# Mechanistic Modeling for Future Forest Management: Predicting Vegetation Shifts in a Dry Mixed Conifer Forest

06/25/2024

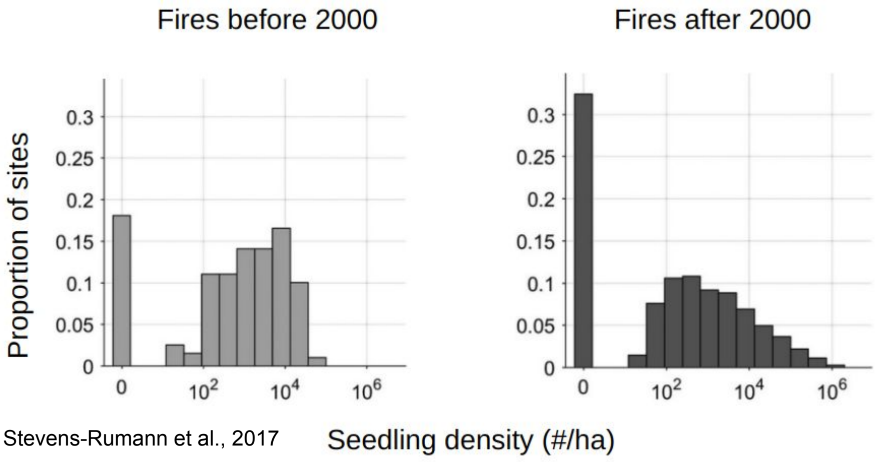
Adam Hanbury-Brown, Claire Tortorelli, Derek Young, Charlie Koven, Xiulin Gao, Ryan Knox, Lara Kueppers, Jennifer Holm, Andrew Latimer

# Widespread concern for dry mixed conifer forests

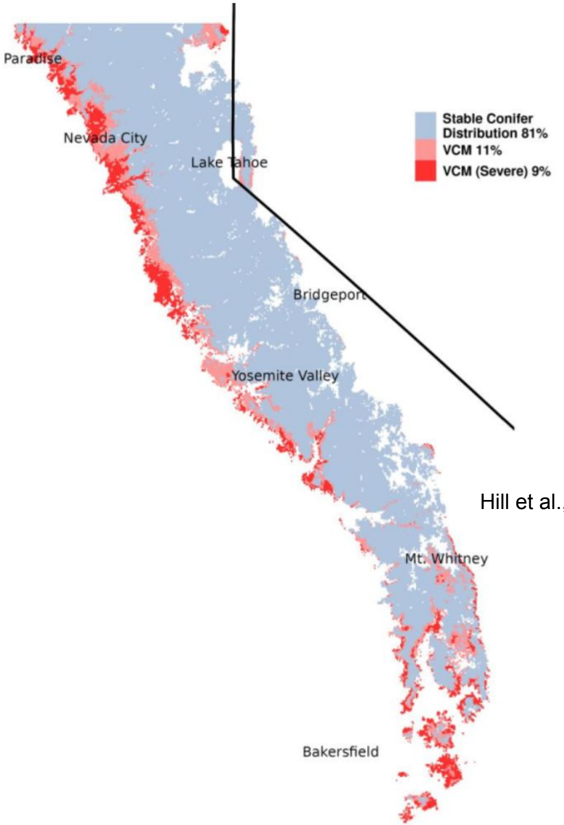
1.2 °C warming since 1930

Vegetation-climate mismatch

Declines in regeneration




Stevens-Rumann et al., 2017




Hill et al., 2023

# Life history strategies in dry mixed conifer forests

## Resist fire, recruit from seed


## Persist in the shade


## Post-fire resprouting


Basal resprouts

## Seed banking

# Managers need projections of future vegetation

To plan climate-smart management interventions

- Where to thin?
- How much to thin?
- How long do fuel reduction treatments last?

How do we best prioritize resources?

Will current practices work in the future?


Photo credit: Sierra Nevada Conservancy

# More mechanistic projections are needed

Prior model predictions omit

- Explicit competition within and between pfts
- Management
- Species' life history strategies
- Ecophysiology

Reliance on shifts in bioclimatic niche

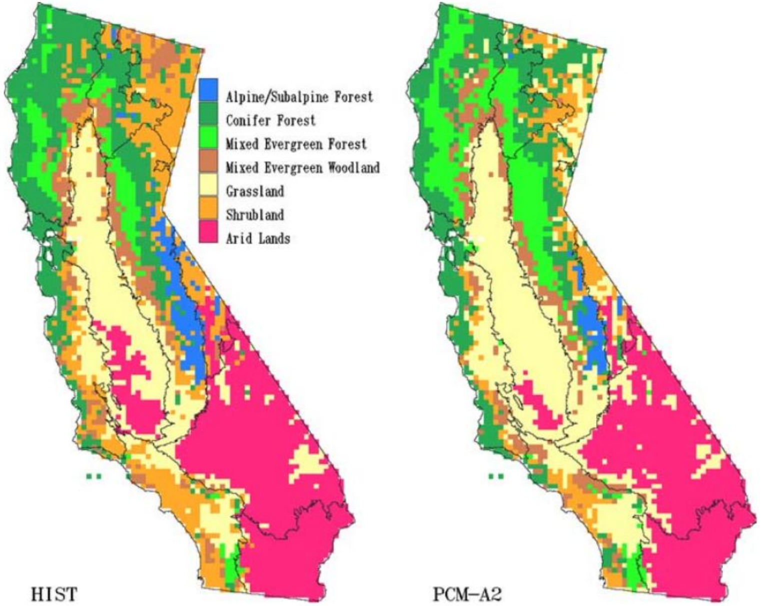



**Fig. 1** Distribution of the vegetation classes simulated for the historical (1961–1990) and PCM1-A2 future period (2070–2099). The vegetation class mapped at each grid cell is the most frequent class simulated during the time period

