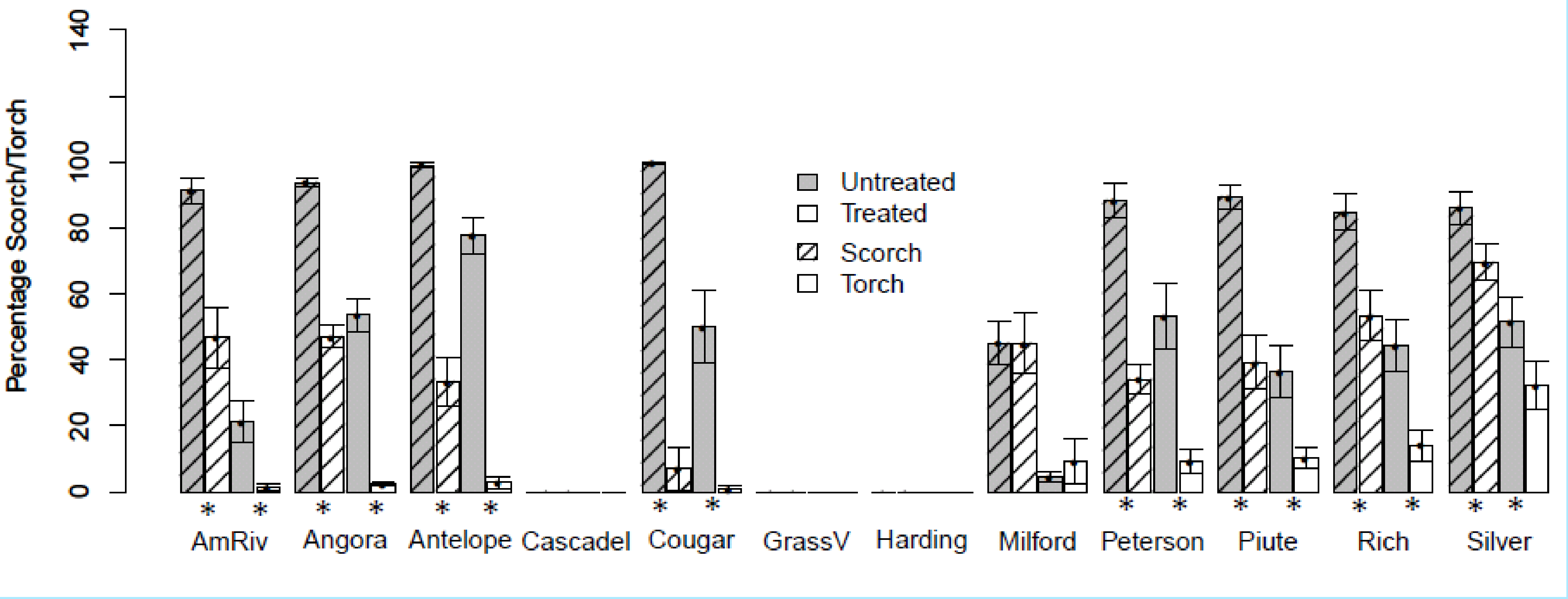
Scorch and torch height



Excepting Milford Fire, always higher in untreated stands, statistically significant in all but one case

