From Past to Present: Revised Estimates of Historical Burned Areas and Emissions in California, and Modern Deviations from Pre-Euroamerican Settlement Fire Return Itervals

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CALIFORNIA DEPARTMENT OF FORESTRY & FIRE PROTECTION
CAL FIRE
SINCE 1885

CALIFORNIA CLIMATE INVESTMENTS
Cap and Trade Dollars at Work

Introduction

California fire regimes are changing at an increasingly rapid pace, leading to ecosystem degradation and increasingly risky conditions for humans

- Increasing smoke from giant wildfires
- Ecosystem impacts of changing fire frequencies
    - Too little fire in montane forests
    - Too much fire in SoCal, Great Basin, and near urban areas
- Conifer forests are having trouble recovering from large and severe fires

Introduction

Science-based responses to these phenomena require consideration of temporal trends

- Directional change only discernable by knowing the starting point
- Reference or baseline conditions needed to understand direction and magnitude of change, and provide context for current conditions
- For some phenomena, past conditions may provide glimpse into “resilient” or “sustainable” conditions
- In others, a “return to the past” may be a necessary first step toward preparing for the future
  - Using history as “waypoints” rather than “endpoints”

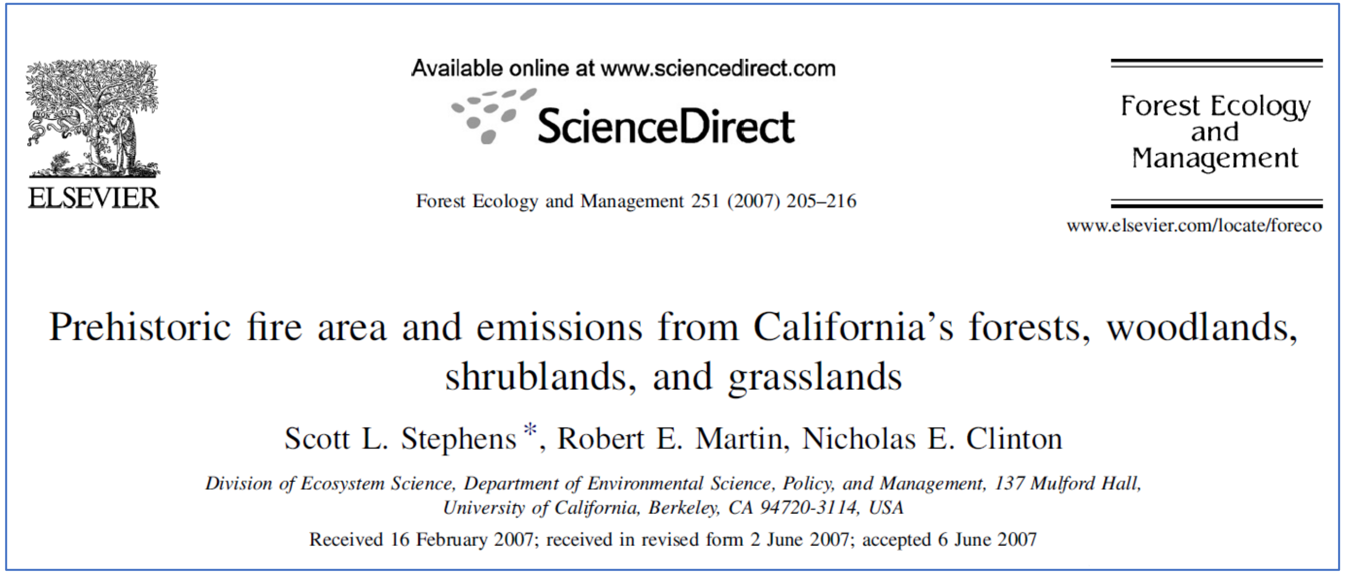
Agreement Objectives

- Build a better estimate of historical burned area baselines in California (pre-EAS)
- Provide new values of ranges of historical emissions for the baseline fire regime
- Improve and recalculate fire return interval departure statistics for California and major ecoregions
- Update POSCRPT model for conifer regeneration postfire (not covered today)

HISTORICAL BURNED AREA

Current best estimate:

- ~ 1.8 million hectares per year
- ~ 34 Teragrams of CO_2 per year



Available online at www.sciencedirect.com

ScienceDirect

Forest Ecology and Management 251 (2007) 205–216

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Forest Ecology and Management

www.elsevier.com/locate/foreco

Prehistoric fire area and emissions from California's forests, woodlands, shrublands, and grasslands

Scott L. Stephens *, Robert E. Martin, Nicholas E. Clinton

Division of Ecosystem Science, Department of Environmental Science, Policy, and Management, 137 Mulford Hall, University of California, Berkeley, CA 94720-3114, USA

Received 16 February 2007; received in revised form 2 June 2007; accepted 6 June 2007

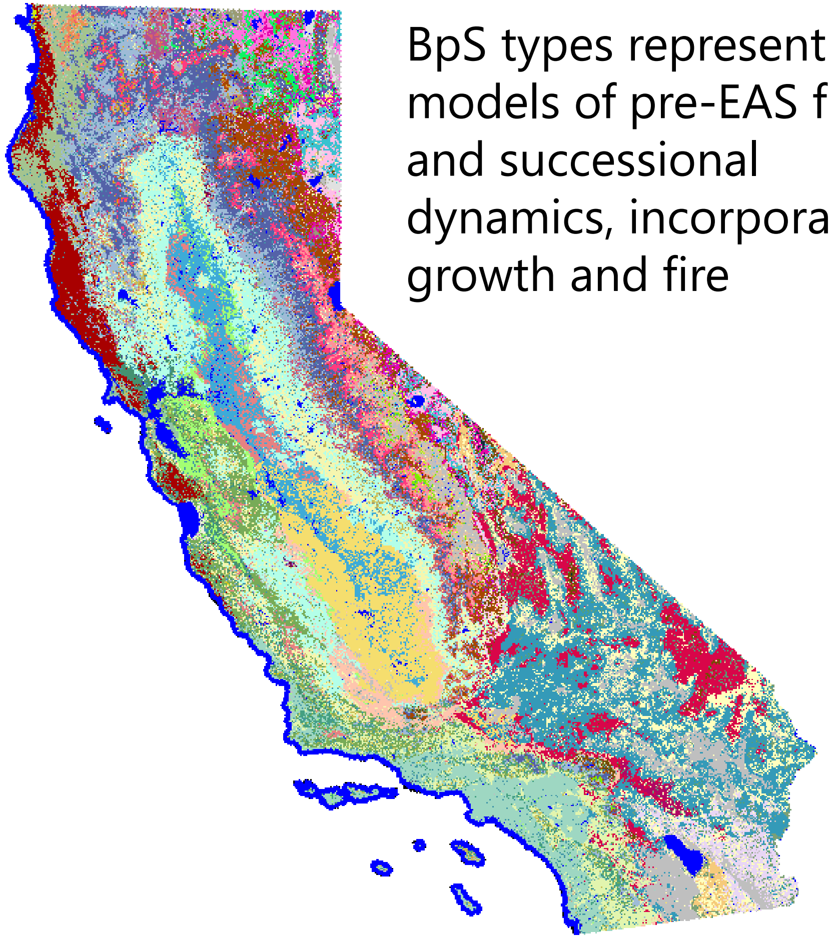
- A lot of new research has been done in the last 18 years
  - Educated guesses in 2007 can now be replaced with data
- We can now use Fire Rotation Period estimations directly
- New vegetation types can be included (riparian, desert, etc.)
- We have better products that better represent historical ecosystem distribution

How can we estimate past burned areas?

1 What type of vegetation covered California?

2 How often did this vegetation burn?

1. Map: Biophysical Settings (LANDFIRE)



BpS types represent models of pre-EAS fire and successional dynamics, incorporating growth and fire

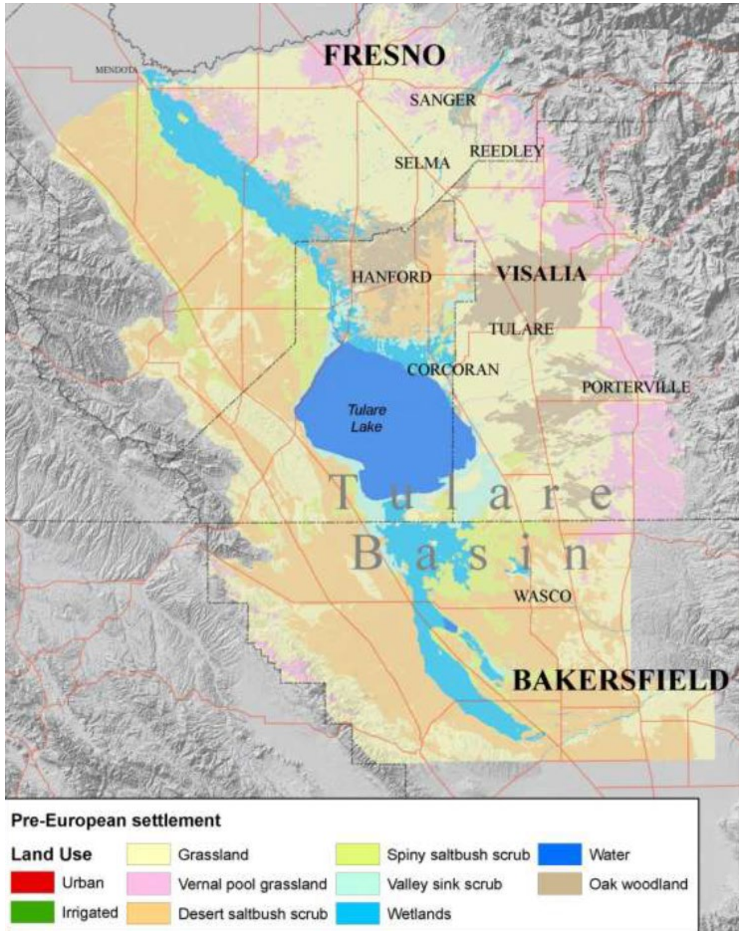
164 BpS types

We cross walked them into 35 Pre-settlement Fire Regime Types : 28 (Van de Water and Safford 2011) and added new PFRs.

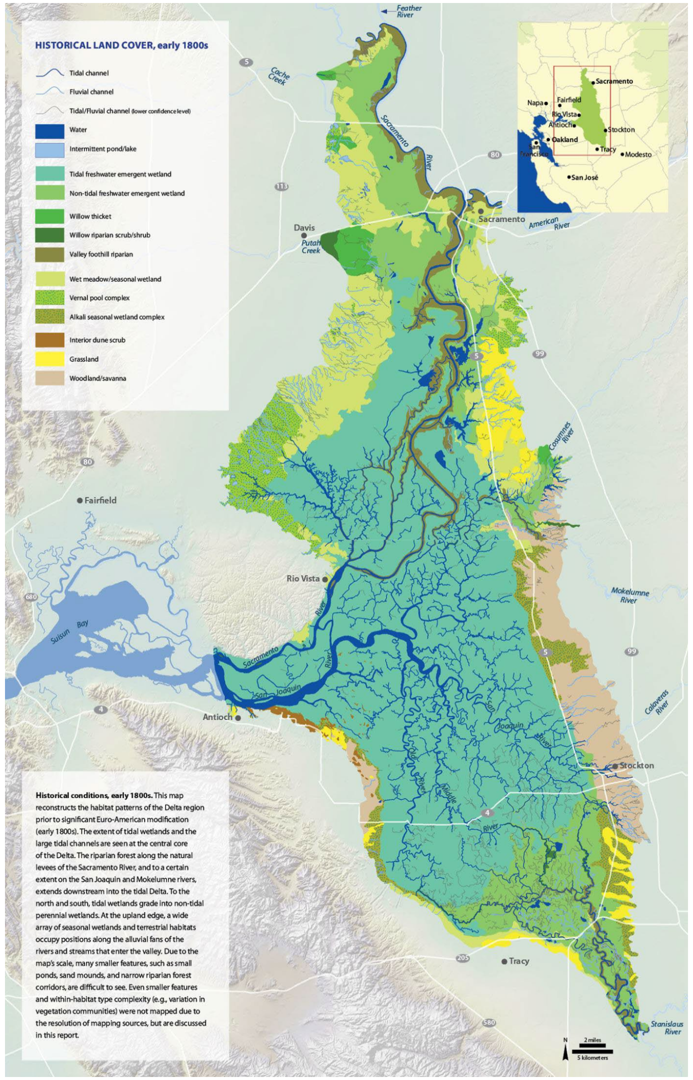
! Although FRI is based on pre-EAS fire regimes, the map is modeled based on modern plots and modern climate

Underprediction of grassland and other herbaceous vegetation in California where pre-EAS population was high

BpS undermaps grasslands: Central Valley reconstructions

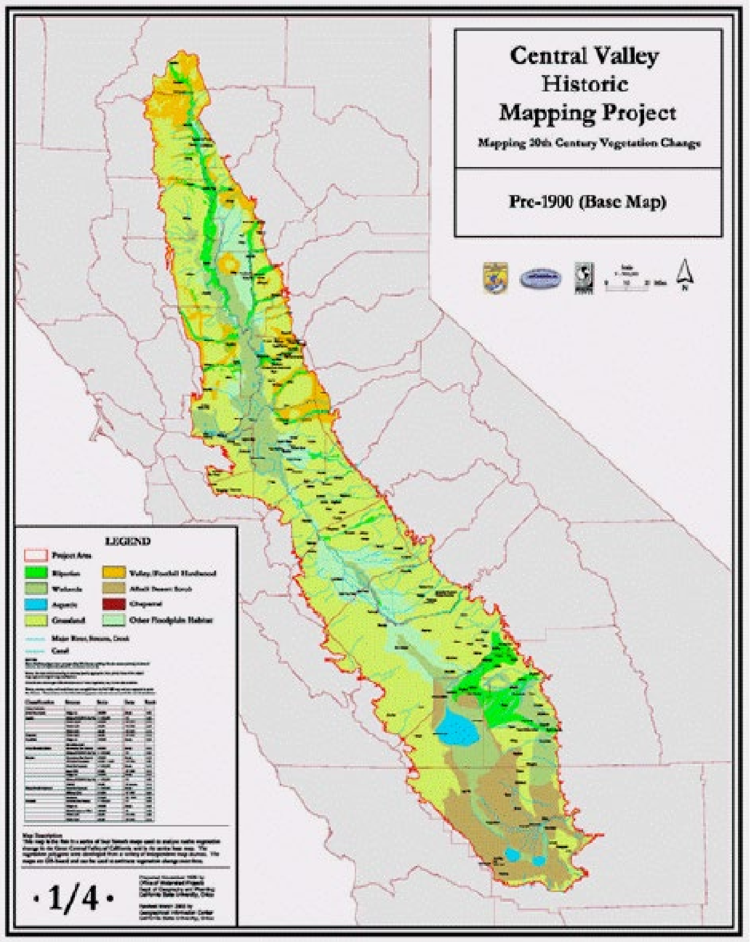


Tulare Basin Map, CSU, Phillips 2006



Historical conditions, early 1800s. This map reconstructs the habitat patterns of the Delta region prior to significant Euro-American modification (early 1800s). The extent of tidal wetlands and the large tidal channels are seen at the central core of the Delta. The riparian forest along the natural levees of the Sacramento River, and to a certain extent on the San Joaquin and Mokelumne rivers, extends downstream into the tidal Delta. To the north and south, tidal wetlands grade into non-tidal perennial wetlands. At the upland edge, a wide array of seasonal wetlands and terrestrial habitats occupy positions along the alluvial fans of the rivers and streams that enter the valley. Due to the map's scale, many smaller features, such as small ponds, sand mounds, and narrow riparian forest corridors, are difficult to see. Even smaller features and within-habitat type complexity (e.g., variation in vegetation communities) were not mapped due to the resolution of mapping sources, but are discussed in this report.