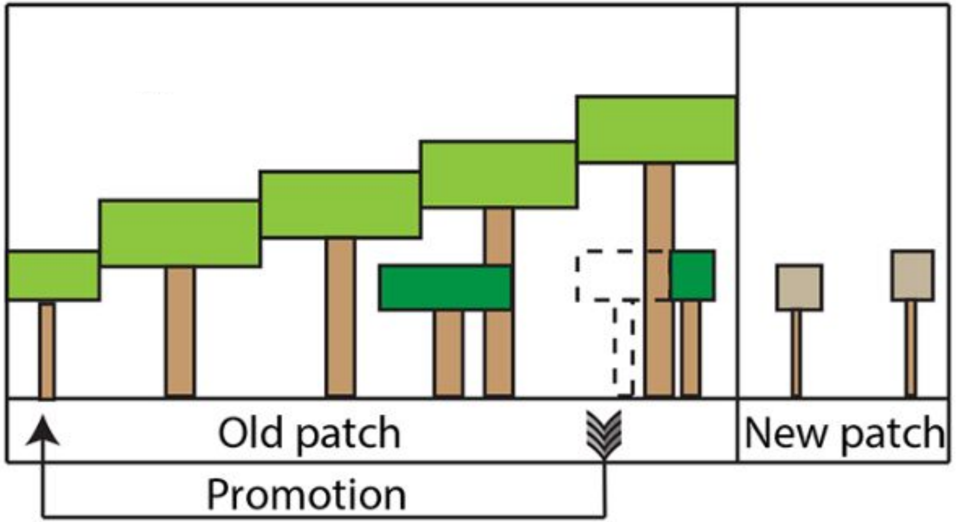
Lenihan et al., 2007

# The Functionally Assembled Terrestrial Ecosystem Simulator

FATES

Represents:

- Ecophysiology
- Competition
- Disturbance - recovery
- Life history strategies
- SPITFIRE (Thonicke, 2010)




Challenges:

- Data hungry (> 200 params)
- No training wheels
- Coexistence is hard

# Research Question and Hypothesis

Question: How do fuel reduction treatments affect future climate and fire resiliency of mixed conifer forest in the Sierra Nevada?

Hypothesis: Future climate and fire will favor shrubs and oaks over conifers, but thinning will make conifer trees more resilient to change

## 5 PFTs


Used Buotte, 2021 as a starting point for conifer PFTs

# Model parameterization and evaluation

**First goal**: Find parameter sets that accurately simulate a pre-Euro-American settlement (PEAS) forest

- Used literature and plant trait databases (e.g. TRY, BAAD, Tallo) to empirically constrain the ranges of key model parameters
- Tested 5,376 possible parameter combinations (ensemble members)
- Simulated a forest using pre-industrial climate and CO2 and allowing it to run for 700 years

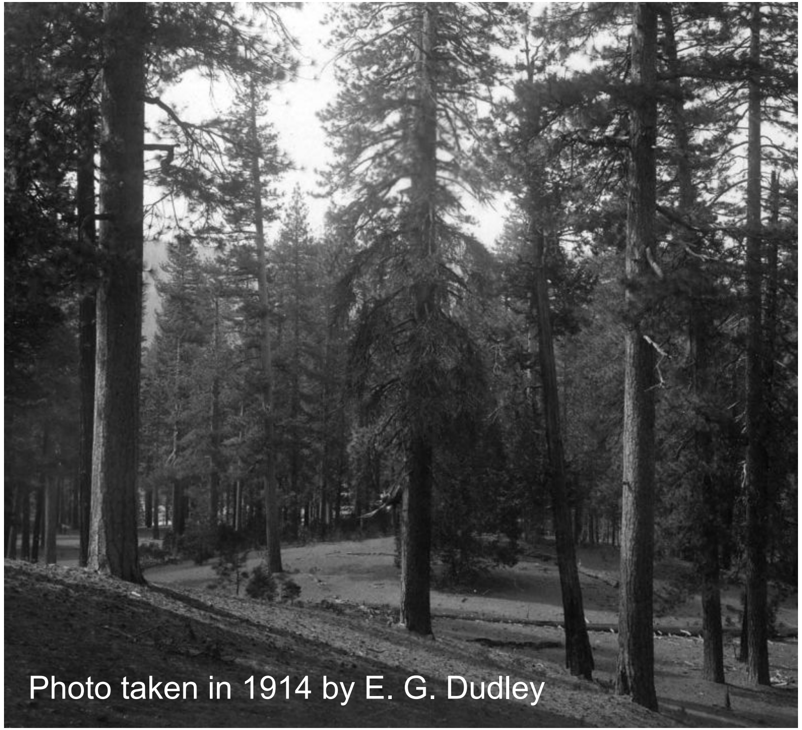
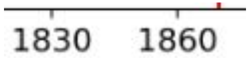