Results

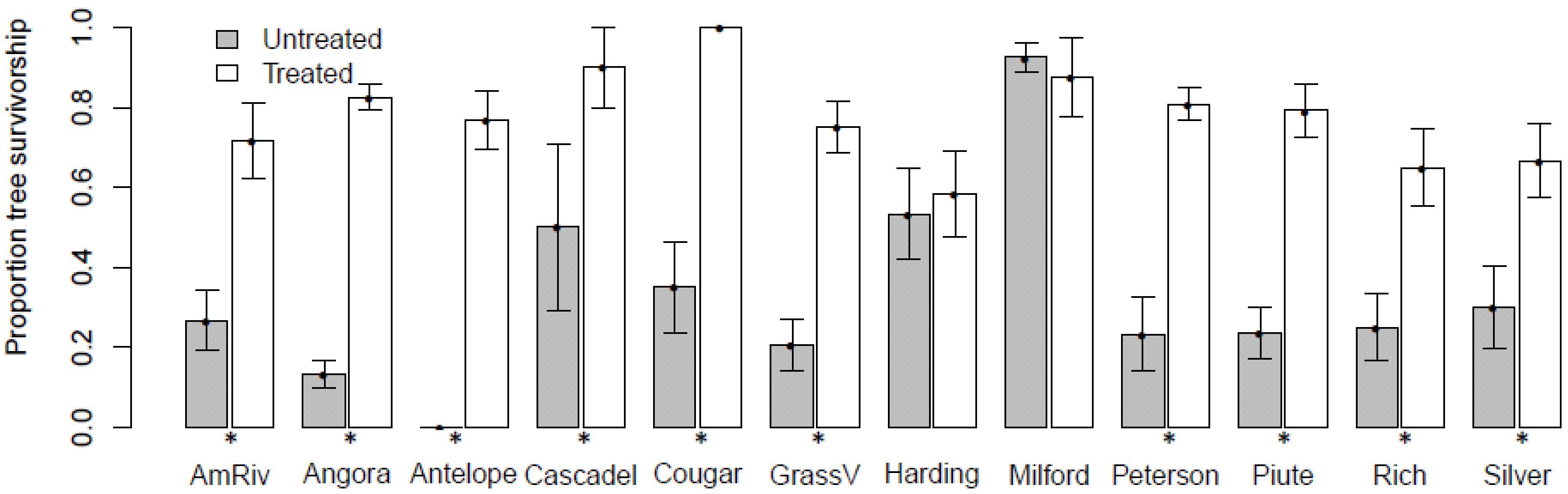
Scorch and torch %



Excepting Milford Fire, always higher in untreated stands, statistically significant in all but one case. Treatments resulted in mean of 46% less crown scorch and 36% less crown torch in burned stands