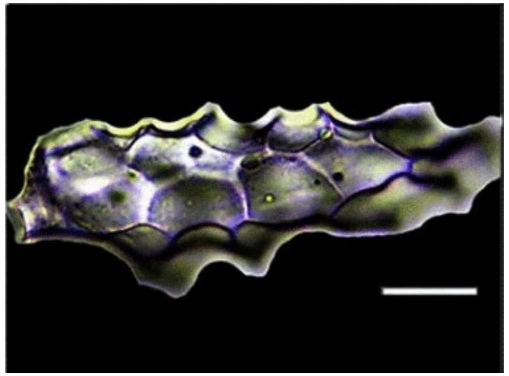
Sacramento-San Joaquin Delta, SFEI 2012



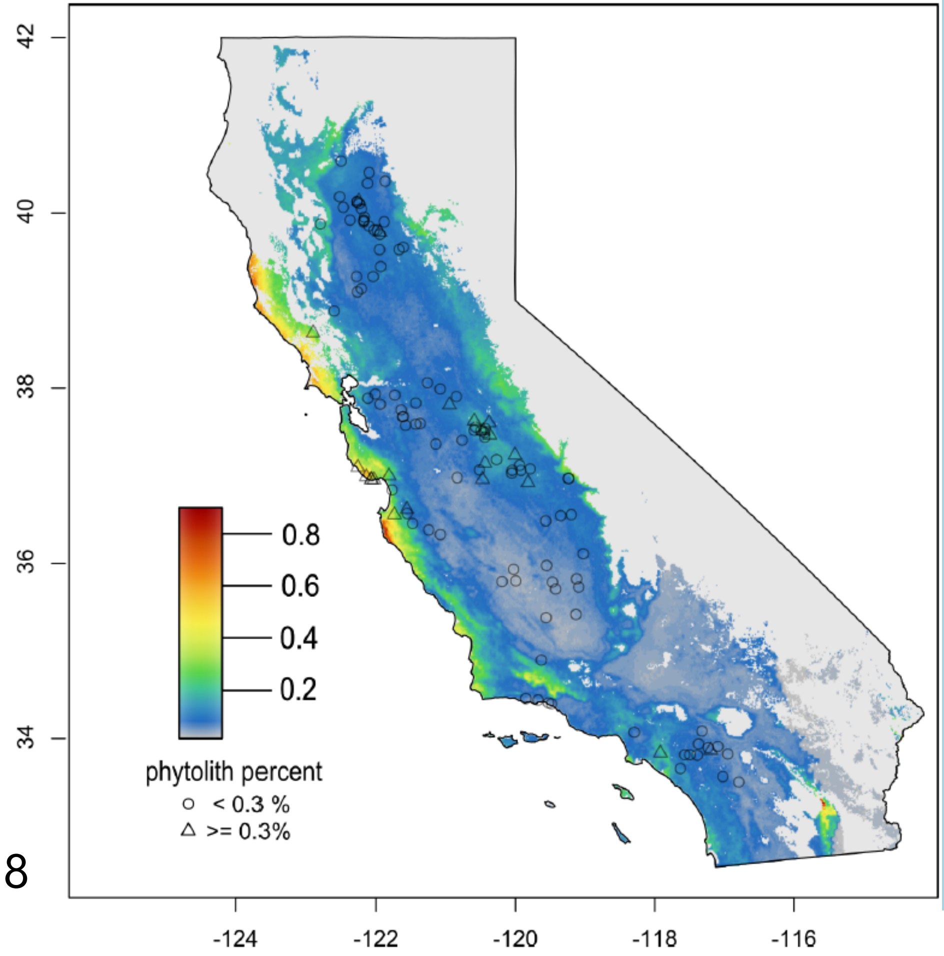
The Central Valley Historic Mapping Project, CSU 2003

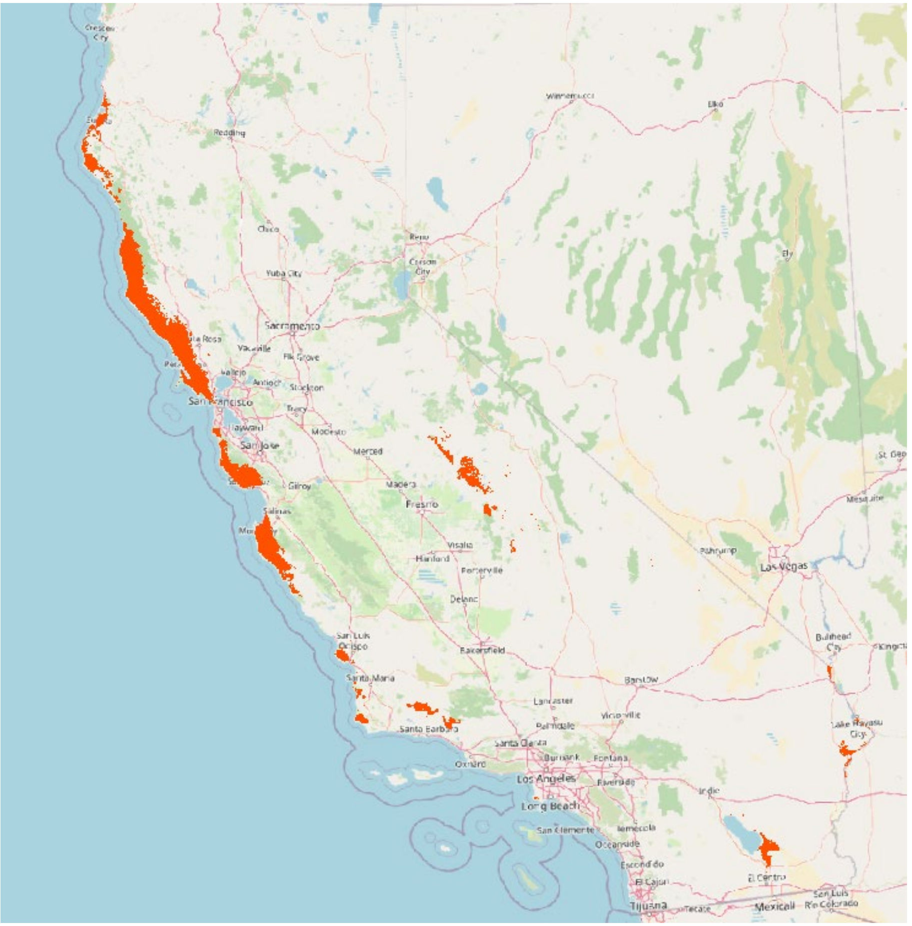
Other grassland paleodata: phytoliths

Phytolith density maps



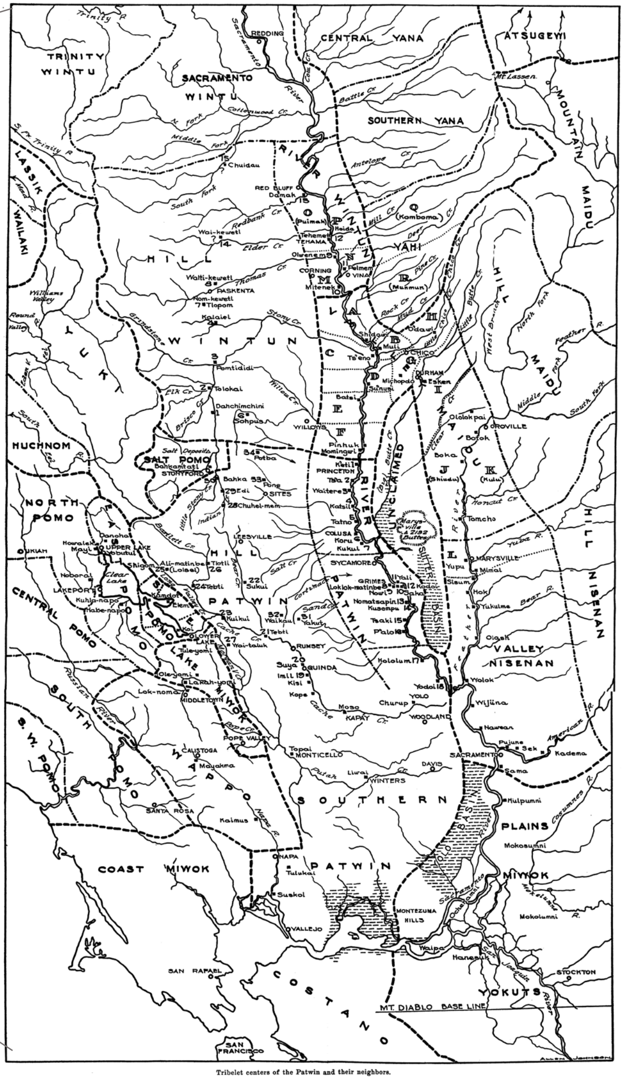
Wikipedia





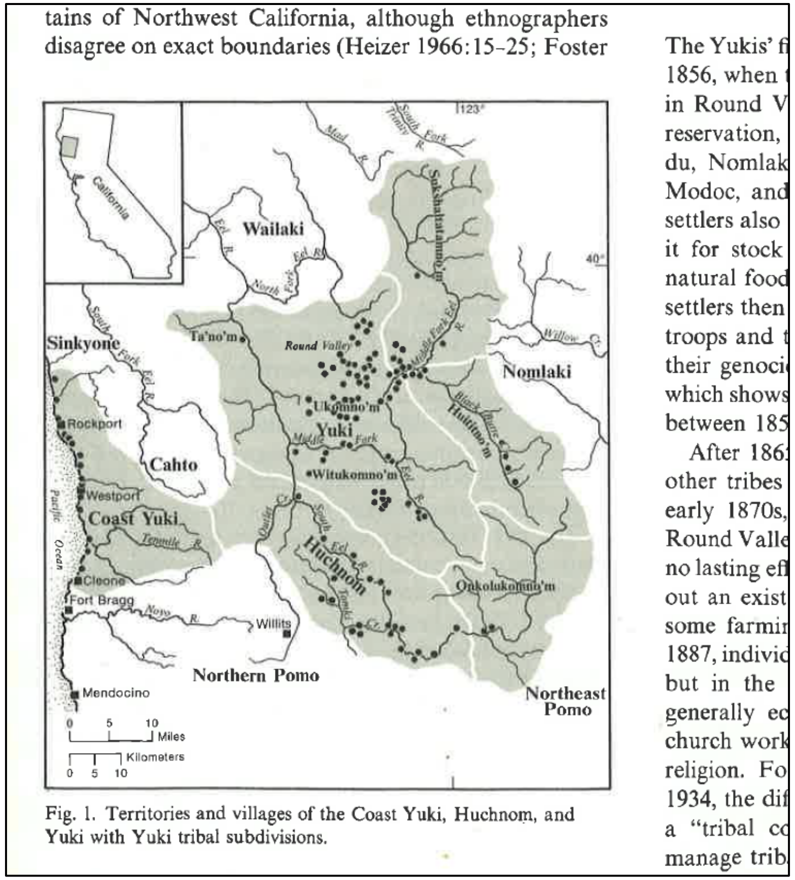
Fick and Evett, 2018

Human impacts: include pre-EAS indigenous mgt



Patwin, Kroeber 1932

Village map digitization



tains of Northwest California, although ethnographers disagree on exact boundaries (Heizer 1966:15–25; Foster

Fig. 1. Territories and villages of the Coast Yuki, Huchnom, and Yuki with Yuki tribal subdivisions.