Photo taken in 1914 by E. G. Dudley

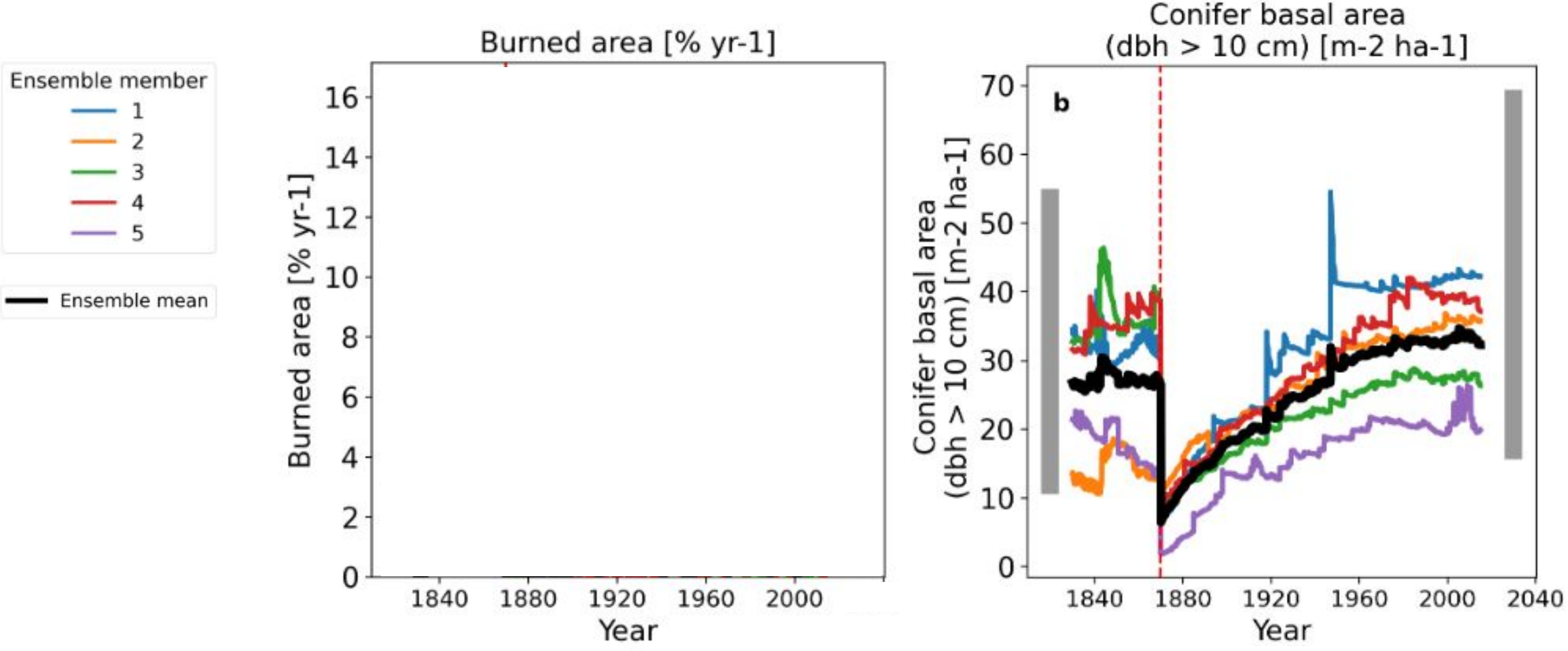
# We evaluated the model in 1870 and 2015 then projected out to 2100