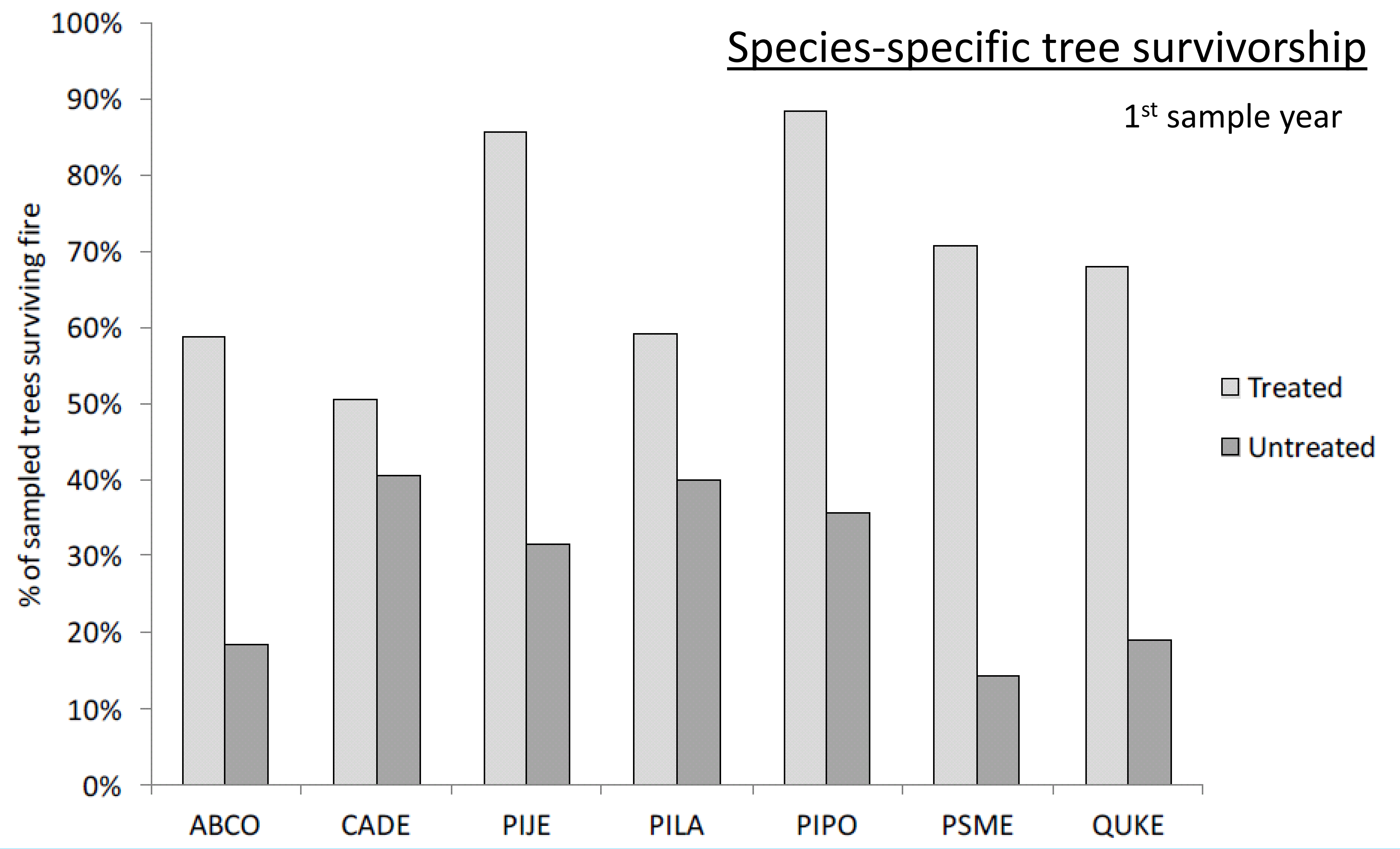
Results

Overall tree survivorship



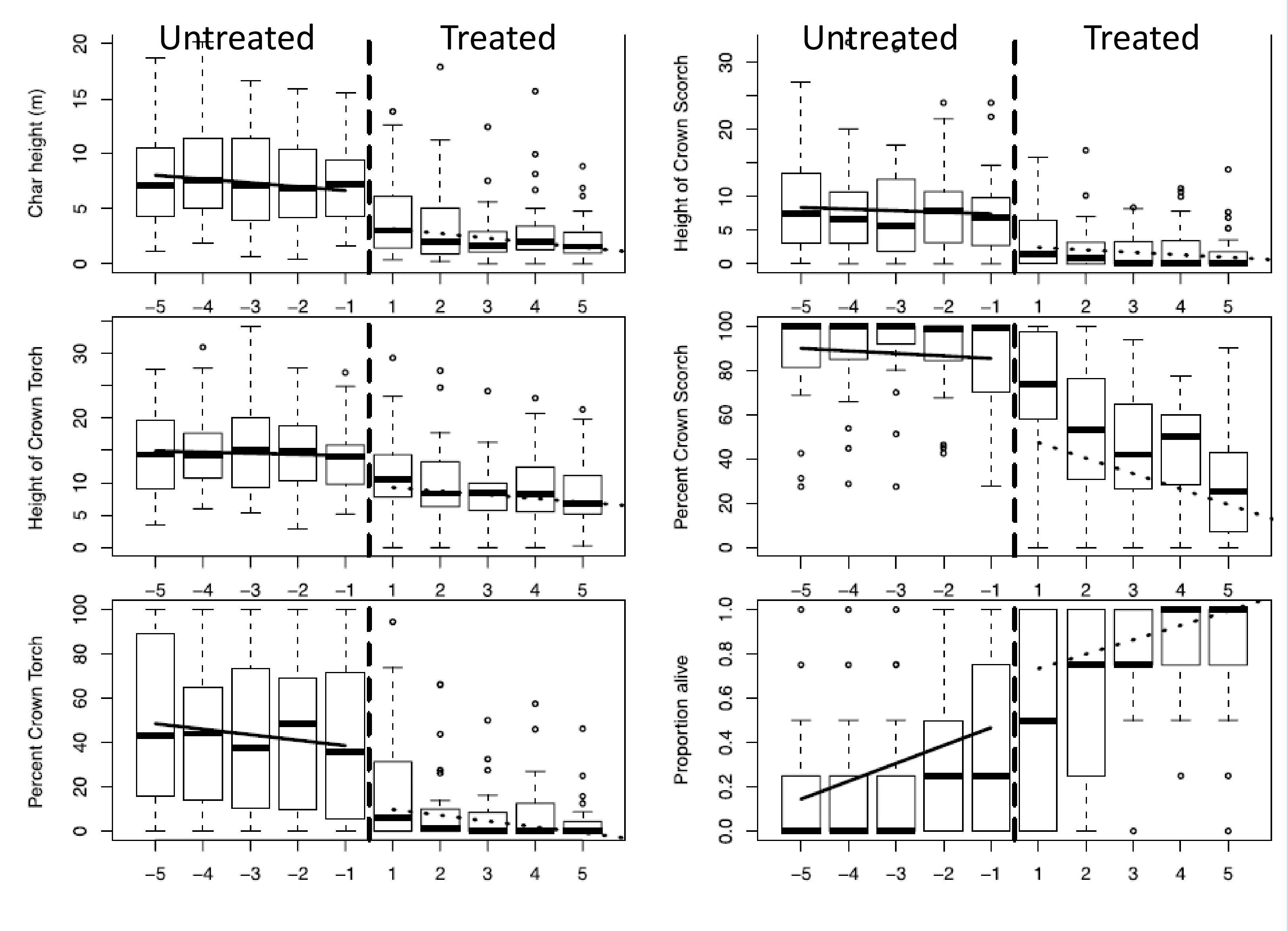
Statistically higher in treated stands in 10/12 fires, Harding and Milford showed no significant difference