The Yukis' f
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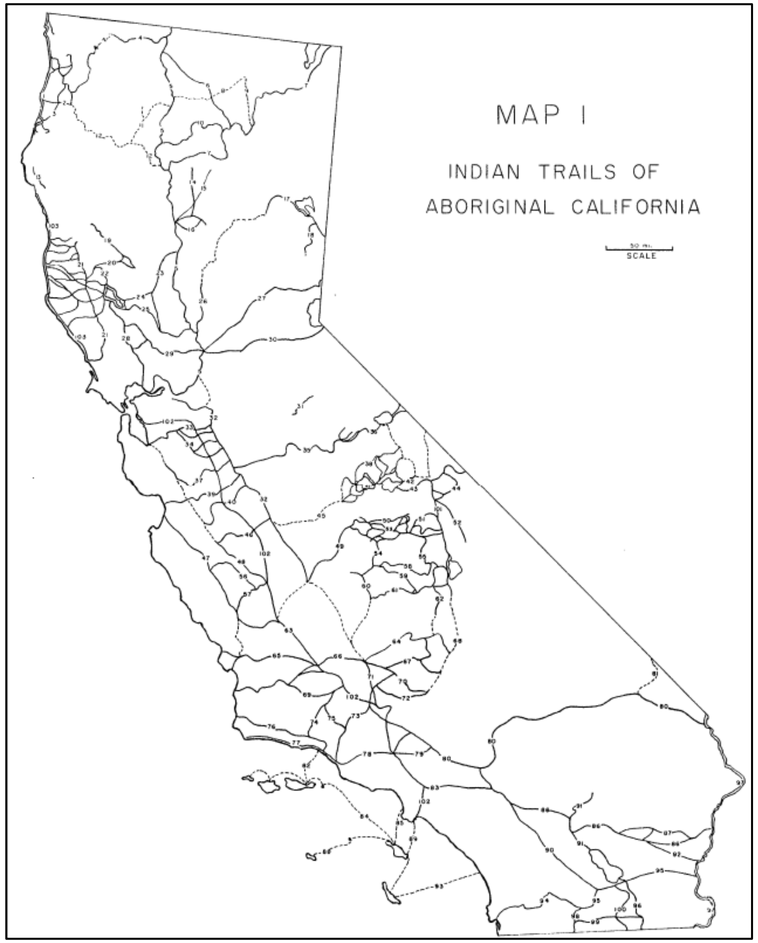
Yuki, Handbook 1932

Chumash, McLendon and Johnson, 1999
Santa Barbara Museum Of Natural History

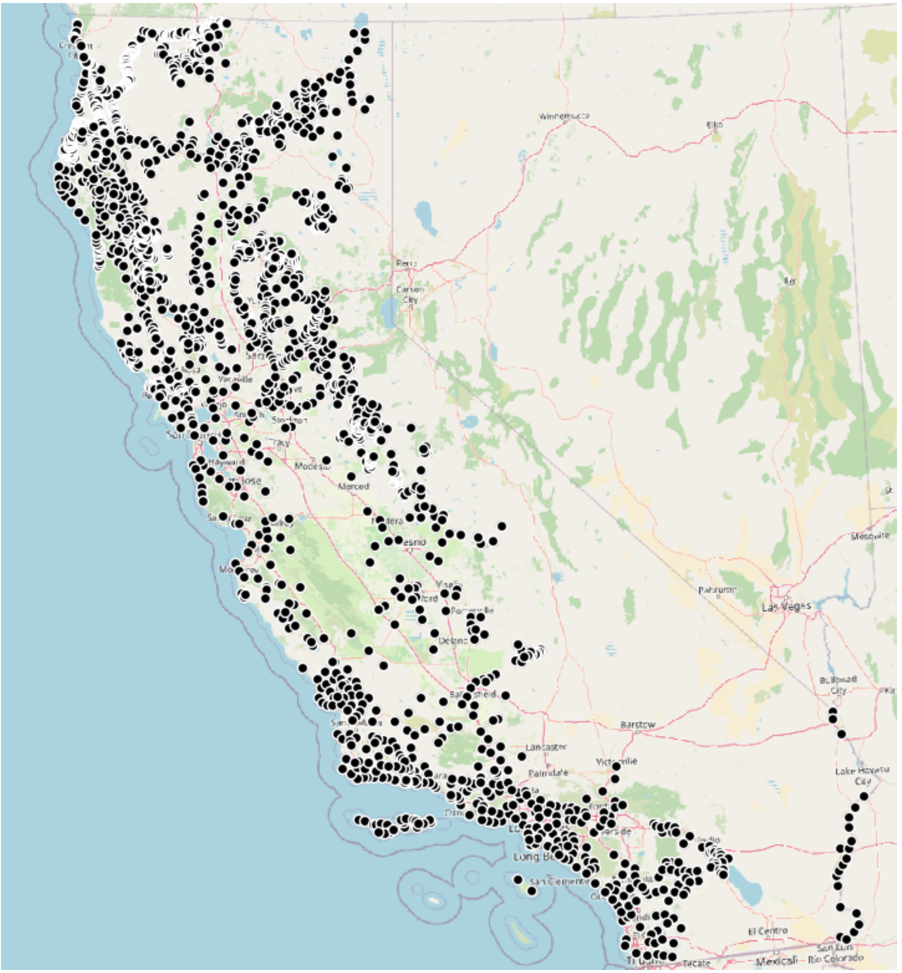


Davis 1961

Village map digitization

Sources:

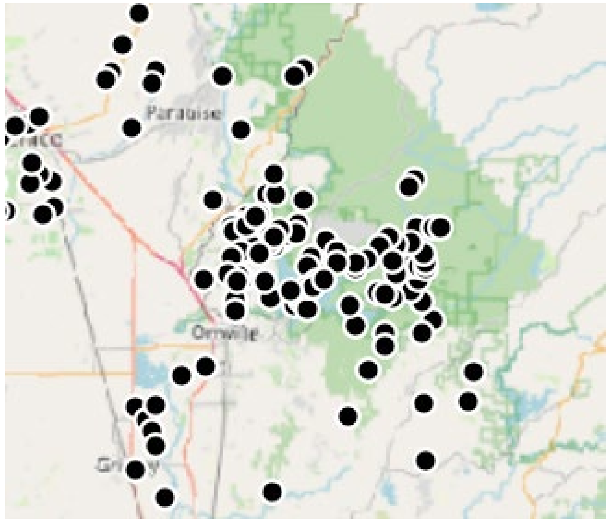
1. Extensive reports:
   - McLendon and Johnson 1999 for the Chumash
   - Krueger 1932 for the Patwin and Nomlaki
   - Heizer 1970 for the Shasta
   - Knifen 1928 for the Achumawi
   - Kroeber 1970 for the Patwin
   - Waterman 1920 for the Sumeg
2. Handbook of North American Indians, Volume 8
3. Atlas of Western Prehistory, Wilson and Wilson 2022



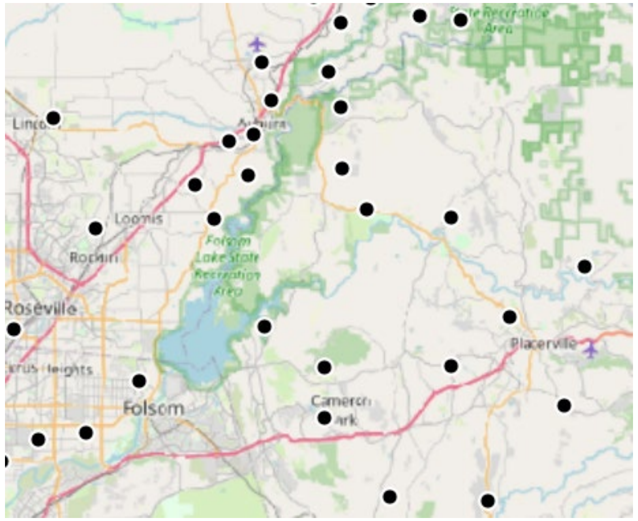
Results:

- 2,117 villages (certainly an underestimate)
- 14,000 km of trails (8,700 miles)

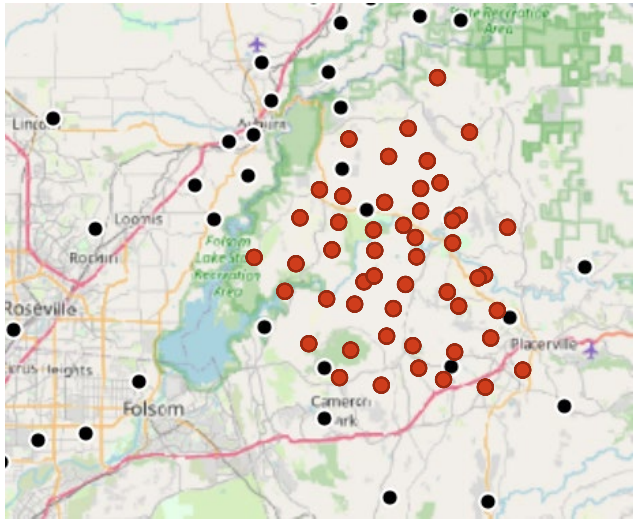
Are we missing part of the story?



- Area around Oroville. High village density (source: Handbook)
- The area covers around 85,000 hectares and includes 85 villages:
- 1 village per 10 square km (3,9 square miles)



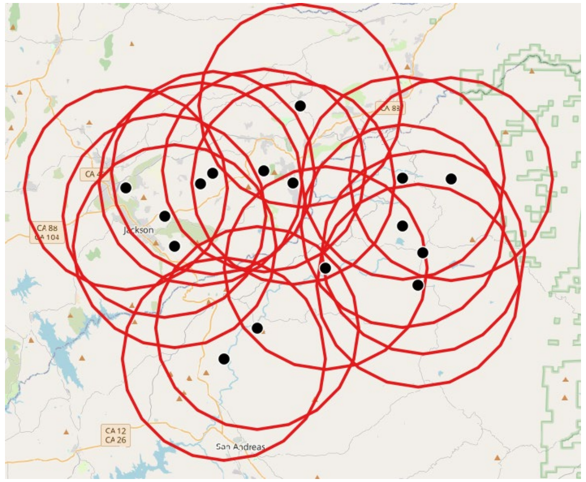
- Similar ecoregion, around East Sacramento and Placerville (source: Handbook)
- An equal surface includes 19 villages.
- 0,22 villages per 10 square km (3,9 square miles) or 1 village per 50 square km (19,5 square miles)



Can we infer the location of potential villages based on vegetation, DEM and ecoregion, until a similar density?

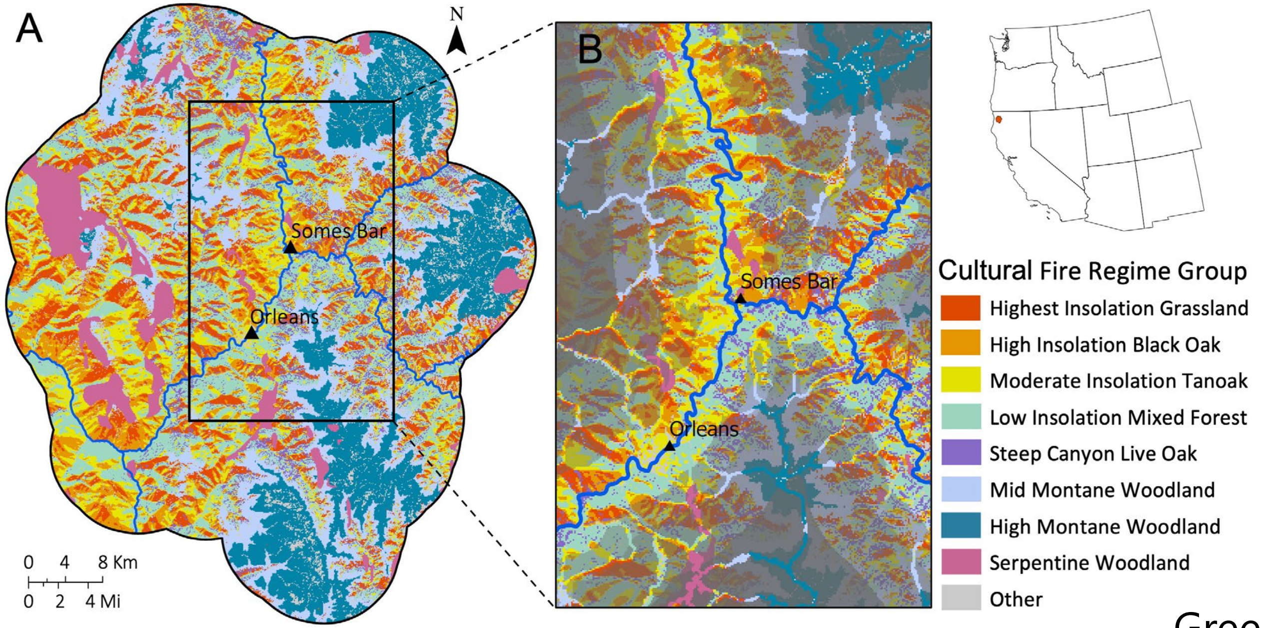
Vegetation type change in intensely managed cultural sites

Miwok area
5 miles buffer



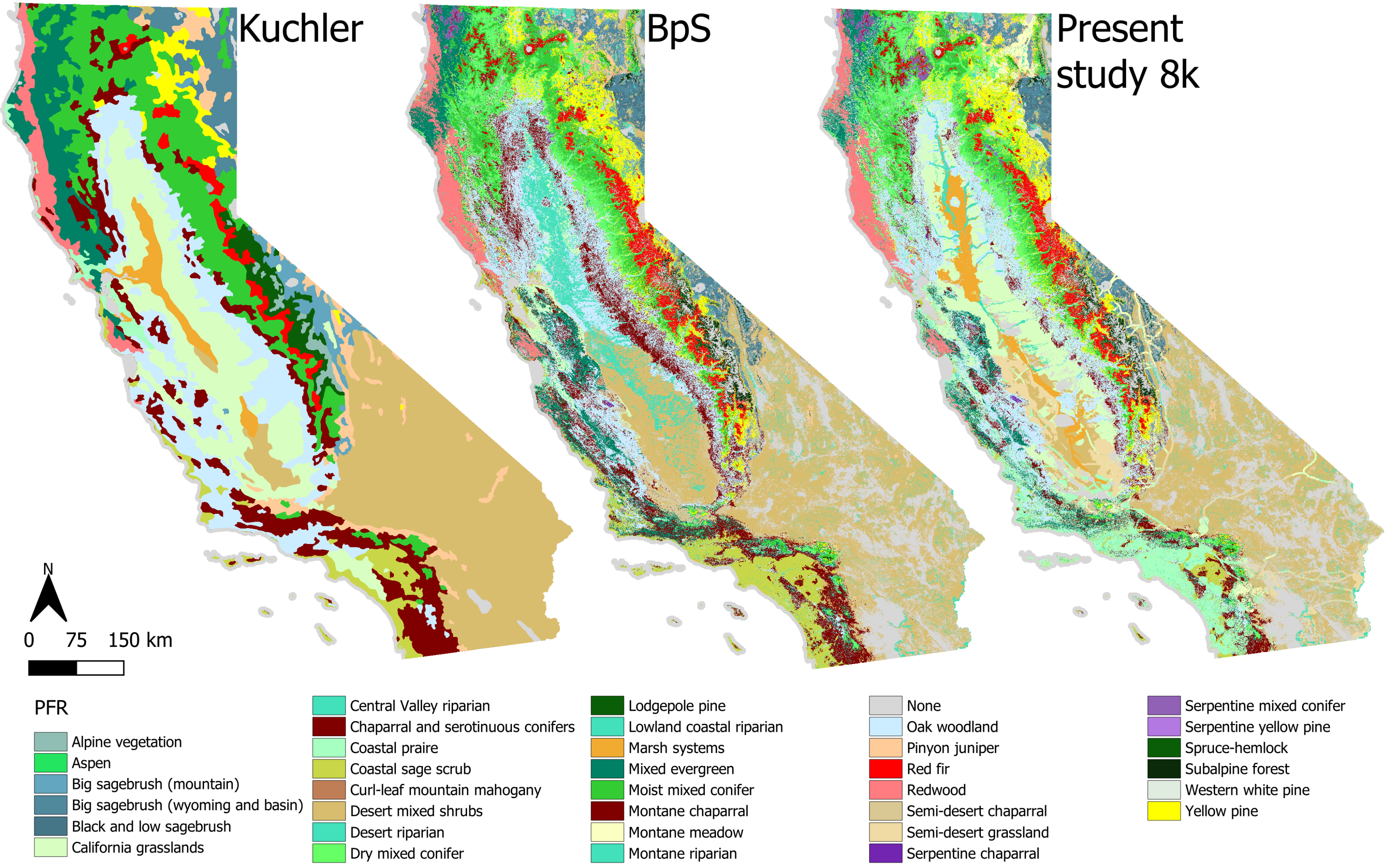
Rules for conversion to fire-maintained grassland/forbland types:

- Applied to certain vegetation types (shrubs, mixed evergreen…)
- Topographically dependent:
  - Not occurring on lower slopes and valleys
  - Different vegetation type according to slope+aspect
- New grassland types assigned according to climate and topographical features (distance to coast, etc.)