700 yr spin-up with PEAS fire regime

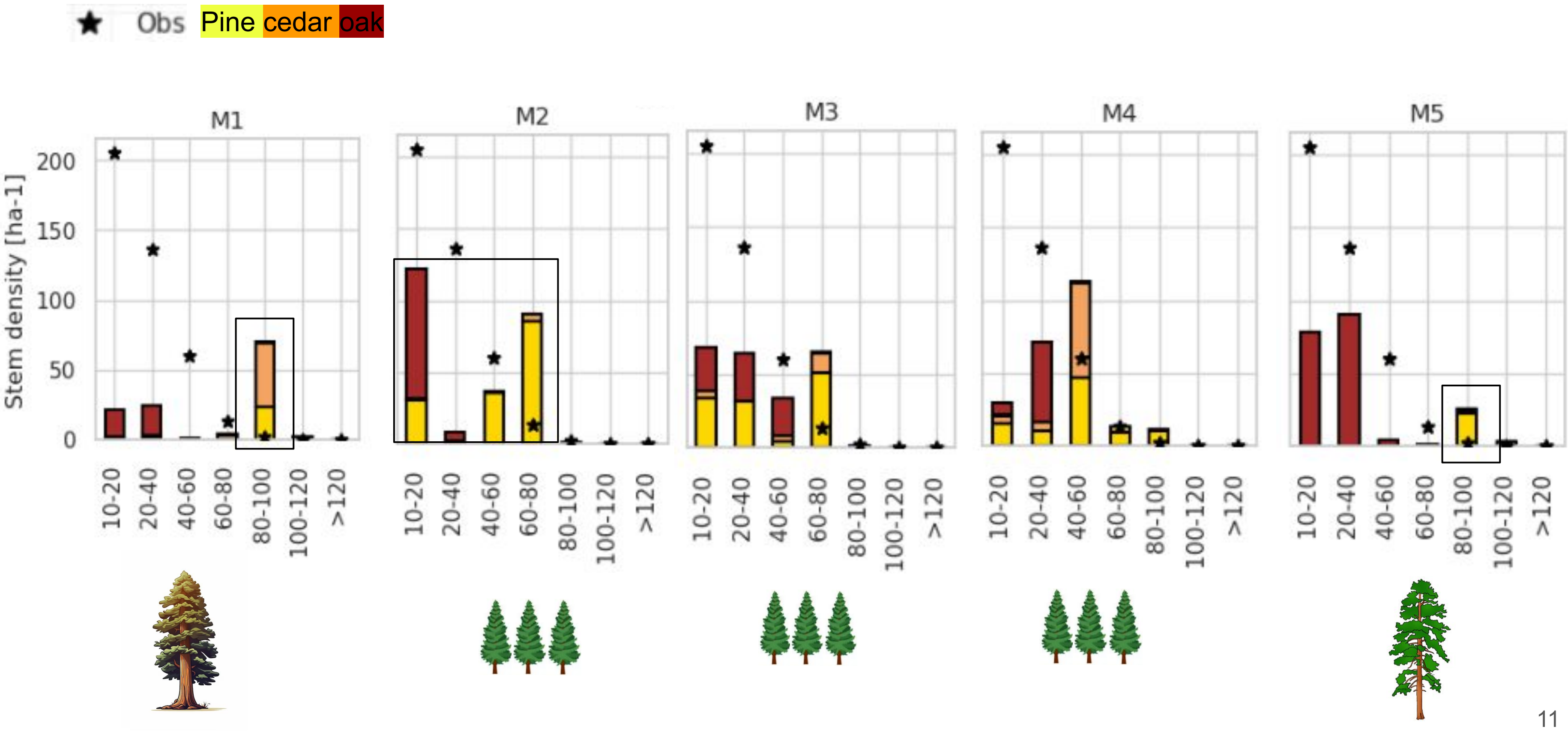



PI climate + $CO_2$

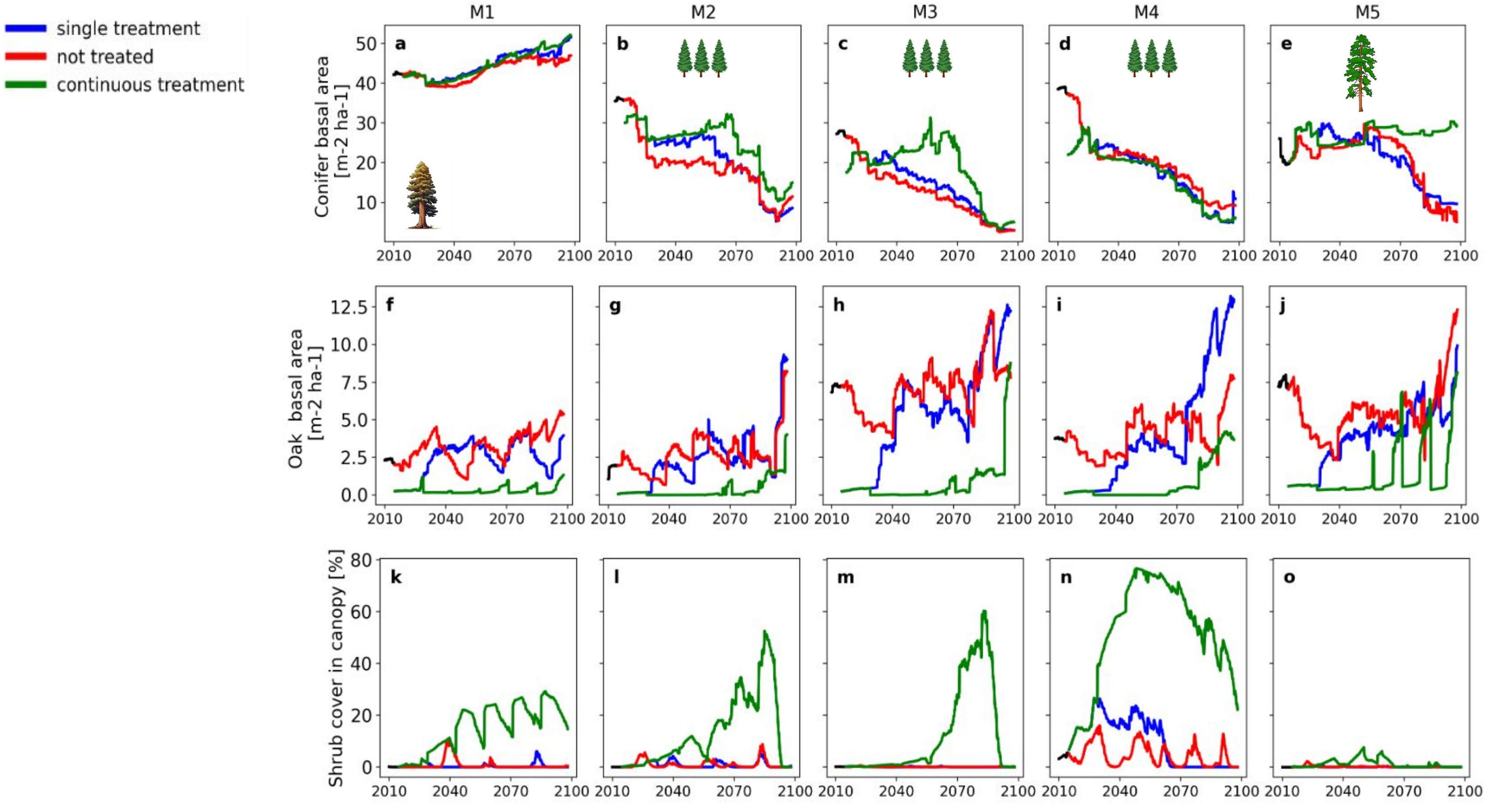
# Model reproduces historical fire regimes and forest structure