Results



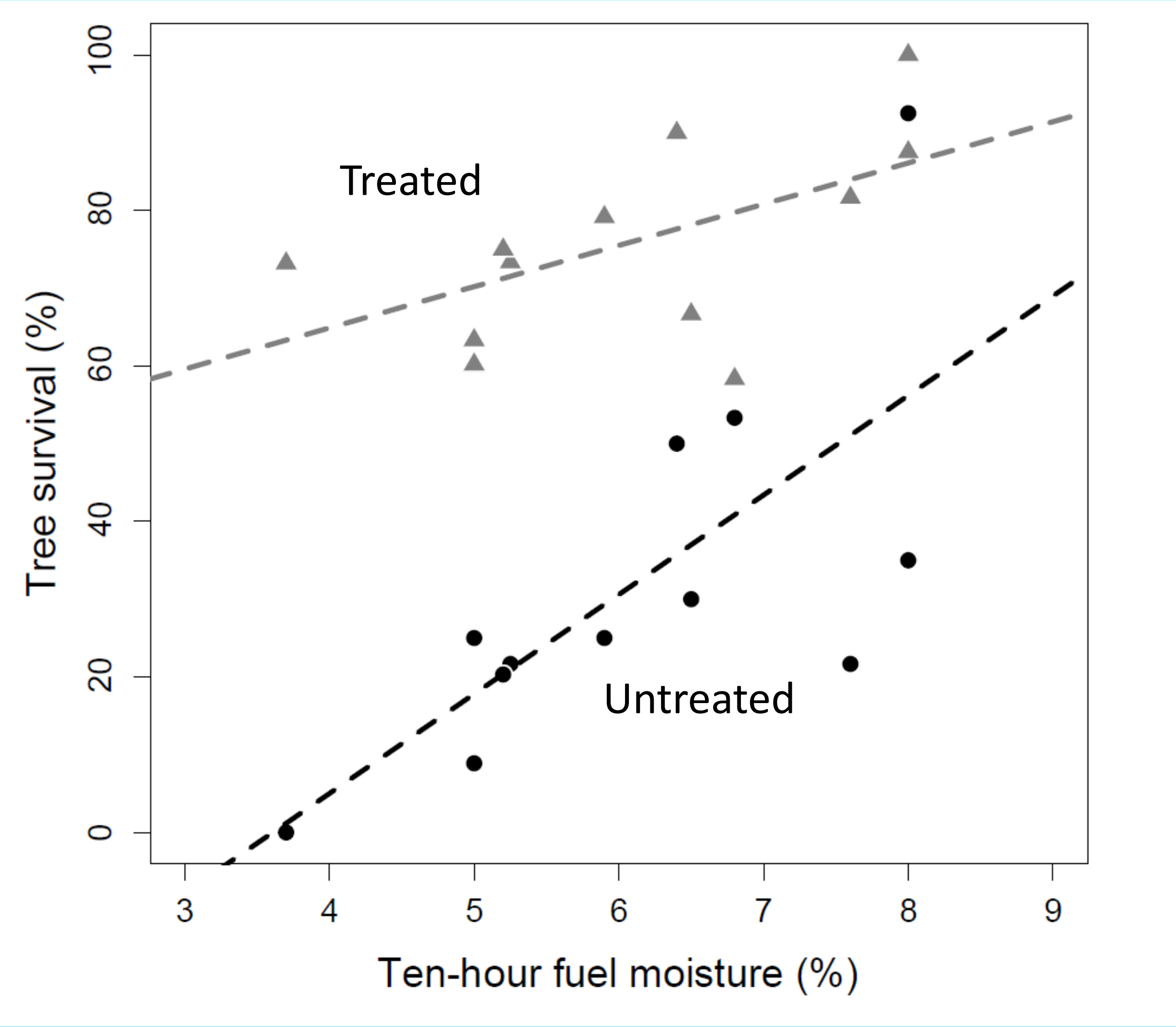
Yellow pines had highest overall survivorship, white fir the lowest