Greenler et al 2024

California pre-EAS vegetation map



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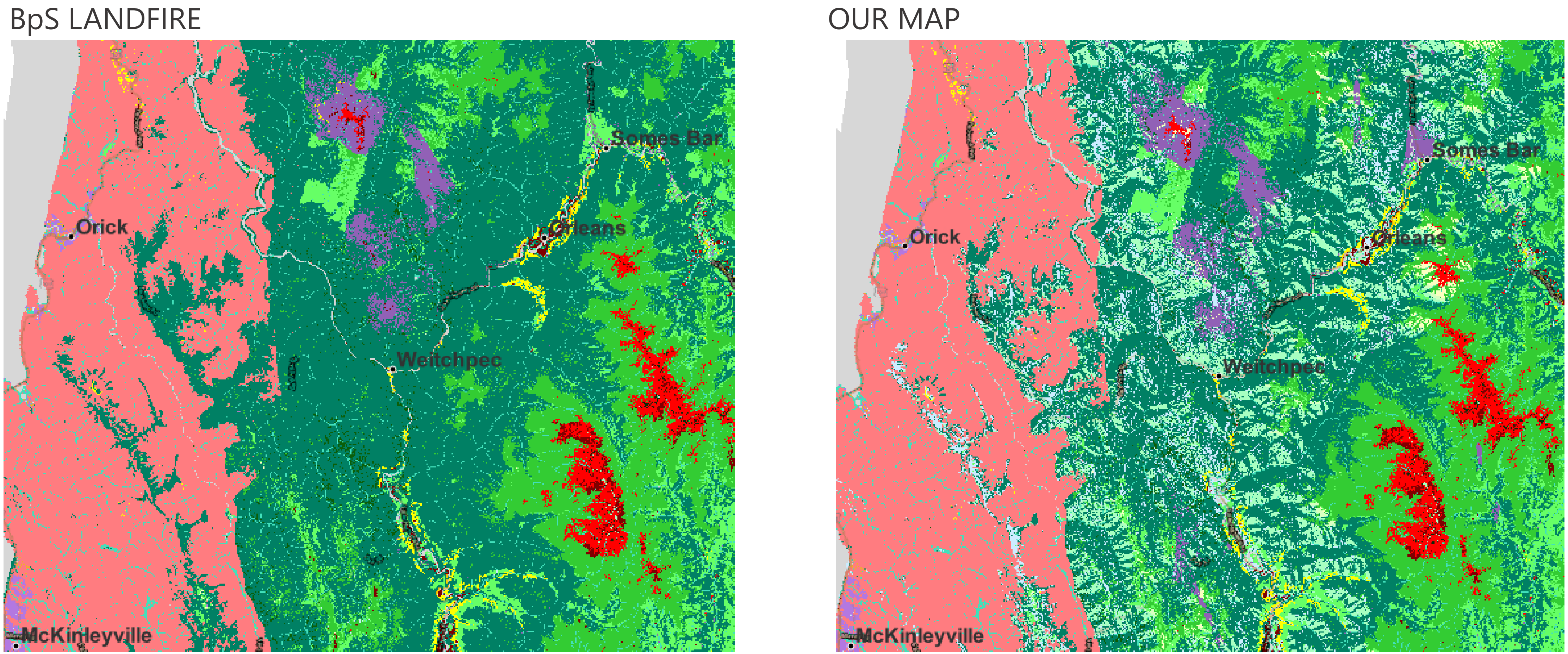
California pre-EAS vegetation map

Karuk-Yurok



BpS LANDFIRE

OUR MAP

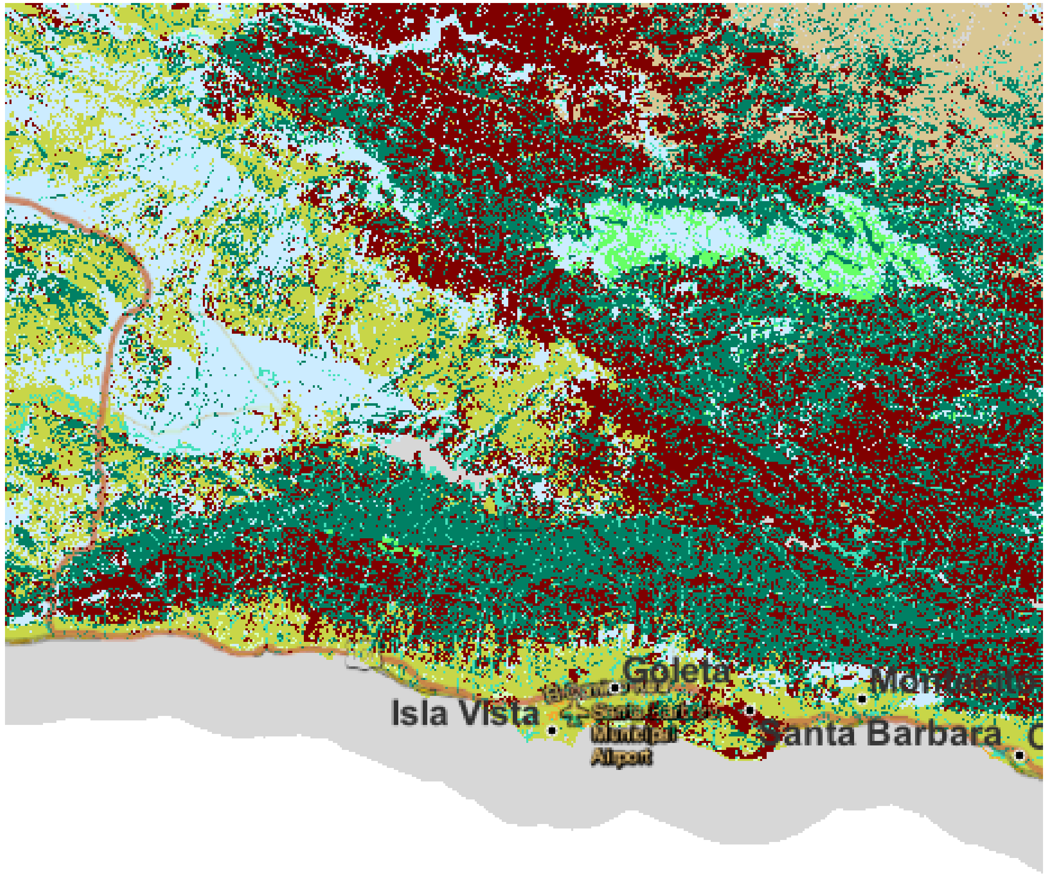
PFR

- 🟩 Alpine vegetation
- 🟩 Aspen
- 🟦 Big sagebrush (mountain)
- 🟦 Big sagebrush (wyoming and basin)
- 🟦 Black and low sagebrush
- 🟩 California grasslands
- 🟩 Central Valley riparian
- 🟥 Chaparral and serotinuous conifers
- 🟩 Coastal praire
- 🟨 Coastal sage scrub
- 🟫 Curl-leaf mountain mahogany
- 🟨 Desert mixed shrubs
- 🟩 Desert riparian
- 🟩 Dry mixed conifer
- 🟩 Lodgepole pine
- 🟩 Lowland coastal riparian
- 🟧 Marsh systems
- 🟩 Mixed evergreen
- 🟩 Moist mixed conifer
- 🟥 Montane chaparral
- 🟨 Montane meadow
- 🟩 Montane riparian
- ⬜ None
- 🟦 Oak woodland
- 🟧 Pinyon juniper
- 🟥 Red fir
- 🟥 Redwood
- 🟨 Semi-desert chaparral
- 🟨 Semi-desert grassland
- 🟪 Serpentine chaparral
- 🟪 Serpentine mixed conifer
- 🟪 Serpentine yellow pine
- 🟩 Spruce-hemlock
- ⬛ Subalpine forest
- ⬜ Western white pine
- 🟨 Yellow pine

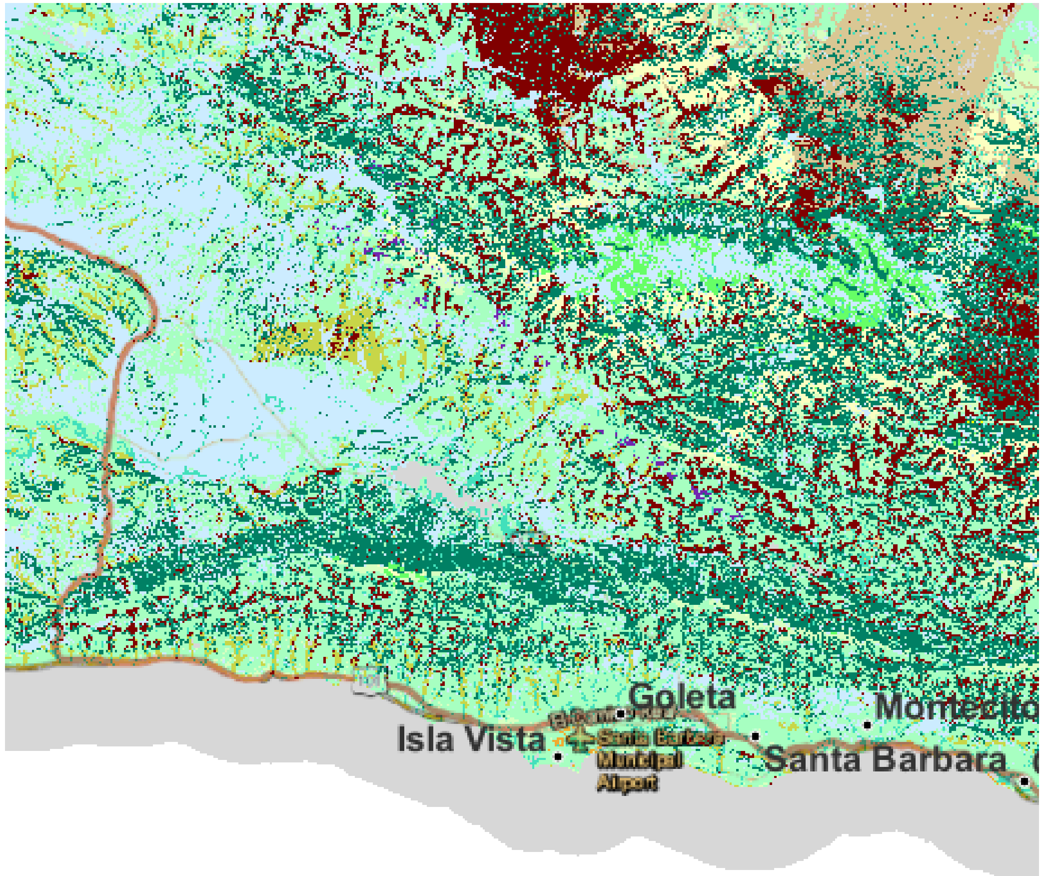
California pre-EAS vegetation map

Chumash

BpS LANDFIRE



OUR MAP



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California pre-EAS vegetation map

provisional results

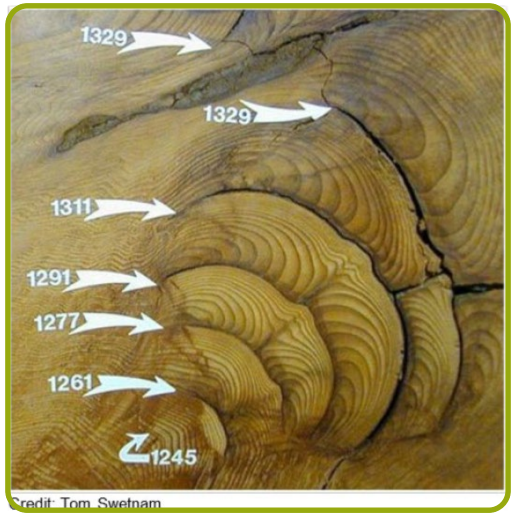
Historical Vegetation Distribution

Jepson Ecoregion	Grasslands*			Shrublands			Forests		
	Historic		Current	Historic		Current	Historic		Current
	BpS (%)	Our map (%)	FVEG (%)	BpS (%)	Our map (%)	FVEG (%)	BpS (%)	Our map (%)	FVEG (%)
Central Western CA	38.70	57.64	51.96	28.40	13.37	25.68	31.18	27.00	8.51
Cascade Ranges	11.36	17.19	15.11	8.71	4.23	10.41	76.10	74.83	64.52
Mojave Desert	0.22	3.19	1.29	68.57	65.62	90.56	1.25	1.24	2.03
Sonoran Desert	0.07	12.80	0.72	56.45	43.74	75.57	0.08	0.06	0.44
Great Valley	24.89	75.19	30.62	43.04	11.91	2.82	28.20	4.43	0.88
Modoc Plateau	0.77	14.82	6.88	45.37	36.33	56.08	46.81	41.81	18.00
North Western CA	15.72	25.05	14.66	9.43	4.32	8.77	73.49	69.31	68.91
Sierra Nevada	20.57	27.51	18.98	14.03	8.32	8.61	57.31	56.30	58.04
East of Sierra Nevada	1.75	11.24	5.03	55.45	47.65	61.29	26.74	25.44	20.36
Southwestern CA	6.72	51.15	11.51	71.97	28.86	46.90	20.05	18.72	10.27
Total CA	13.59	31.43	16.53	39.69	26.17	36.91	34.82	29.77	25.23

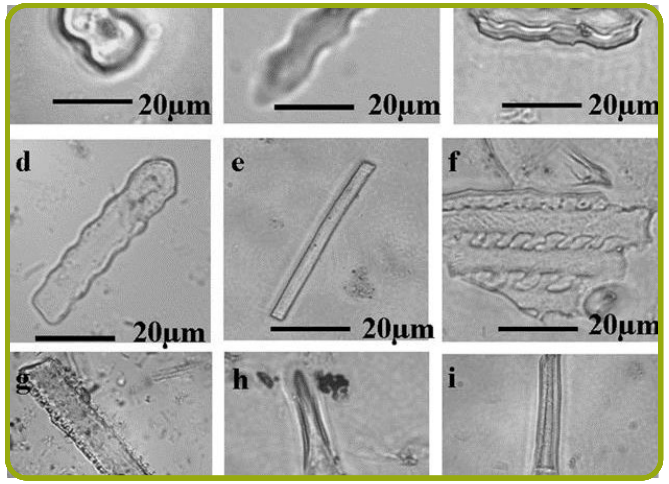
2. How often DID vegetation burn?