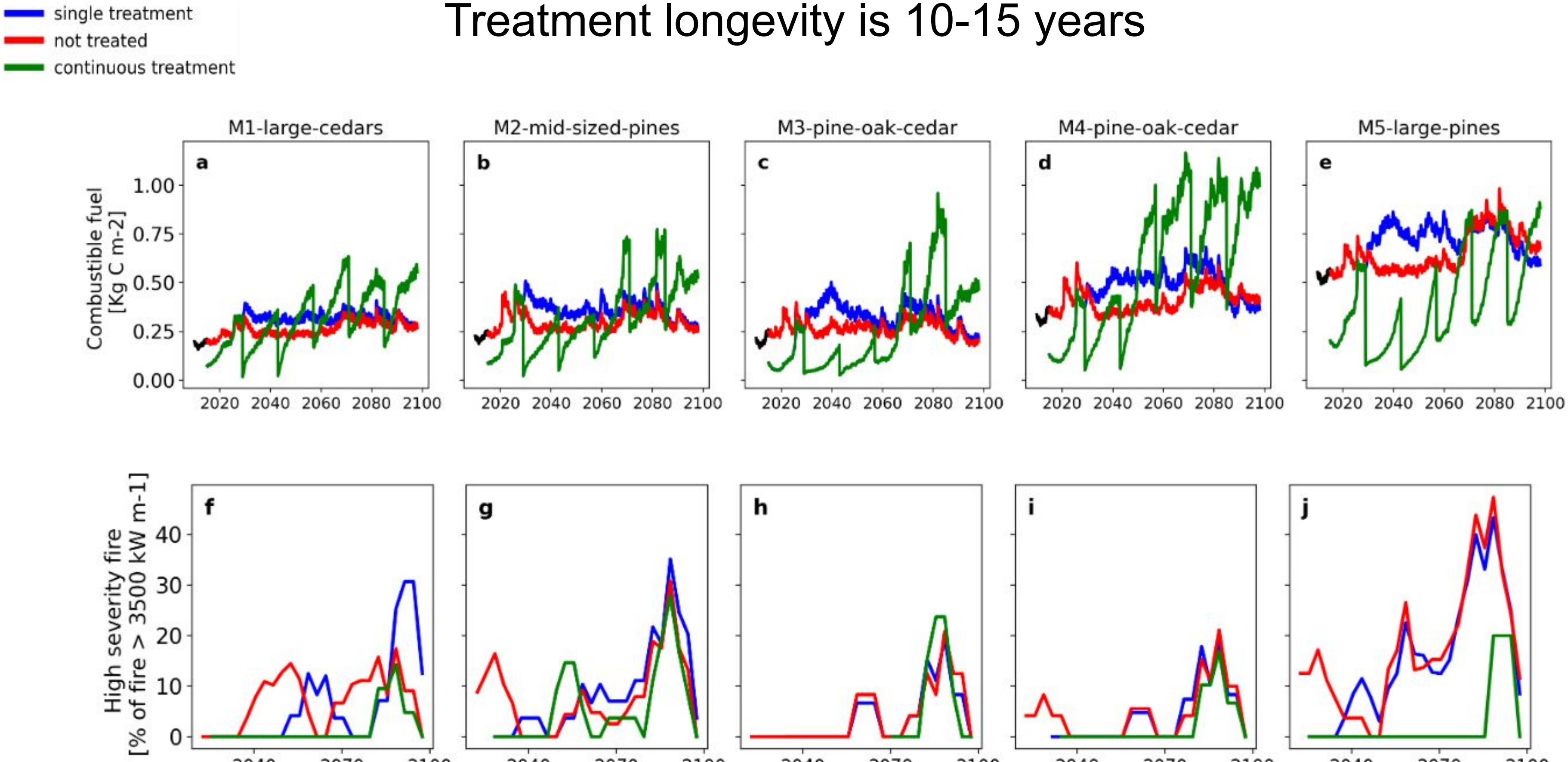
# Each ensemble member differs in structure and composition



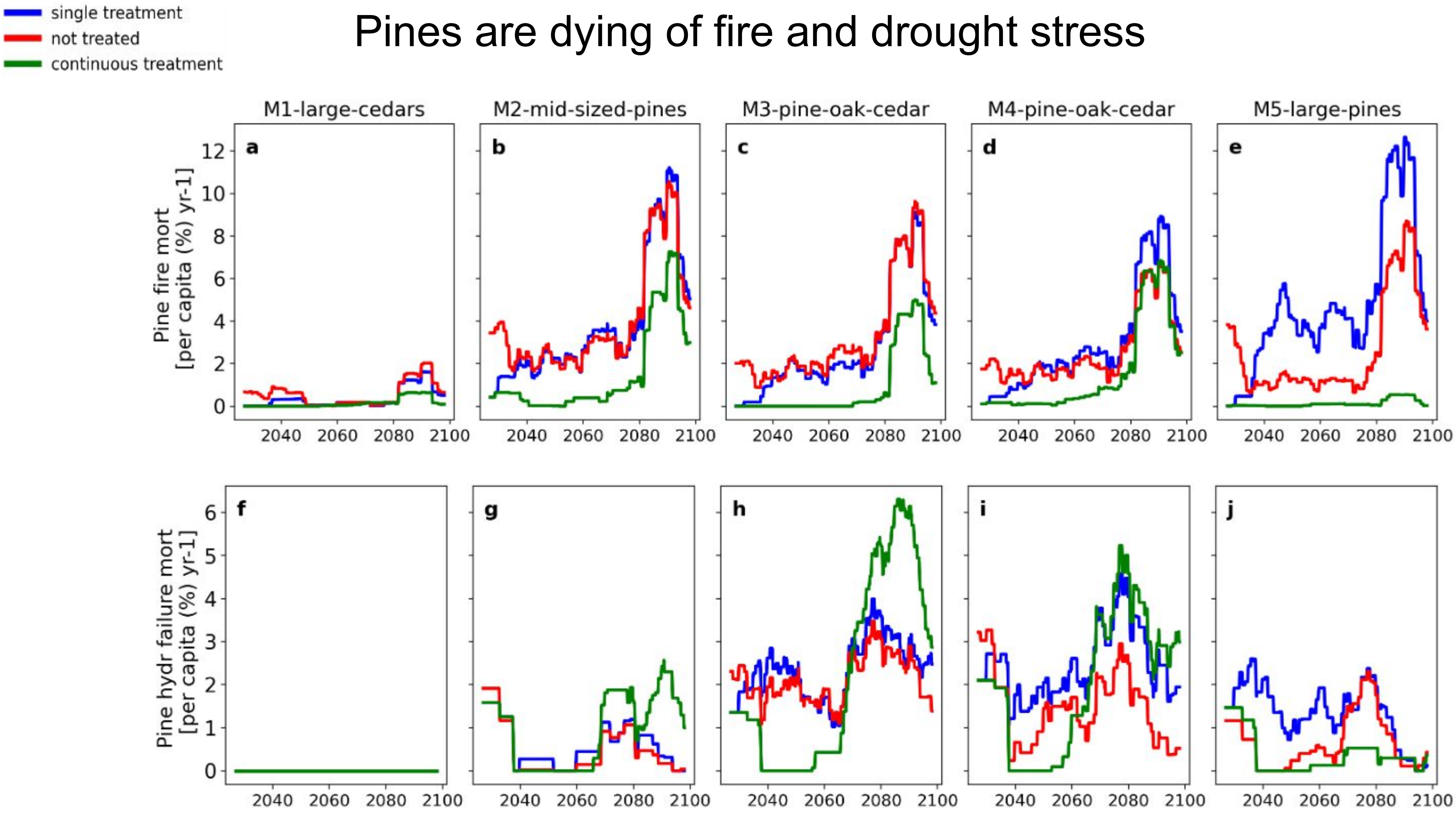
# Model predicts a shift from conifers to oaks