Results: linear trends in severity



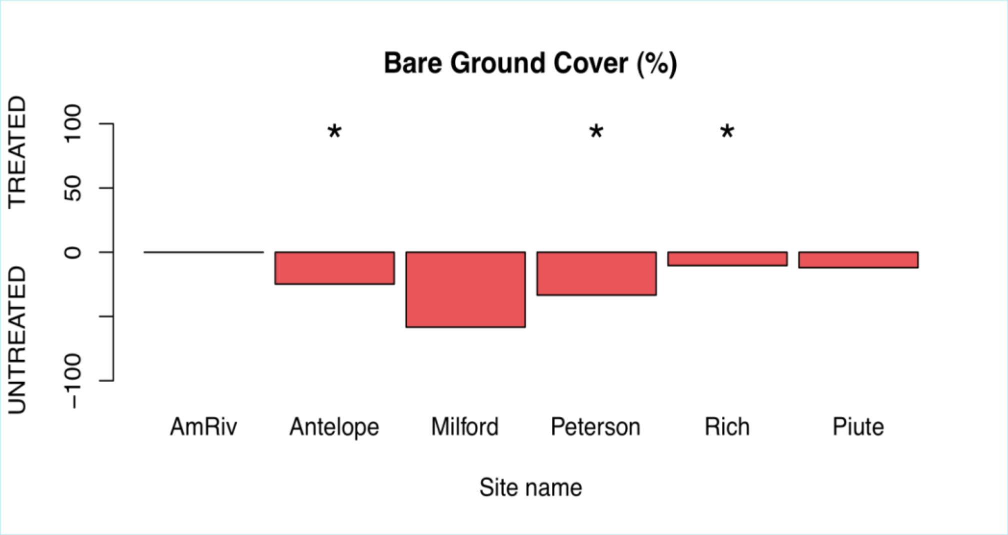
Crown fire transitions to ground fire in 40-70 m under most conditions

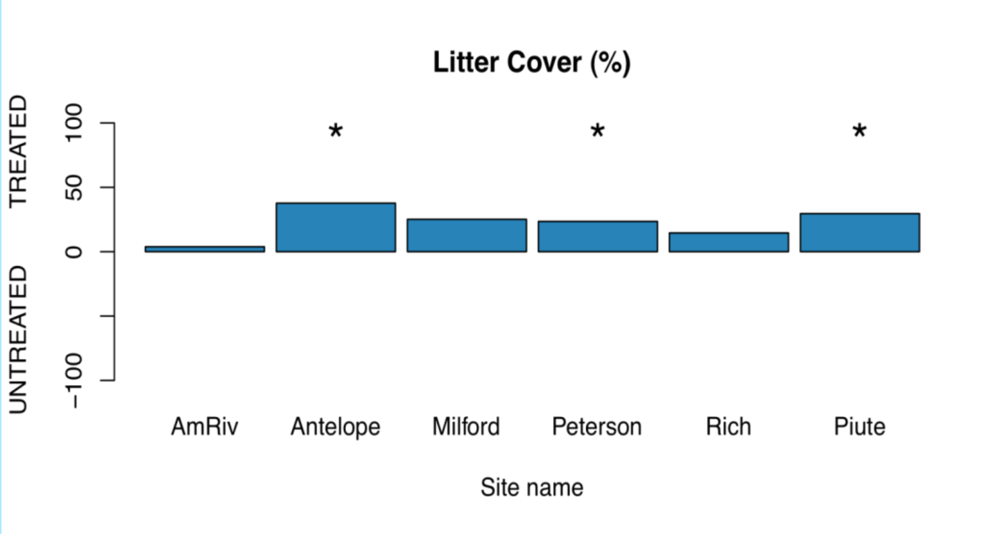
Fuel moisture is a better predictor of mortality in untreated stands, fuel loading a better predictor in treated stands. Slope only important in treated stands.