- fire scar dendrochronology
- lake and ocean sediment cores
- oral histories
- writings

All vegetation types, including grasses, desert, riparian…



Credit: Tom Swetnam



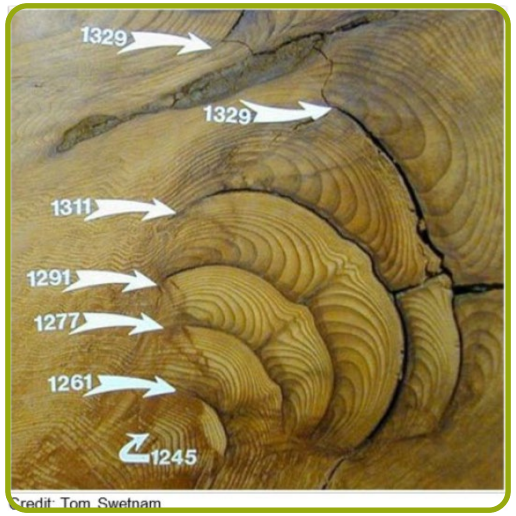
Fire Rotation Periods

- Fire Return Intervals (FRI)
  Number of years between fires

$$FRI = \frac{period\ (years)}{number\ of\ fires}$$

  - Fire Rotation period (FR)
    Number of years needed to burn a region of interest

$$FR = \frac{region\ area}{burned\ area\ per\ year}$$



Credit: Tom Swetnam

- $\boldsymbol{burned\ area\ per\ year} = \frac{region\ area}{FR}$

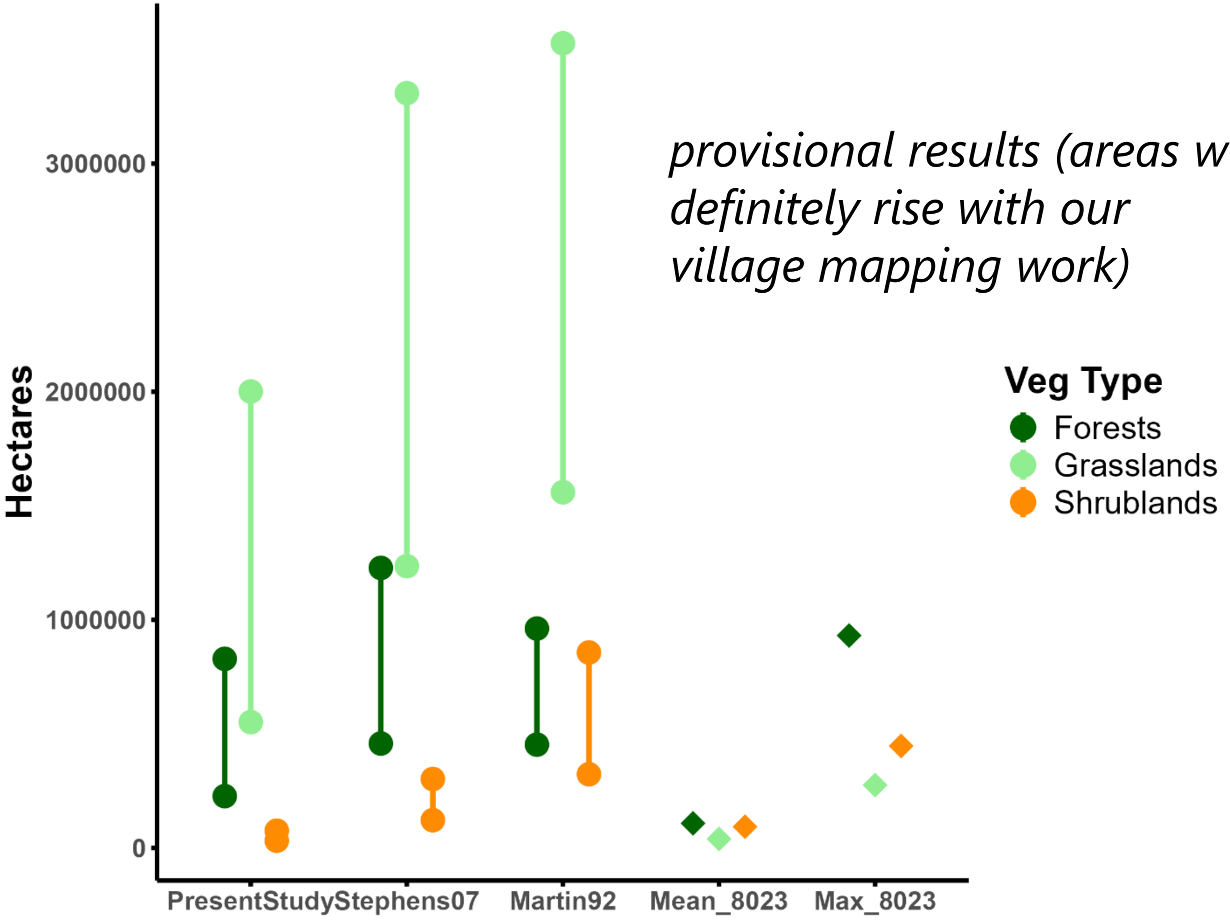
New Fire Rotation periods

PFR	Years	PFR	Years	PFR	Years
Aspen	38	Serpentine yellow pine	33	Big sagebrush (mountain)	120
Central Valley riparian	11	Spruce-hemlock	672	Big sagebrush (wyoming)	223
Dry mixed conifer	23	Subalpine forest	425	Black and low sagebrush	1100
Lodgepole pine	63	Western white pine	79	Chaparral and serot. conif	72
Lowland coastal riparian	800	Yellow pine	22	Coastal sage scrub	100
Mixed evergreen	40	Alpine vegetation	8200	Curl-leaf moun. mahogany	130
Moist mixed conifer	31	California grassland	11	Desert mixed shurb	1901
Montane riparian	48	Coastal prairie	6	Desert riparian	3130
Pinyon-juniper	404	Marsh systems	8	Montane chaparral	54
Red fir	79	Montane meadow	18	Semi-desert chaparral	160
Redwood	25	*Oak woodland*	18	Serpentine chaparral and ser.	108
Serpentine mixed conifer	47	Semi-desert grassland	103		

RESULTS

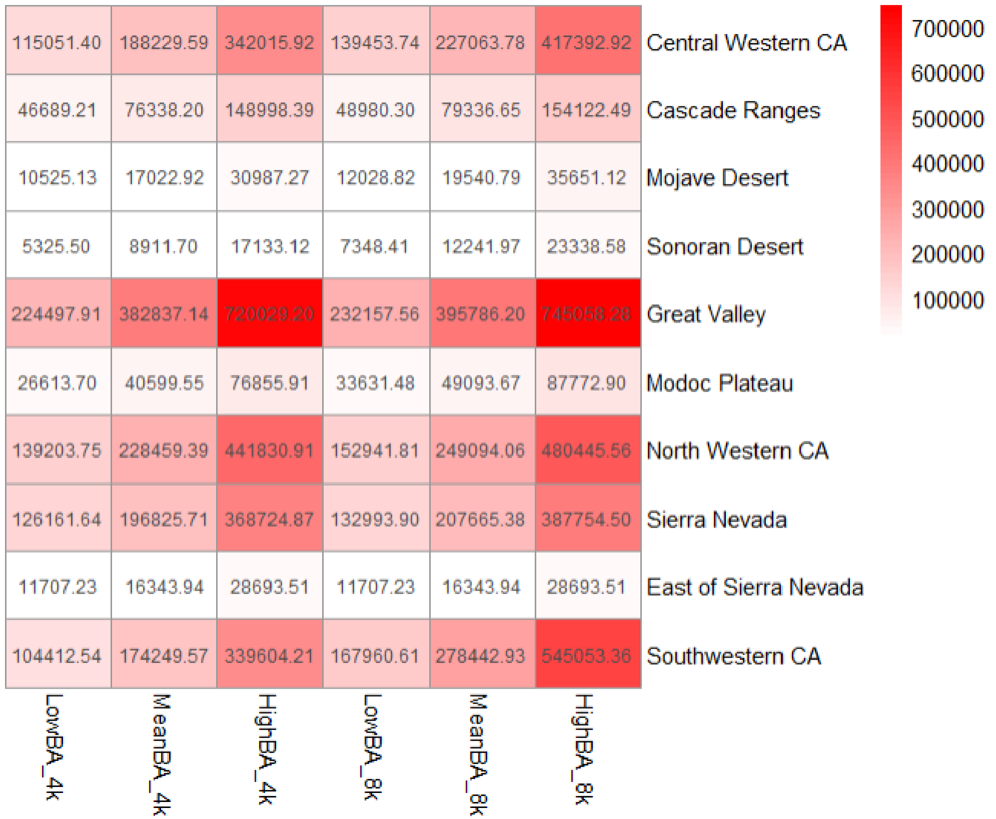
Historical Burned Area

provisional results (areas will definitely rise with our village mapping work)



provisional results

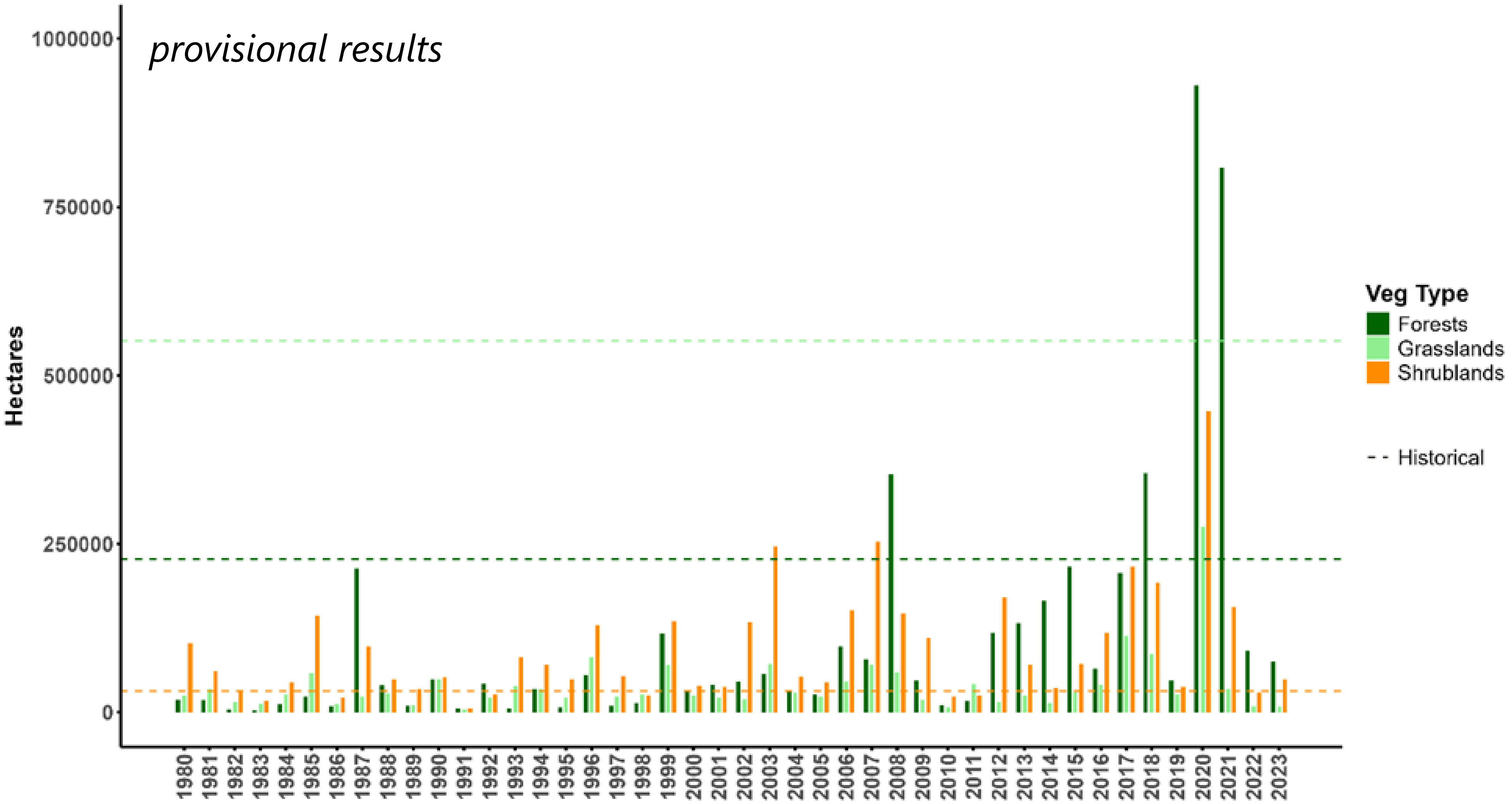
Burnt hectares



LowBA_4k	MeanBA_4k	HighBA_4k	LowBA_8k	MeanBA_8k	HighBA_8k	
115051.40	188229.59	342015.92	139453.74	227063.78	417392.92	Central Western CA
46689.21	76338.20	148998.39	48980.30	79336.65	154122.49	Cascade Ranges
10525.13	17022.92	30987.27	12028.82	19540.79	35651.12	Mojave Desert
5325.50	8911.70	17133.12	7348.41	12241.97	23338.58	Sonoran Desert
224497.91	382837.14	720029.20	232157.56	395786.20	745058.28	Great Valley
26613.70	40599.55	76855.91	33631.48	49093.67	87772.90	Modoc Plateau
139203.75	228459.39	441830.91	152941.81	249094.06	480445.56	North Western CA
126161.64	196825.71	368724.87	132993.90	207665.38	387754.50	Sierra Nevada
11707.23	16343.94	28693.51	11707.23	16343.94	28693.51	East of Sierra Nevada
104412.54	174249.57	339604.21	167960.61	278442.93	545053.36	Southwestern CA