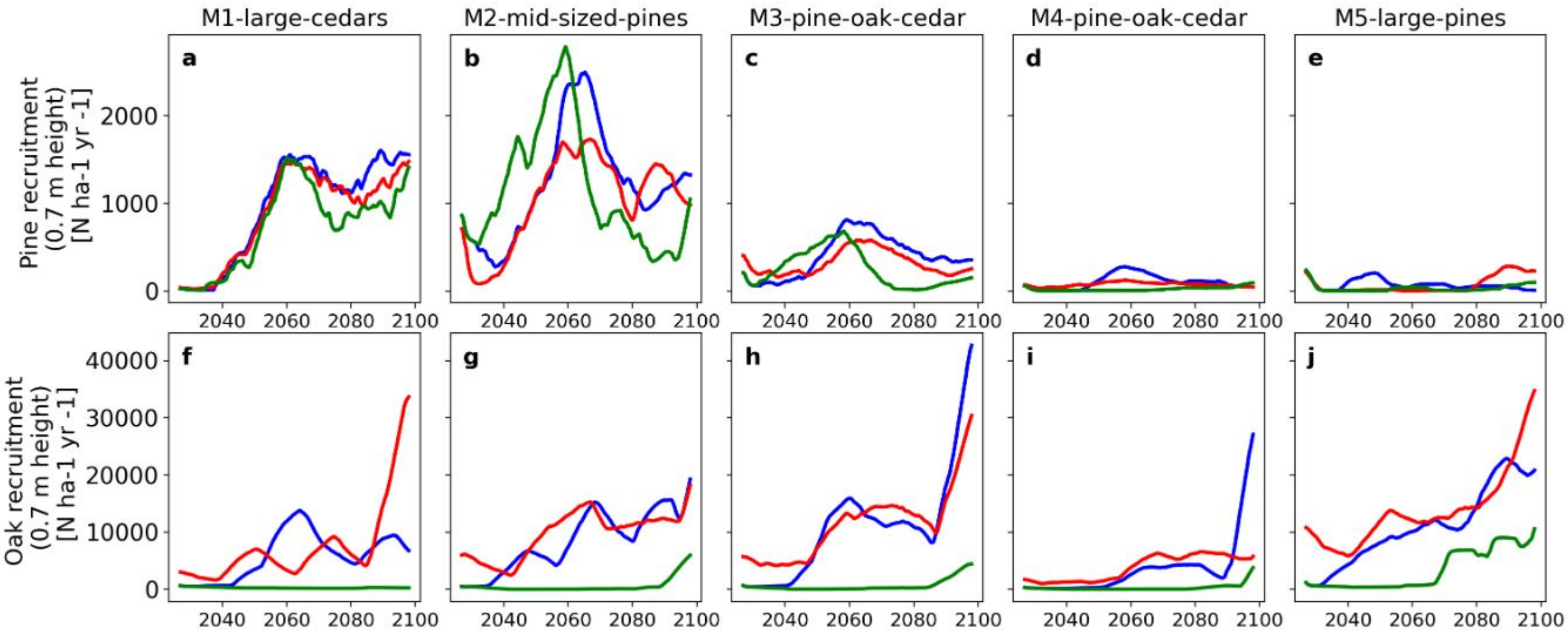
# Treatment longevity is 10-15 years



# Pines are dying of fire and drought stress



# Oaks stay more productive and recruit at higher rates



# Implications for management

- Single treatments not effective in long-term
- Continuous treatment more effective, but conifer declines still possible (especially after 2060)
- Prioritize conservation of large cedars
- Prioritize stands of large pines for treatment
- Efficacy of fuel reduction can change over time (e.g. shrub-fuel feedback)