Some ecological effects…

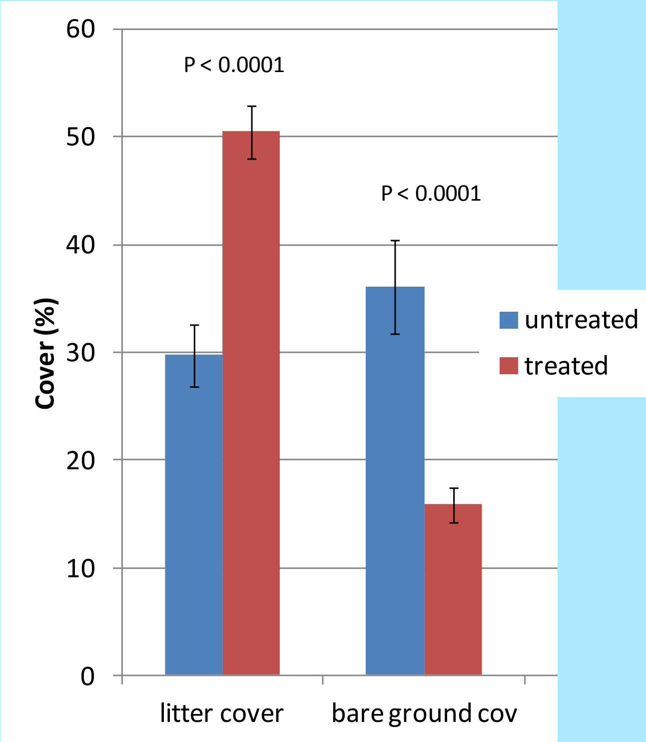
Ground cover





% difference between treated and untreated

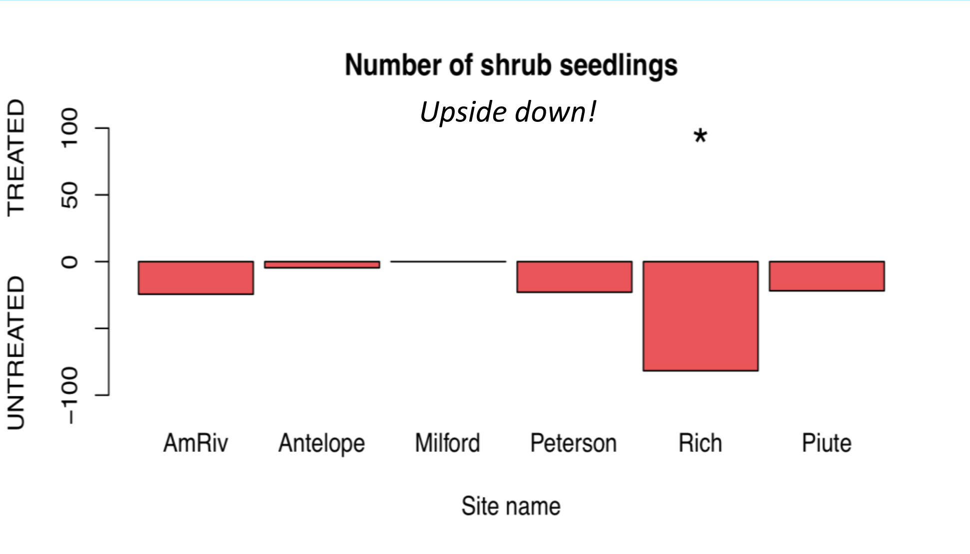
Angora Fire



c. 30% of untreated plots have >60% bare ground, which is a major erosion threshold under heavy rain