RESULTS

Comparison with recent trends



Historical burned area and emissions

1 What type of vegetation covered California?

2 How often did this vegetation burn?

3 What were the associated emissions?

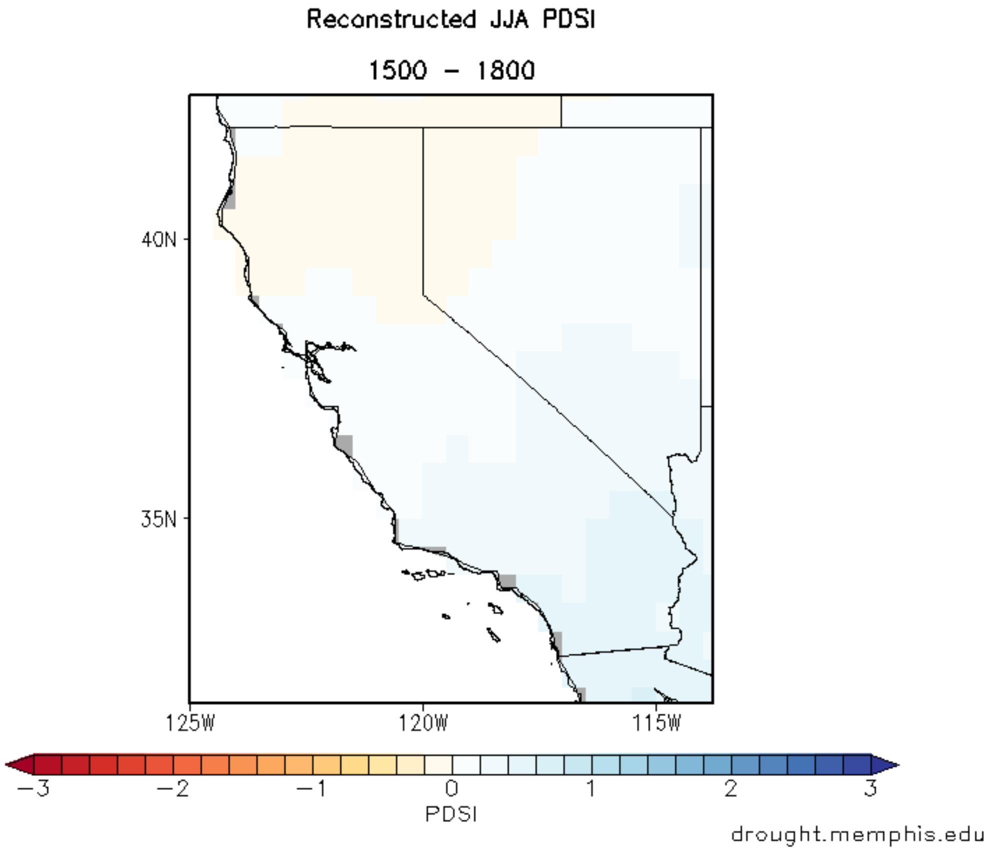
3. Historical Emissions

Modern simulator:

Vegetation types and surface burned → ✓

Fuel loading → ?

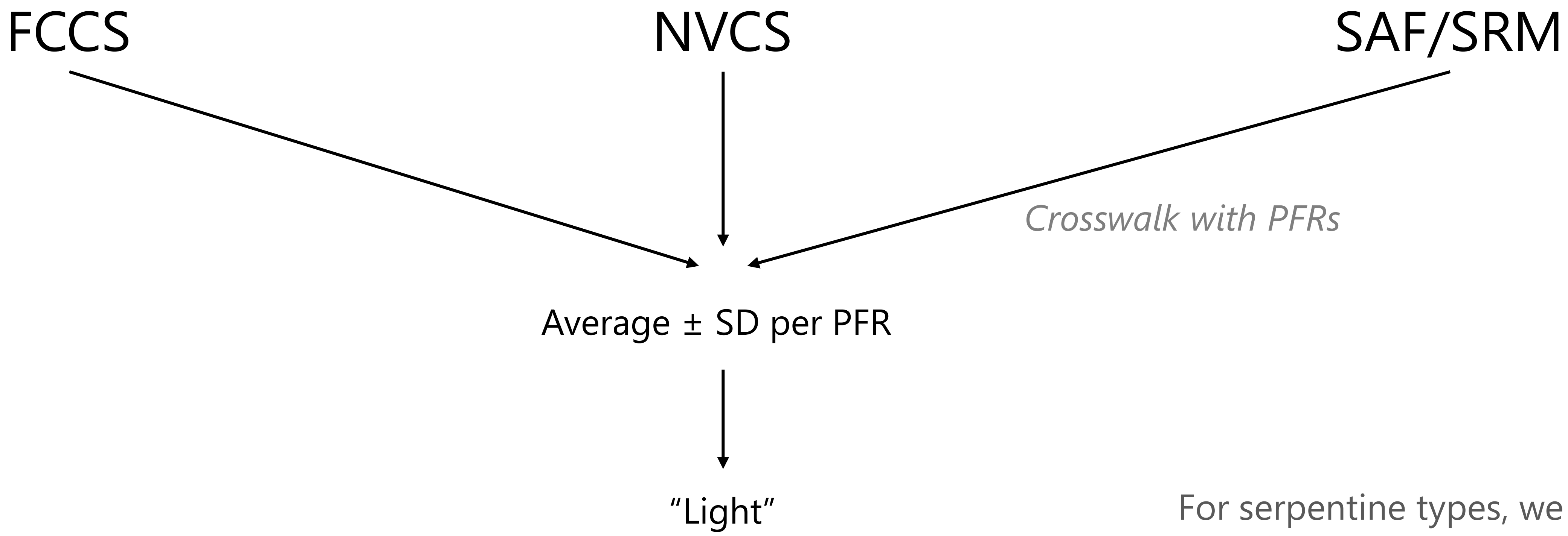
Weather → ?



Reconstructed climate:
Average of Palmer drought index for June-July-August between 1500 and 1800

Historical Emissions

Fuel Loads from FOFEM database



FCCS

NVCS

SAF/SRM

Crosswalk with PFRs

Average ± SD per PFR

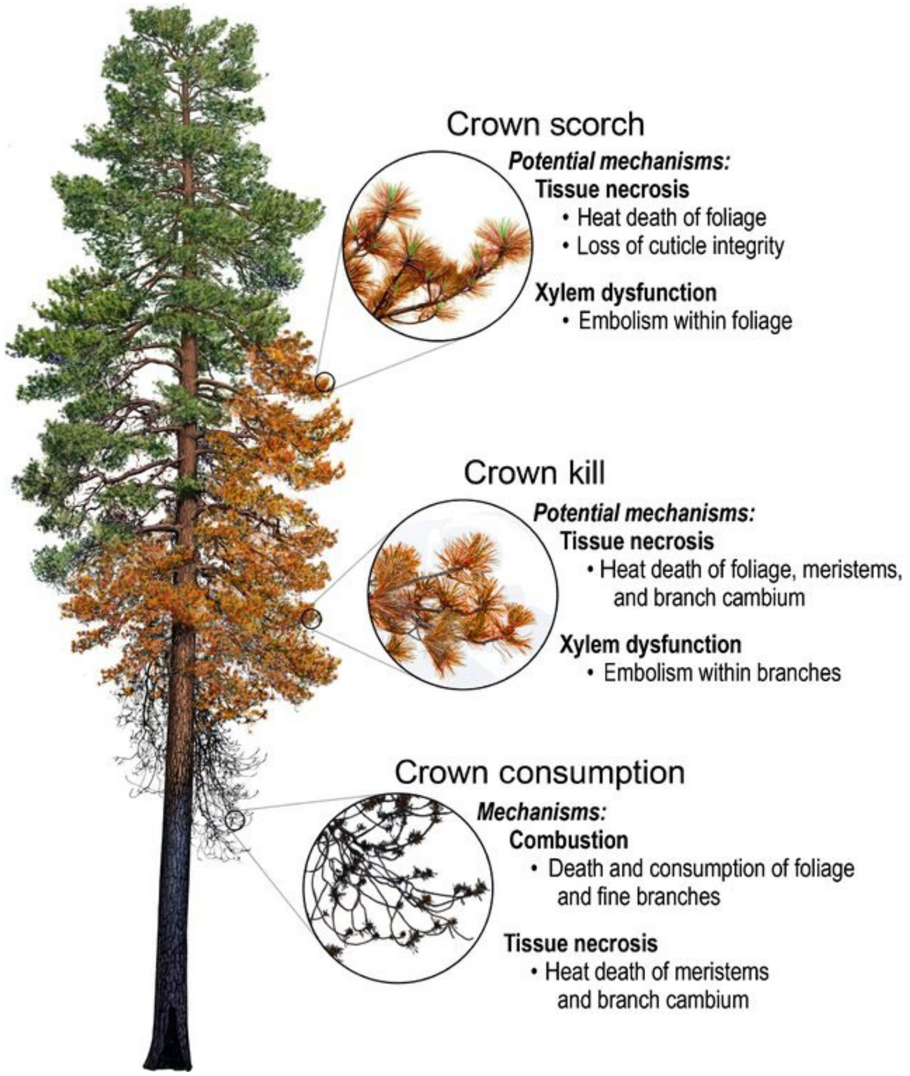
“Light”

For serpentine types, we modified the values according to De Siervo et al 2015 results

Historical Emissions

Historical percentage crown consumed

PFR	%	PFR	%
Aspen	15	Pinyon-juniper	30
Central Valley riparian	5	Red fir	10
Chaparral and serot	65	Redwood	5
Curl-leaf Mtn mahgny	25	Serp. chap and serot	40
Dry mixed conifer	5	Serp. mixed conifer	5
Lodgepole pine	25	Serp. yellow pine	5
Lowland coastal ripa	25	Spruce-hemlock	40
Mixed evergreen	5	Subalpine forests	15
Moist mixed conifer	5	Western white pine	10
Montane riparian	20	Yellow pine	5
Oak woodland	5		



Historical Emissions

Weather

As in Stephens et al 2007 :

- 2/3 in fall under dry conditions
- 1/3 in summer under very dry conditions

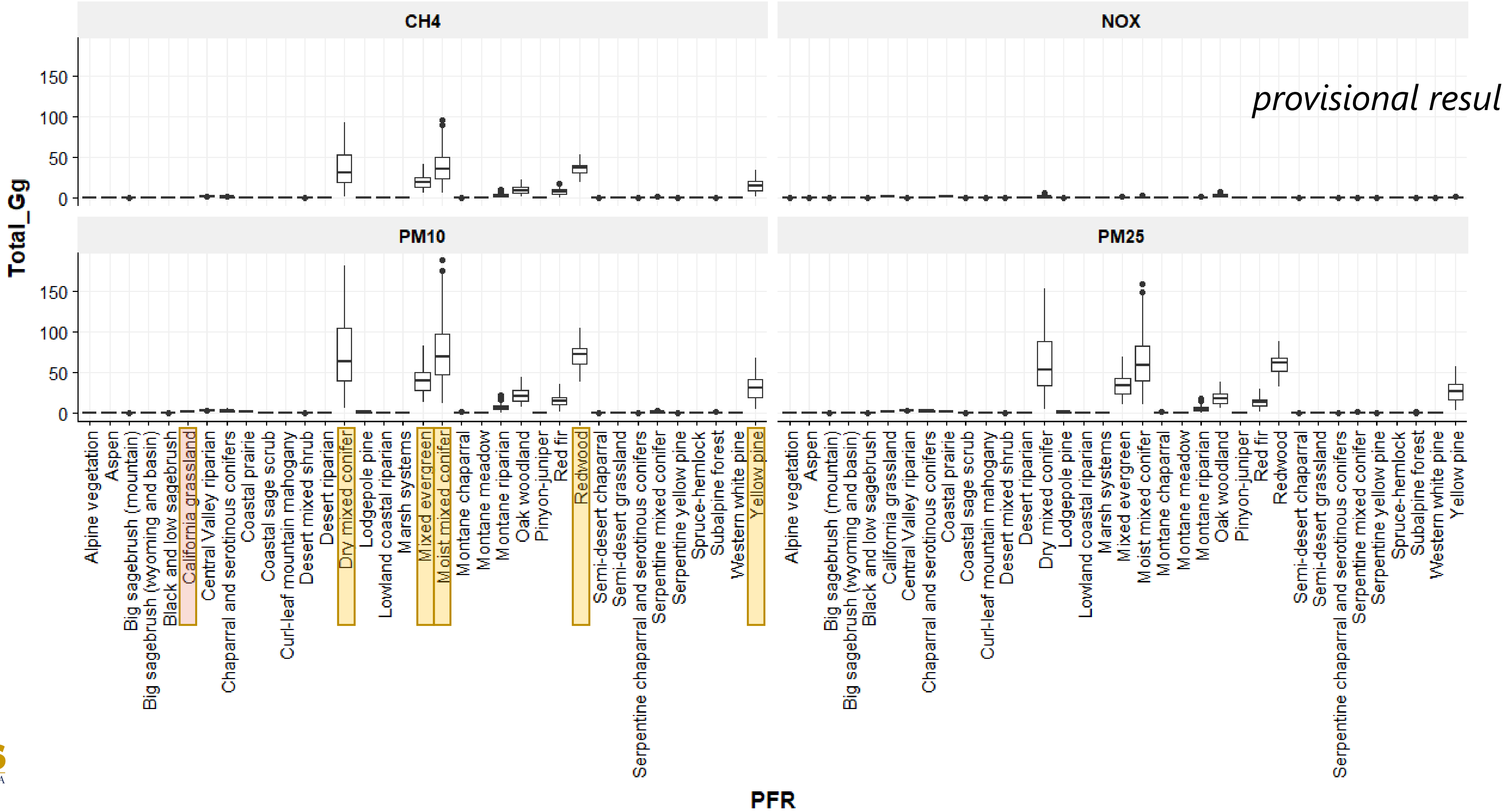
[+ sensitivity?]