Photo credit: Sierra Nevada Conservancy

# Management outcomes will depend on key physiological traits and processes

**Most influential traits and parameters**

1. Litter decomposition rates
2. Oak specific leaf area
3. Pine, oak, and cedar Vcmax (drives photosynthesis rates)
4. Oak scorch height
5. Shrub diameter to crown area ratio
6. Shrub leaf turnover rates

Wayne S. Grazio via Flickr

# Next Steps

- Collect data on most influential parameters
- Run with alternate future climate scenarios
- Regional simulations

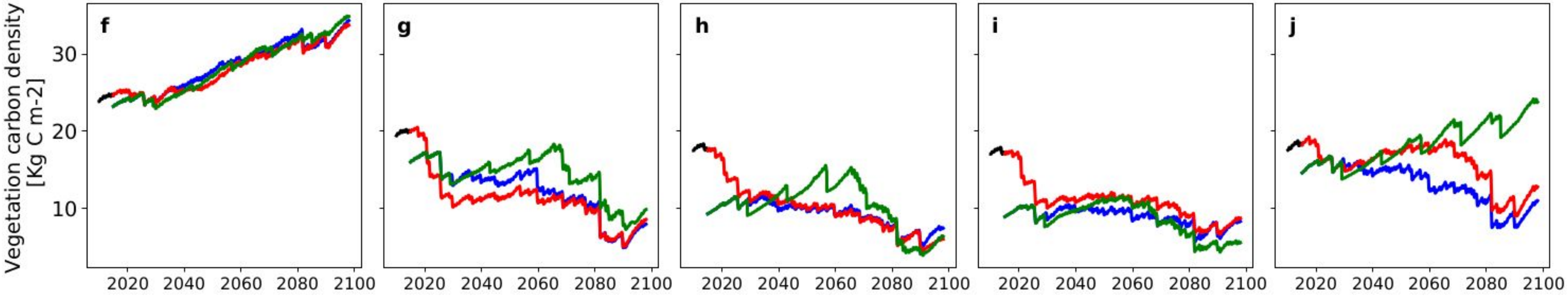

UCDAVIS
UNIVERSITY OF CALIFORNIA
CAL FIRE
SINCE 1885
FATES
BERKELEY LAB

# Thank you!


Thank you!

# Extra Slides Below

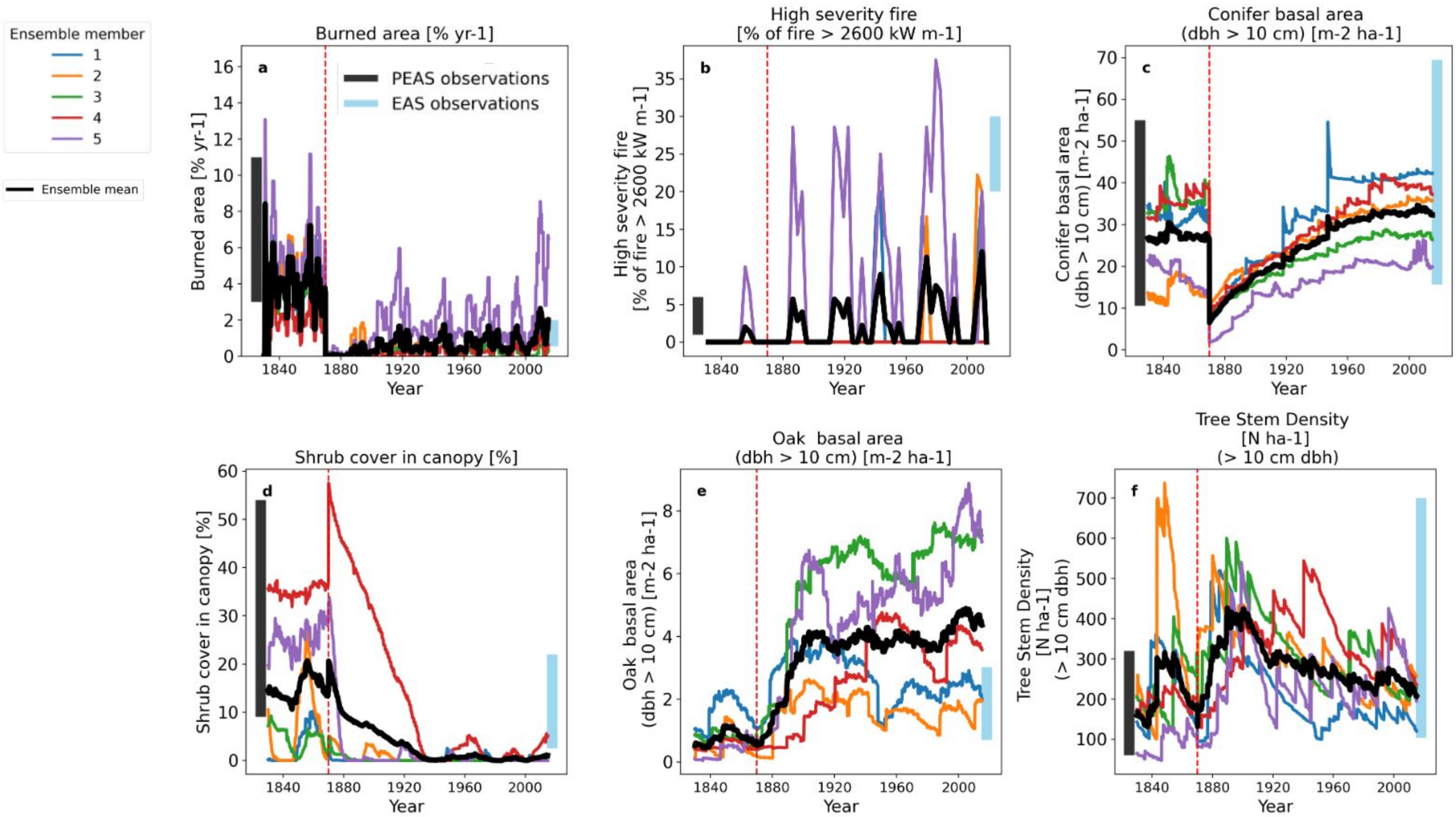
# Carbon stocks decrease when conifer basal area decreases