Some ecological effects…

Postfire succession

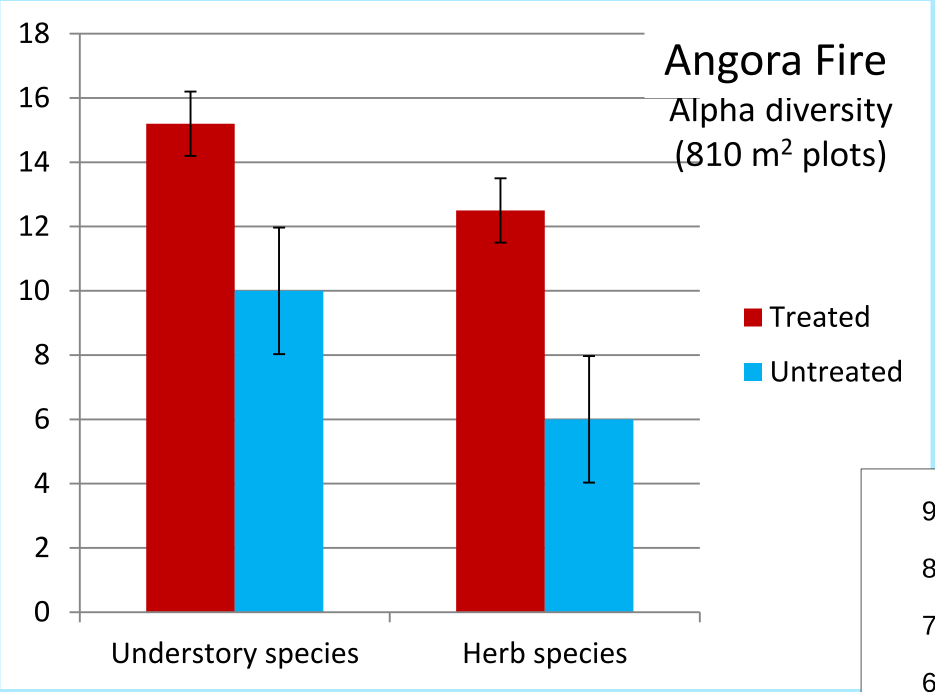


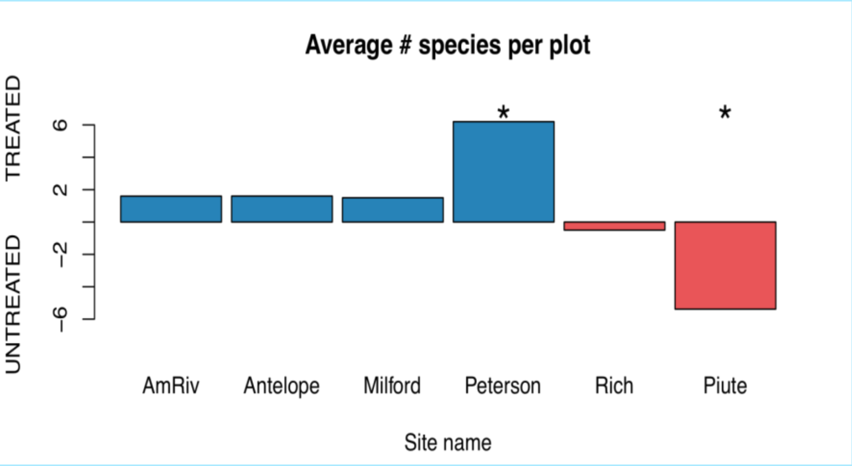
% difference between treated and untreated

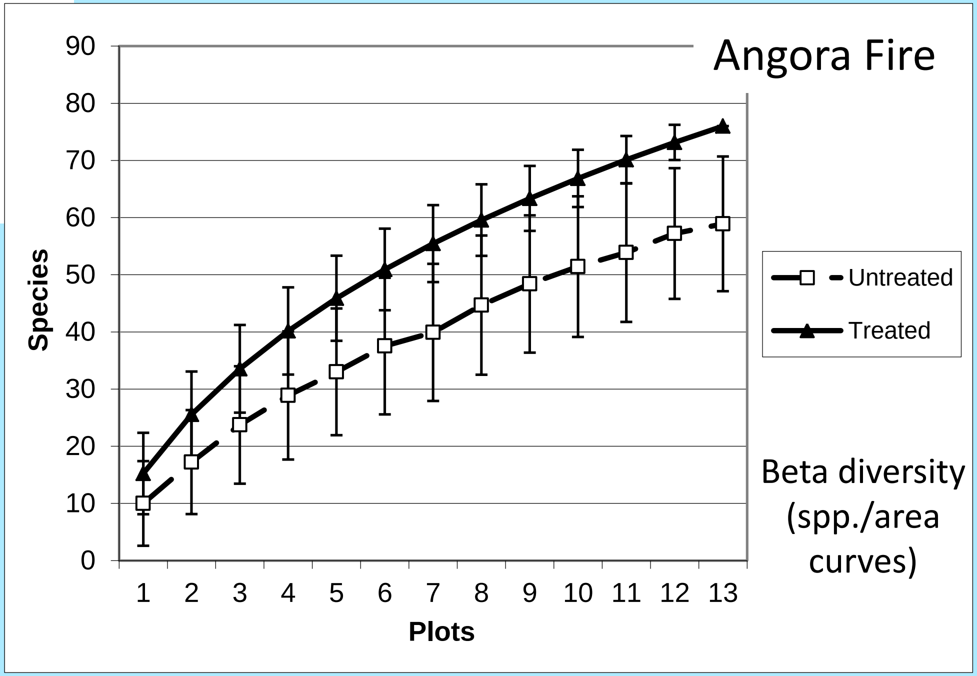
Most severely burned conifer stands will transition to shrubfields for many decades. Depending on the point of view and desired conditions, this successional process has both positive and negative outcomes.