Sources of uncertainty

- Fuel load estimation → Monte Carlo methodology

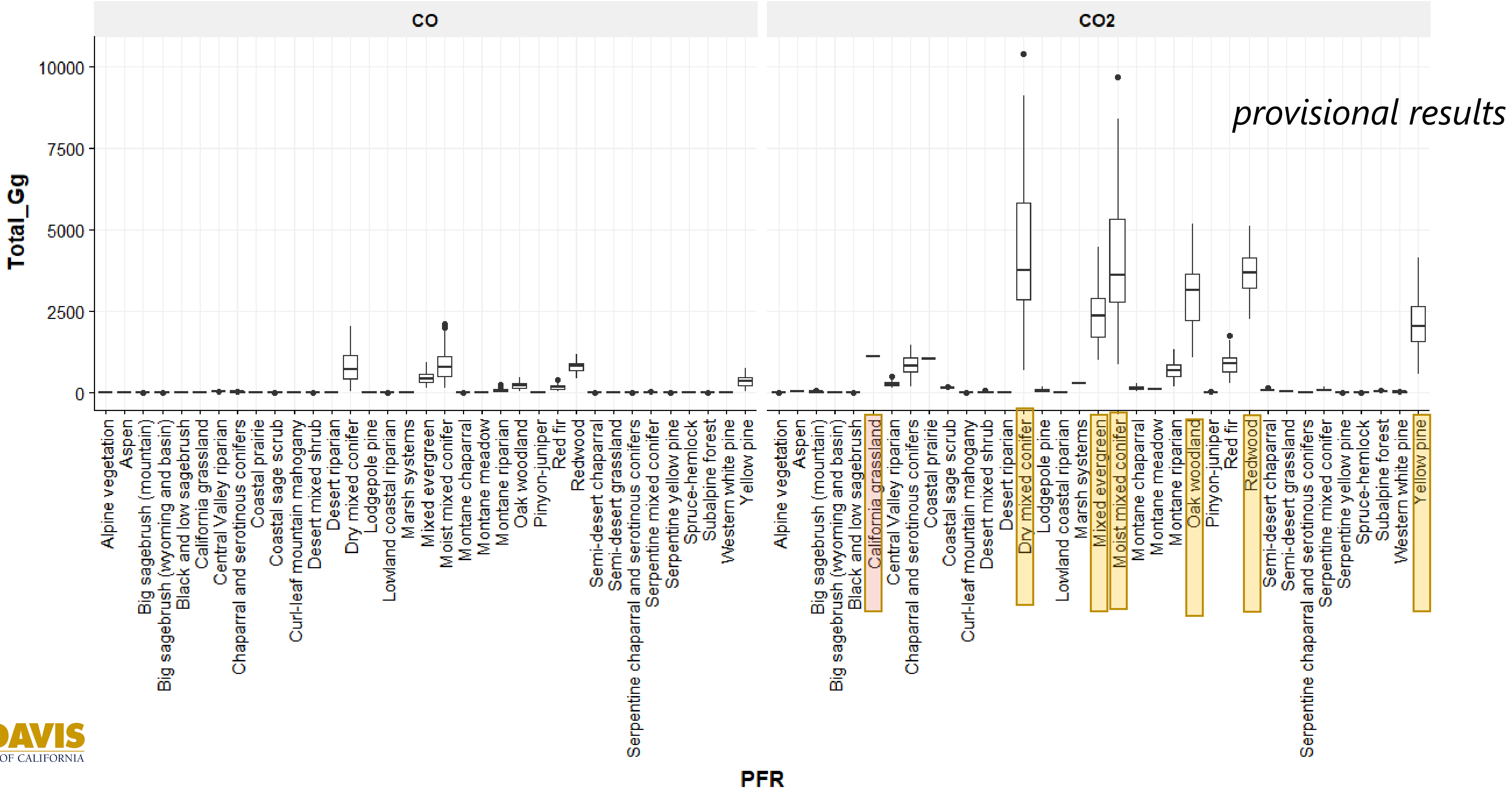
1000 FOFEM simulations using different fuel loadings

RESULTS: Average emissions per vegetation type per year



provisional results

RESULTS: Average emissions per vegetation type per year



provisional results

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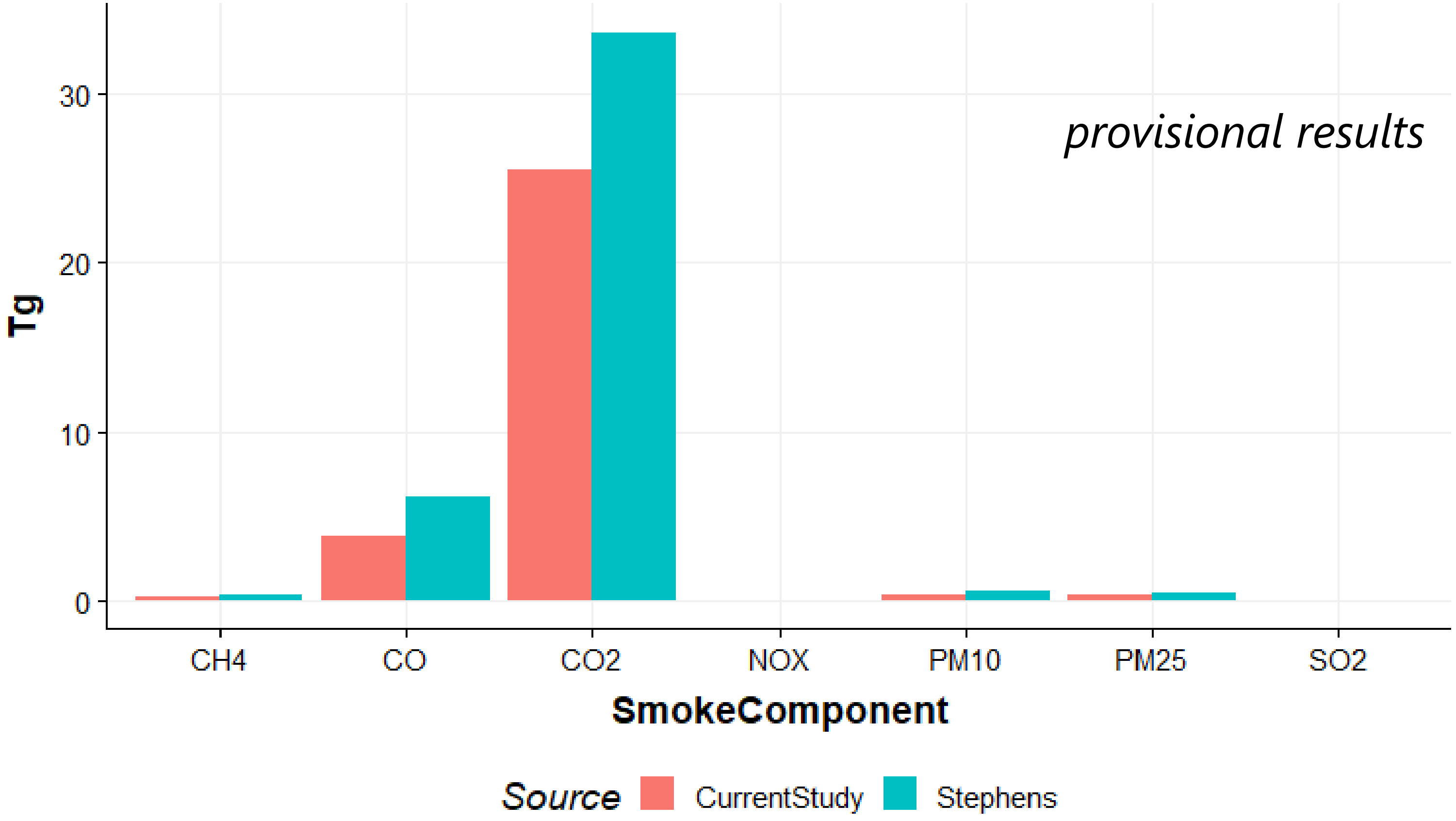
RESULTS

Comparison to Stephens 2007

Lower part of the estimate



RESULTS

For our average estimate (1.5 million hectares burned):

provisional results

Our estimates for mean CO_2 emissions:

6.73 metric tons per acre burned

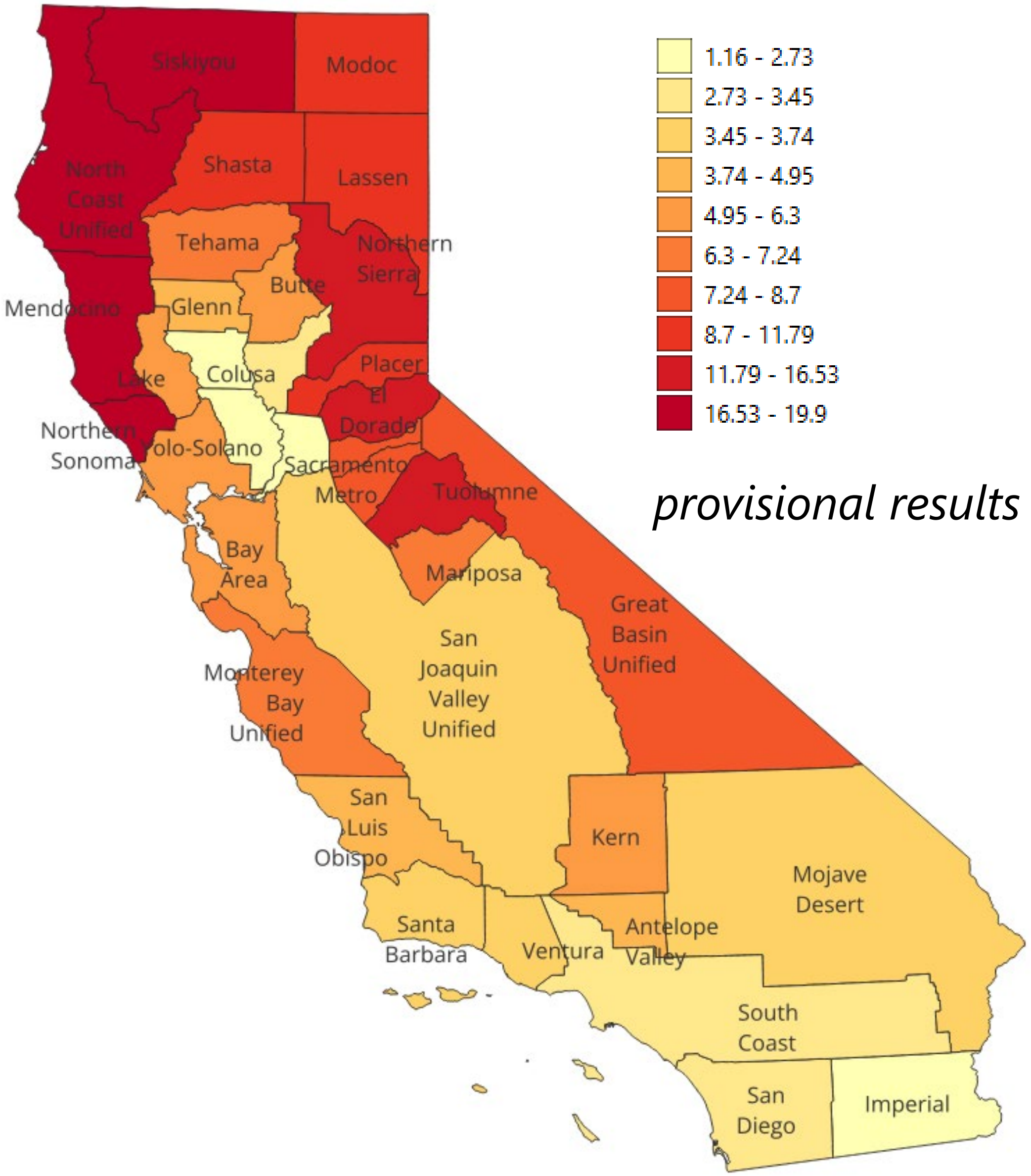
Stephens et al 2007 mean CO_2 emissions:

7.5 metric tons per acre burned

Modern fires 2000-2020 (CARB):