# Ecological criteria for PEAS MCF forest

| Criterion | Supporting observations |
| --- | --- |
| Annual burned area is 2-12% of land area | Mallek et al., 2013; Safford and Stevens, 2017; Williams et al., 2023 |
| Fires are predominantly low intensity (mean fire line intensity < 350 kW m-1) | Mallek et al., 2013; Safford and Stevens, 2017; Williams et al., 2023 |
| Conifer basal area is 10 – 55 m2 ha -1 | Scholl & Taylor, 2010; Collins et al., 2015; Stephens et al., 2015; Safford & Stevens, 2017 |
| Tree stem density (> 10 cm dbh) is < 400 N ha-1 | Knapp et al., 2012; Stephens et al., 2015; Safford and Stevens, 2017 |
| There are ≥ 5 "big" (> 80 cm dbh) conifers ha-1 | Safford and Stevens, 2017 |
| Some pine survives (> 1 $m^2$ $ha^{-1}$ pine basal area) | Safford and Stevens, 2017; Stephens et al. 2015 |
| Some oak survives (> 0.1 $m^2$ $ha^{-1}$ oak basal area) | Safford and Stevens, 2017; OAK CITATION |
| Shrub cover is 5-54% of the site's surface area | Show & Kotok, 1924; Bonnicksen & Stone, 1982; Cronemiller, 1959; Knapp et al., 2013; Collins et al., 2015; Stephens et al., 2015; Safford & Stevens, 2017 |
| NPP is 0.54-0.9 g C m-2 yr -1 | Tague et al., 2009; He et al., 2012; Goulden et al., 2012; Dore et al., 2016; Bogan et al., 2018 |
| All pfts coexisting (> 0.1 m2 ha-1 of basal area per pft) | Coexistence required for model experiment |

| Parameter | Pft | M1 | M2 | M3 | M4 | M5 |
|---|---|---|---|---|---|---|
| fates_frag_maxdecomp | all | 87 | 98 | 10 | 81 | 42 |
| fates_leaf_slatop | oak | 90 | 94 | 32 | 86 | 77 |
| fates_leaf_vcmax25top | oak | 72 | 20 | 92 | 63 | 31 |
| fates_leaf_vcmax25top | pine | 13 | 38 | 60 | 33 | 75 |
| fates_leaf_vcmax25top | cedar | 38 | 44 | 5 | 9 | 38 |
| fates_fire_alpha_SH | oak | 94 | 48 | 60 | 3 | 40 |
| fates_allom_d2ca_coefficient_max | shrub | 98 | 8 | 52 | 64 | 68 |
| fates_leaf_slatop | pine | 97 | 59 | 92 | 79 | 57 |
| fates_allom_agb1 | oak | 97 | 34 | 98 | 91 | 45 |
| fates_leaf_vcmax25top | shrub | 31 | 29 | 83 | 8 | 74 |
| fates_frag_seed_decay_rate | shrub | 66 | 11 | 33 | 62 | 85 |
| fates_turnover_leaf | shrub | 1 | 19 | 51 | 18 | 51 |
| fates_leaf_slatop | fir | 97 | 56 | 73 | 92 | 34 |
| fates_leaf_slatop | cedar | 97 | 56 | 73 | 92 | 34 |
| fates_recruit_seed_alloc_mature | pine | 84 | 23 | 4 | 72 | 2 |
| fates_fire_drying_ratio | all | 63 | 39 | 73 | 8 | 83 |
| fates_recruit_seed_germination_rate | conifer | 68 | 86 | 18 | 41 | 87 |
| fates_nonhydro_smpsc | pine | 74 | 25 | 0 | 11 | 59 |
| fates_fire_frac_resprout | shrub | 60 | 5 | 70 | 55 | 19 |
| fates_nonhydro_smpsc | fir | 34 | 11 | 54 | 29 | 71 |
| fates_turnover_leaf | oak | 0 | 44 | 96 | 12 | 53 |
| fates_alloc_storage_cushion | oak | 42 | 49 | 56 | 58 | 42 |
| fates_recruit_seed_dbh_repro_threshold | conifer | 39 | 58 | 67 | 73 | 54 |
| fates_leaf_vcmax25top | fir | 44 | 48 | 15 | 10 | 62 |
| fates_nonhydro_smpsc | cedar | 61 | 88 | 8 | 85 | 38 |



Ensemble member
1
2
3
4
5
Ensemble mean
Burned area [% yr-1]
a
PEAS observations
EAS observations
Burned area [% yr-1]
Year
High severity fire
[% of fire > 2600 kW m-1]
b
High severity fire
[% of fire > 2600 kW m-1]
Year
Conifer basal area
(dbh > 10 cm) [m-2 ha-1]
c
Conifer basal area
(dbh > 10 cm) [m-2 ha-1]
Year
Shrub cover in canopy [%]
d
Shrub cover in canopy [%]
Year
Oak basal area
(dbh > 10 cm) [m-2 ha-1]
e
Oak basal area
(dbh > 10 cm) [m-2 ha-1]
Year
Tree Stem Density
[N ha-1]
(> 10 cm dbh)
f
Tree Stem Density
[N ha-1]
(> 10 cm dbh)
Year