Some ecological effects…

Plant species diversity



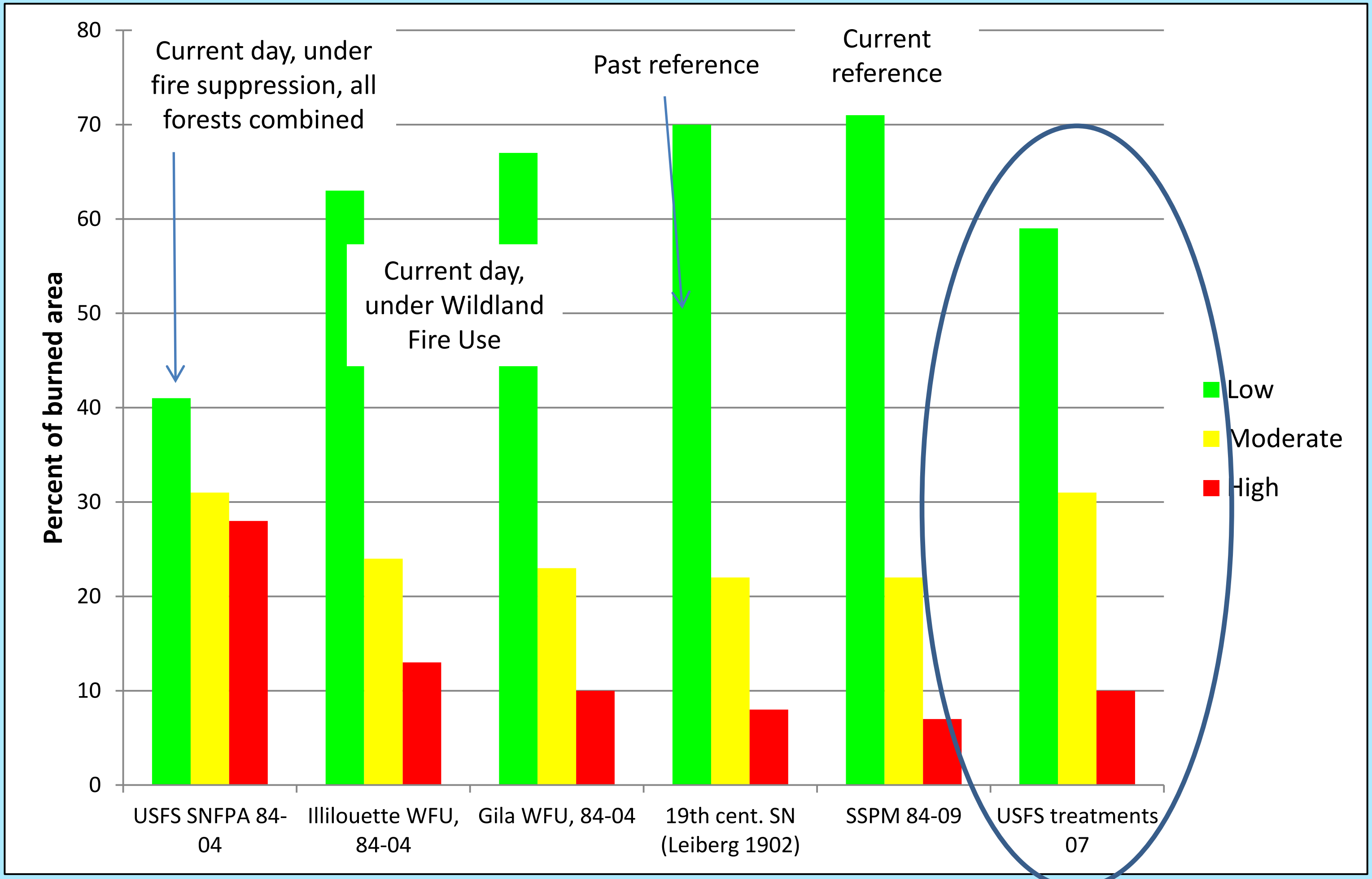




In most of our fires, plant diversity is higher in treated (i.e. less severely burned) stands. Makes evolutionary sense: large areas of stand-replacing fire were relatively rare under natural conditions in FR I forests

Some ecological effects…

Fire severity at the landscape scale



Fuel treatments burn much like reference forests, with similar proportions of hi-mod-low severity fire

Conclusion

Properly implemented fuel treatments in FR I forests work well at slowing fire and ameliorating fire behavior. They also:

- Reintroduce low severity fire to the ecosystem
- Reduce forest density closer to reference conditions
- Restore tree size-class distributions (to dominance by larger trees)
- Increase forest floor light incidence, increasing understory plant diversity and abundance
- Increase heterogeneity in stand structure at multiple scales = positive influence on animal diversity and abundance
- Reduce large tree mortality in subsequent fire = increased carbon retention, ecosystem resilience, aesthetics
- Reduce postfire soil erosion by reducing fire severity and canopy mortality

Prefire fuel treatment in Fire Regime I forests is relatively easy to align with ecological restoration goals

Treatment

- Treatments restricted primarily to surface and ladder fuels, older/larger trees retained, drought- and fire-tolerant spp. should be favored
- Prescribed fire should be utilized whenever possible
- Periodic re-entry is necessary for maintenance
- Follow GTR-220 principles for stand structure and heterogeneity

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Thank you

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