24 metric tons per acre burned

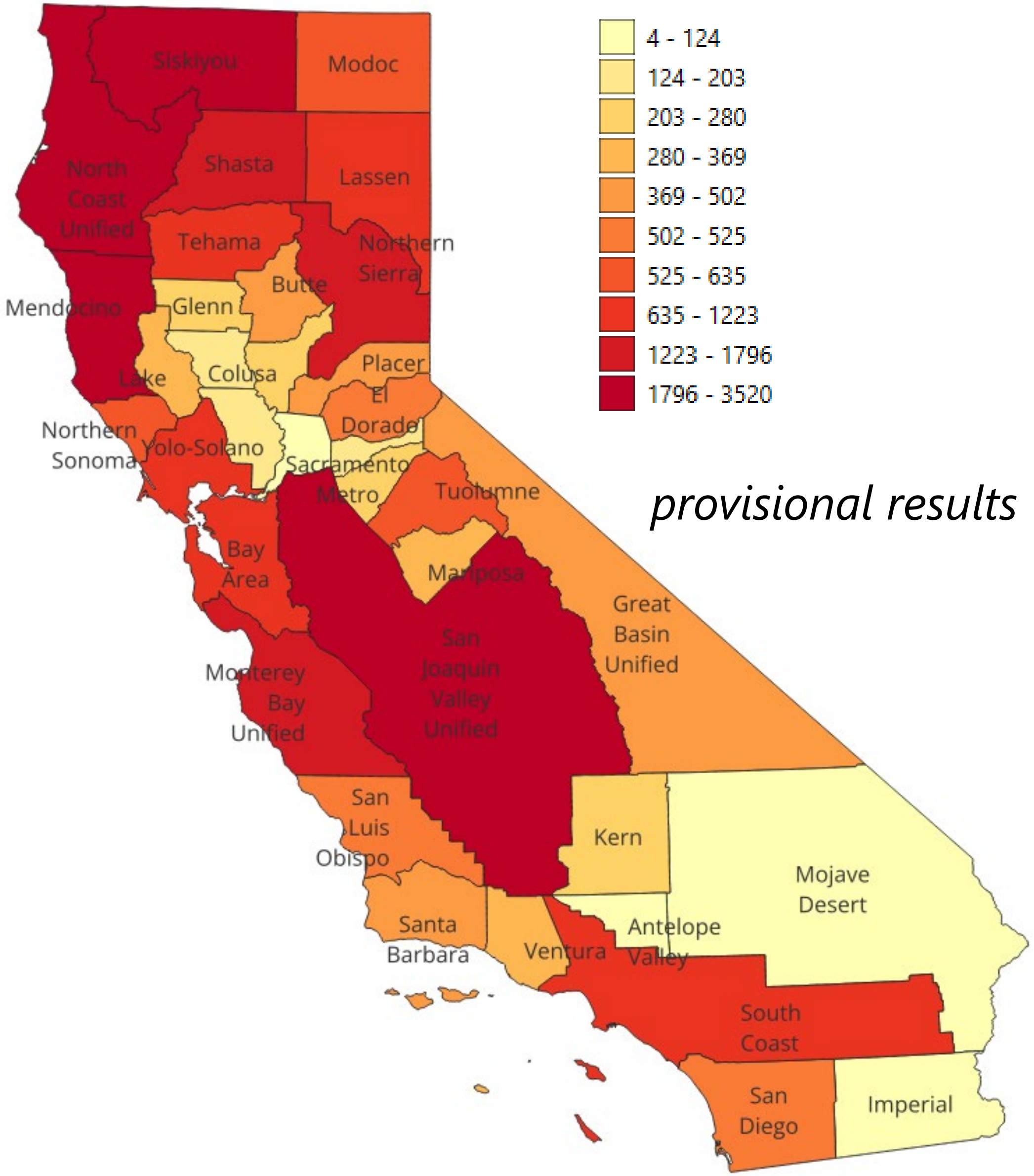
Mean metric tons CO_2 per burned acre per year



provisional results

Assumes equal spatial probability of burning across all pixels.

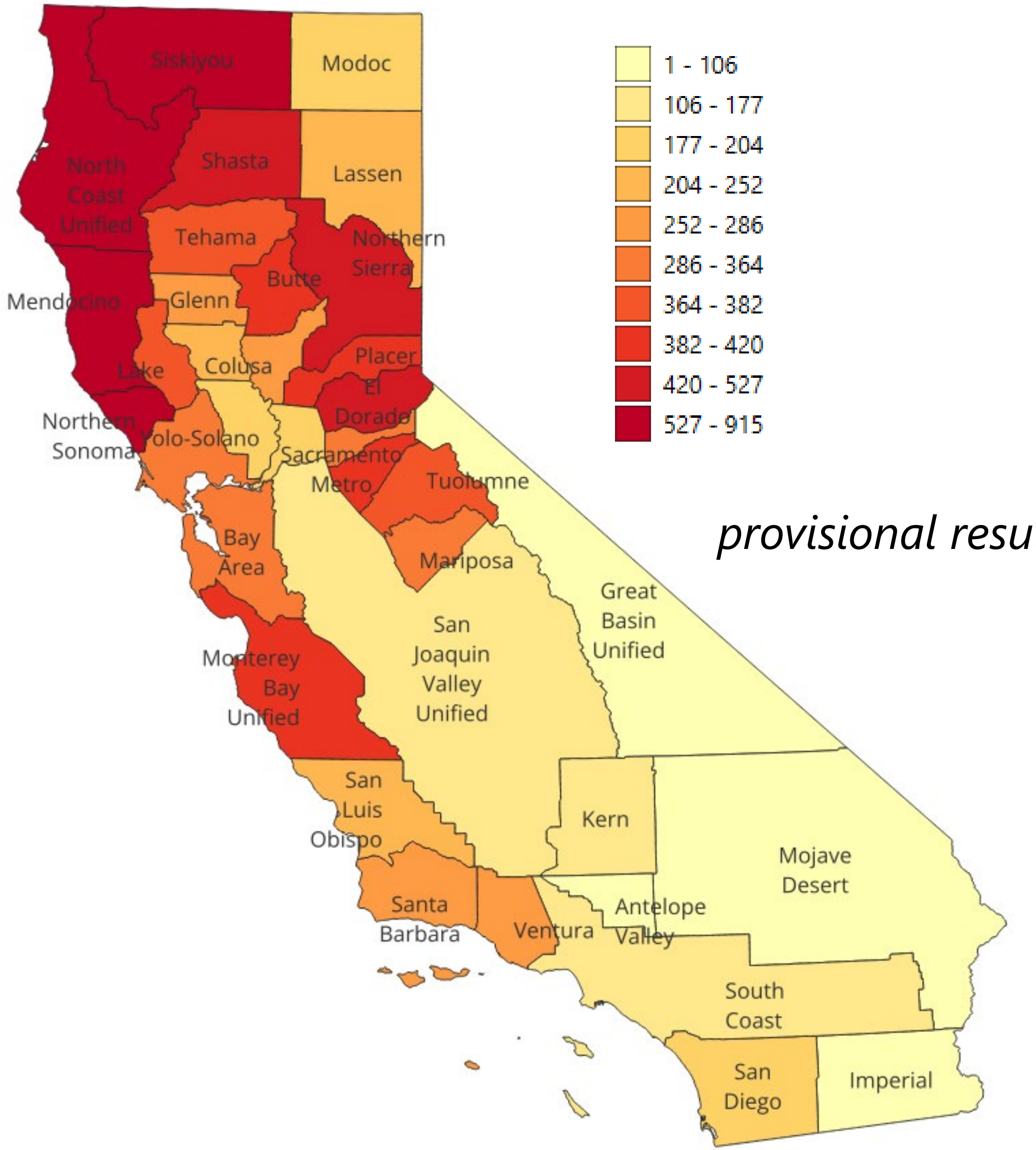
Annual Gg CO_2 in each air district



provisional results

Assumes equal spatial probability of burning across all pixels.

Mean Kg CO_2 per acre (whole district) per year



provisional results

Assumes equal spatial probability of burning across all pixels.

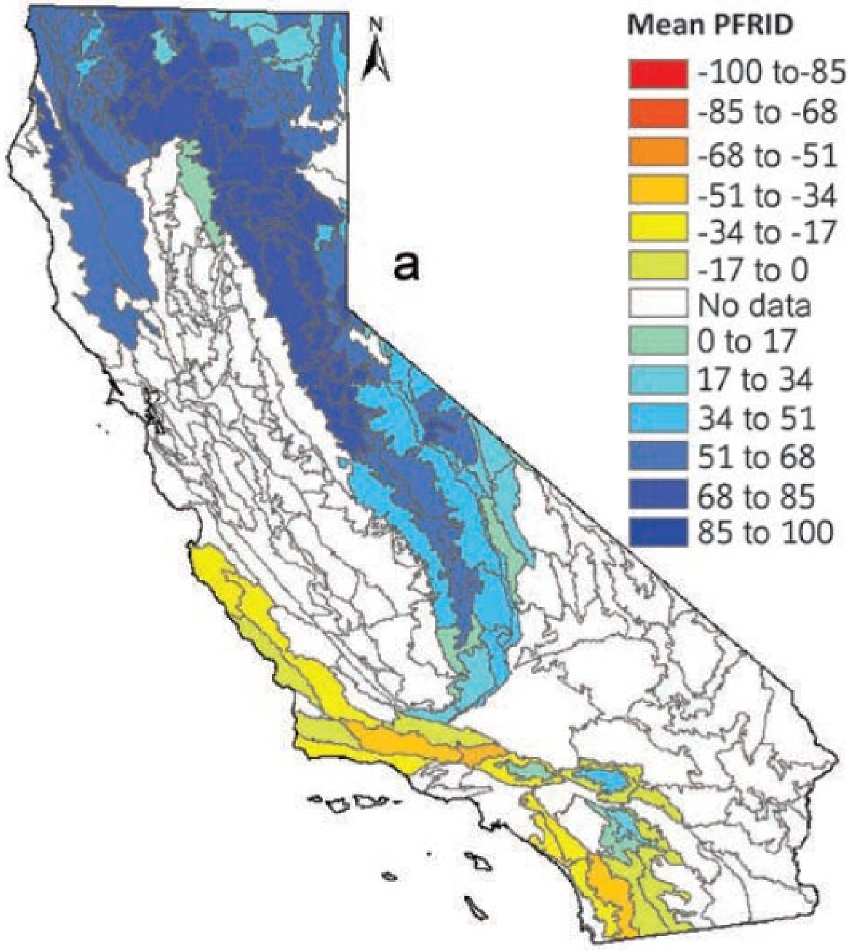
New PFRID calculations

Safford and Van de Water 2014

$$\text{departure} = \frac{\text{current - hist}}{\text{max(current, hist)}}$$

<u>Fire Return Interval Departure (FRID)</u>

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



New PFRID

Limitations of current FRID:

Federal lands

Not all vegetation types

Base map is 2011 CALVEG/EVEG

Potential improvements:

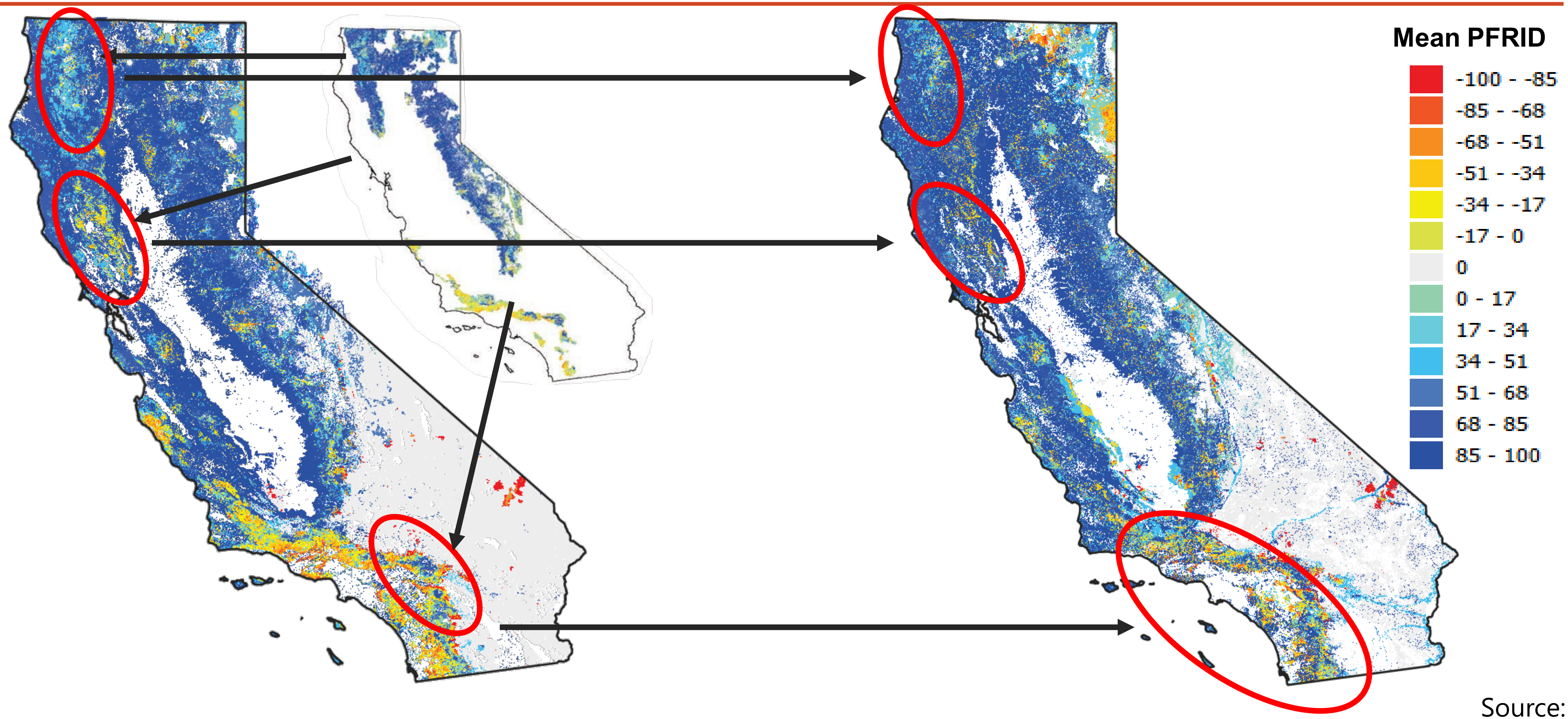
Updated FRIs for all vegetation types

Use of FVEG for current vegetation across the whole state

Use of new historical map for “potential” vegetation

New uncertainty measure

New PFRID



Source: own
Base map: **EVEG+FVEG**
Fires: 1908-2023
FRIs: Van de Water and Safford 2011 + LANDFIRE

Source: own
Base map: **BpS-modified**
Fires: 1908-2023
FRIs: Van de Water and Safford 2011 + LANDFIRE
Excluded current anthropic areas according to FVEG

Takeaway messages

Reproducing historical fire regimes is challenging; recent data and methods advances provide better estimates

Historical fire regime reconstruction can quantitatively incorporate indigenous cultural burning in the estimation of vegetation type distribution and fire regimes

Our provisional results mechanistically account for indigenous burning, which increases the grassland-type cover. This expands the total burned area, but it decreases total emissions

Recent wave of large fires is shrinking positive FRI departures in some Northern California forests. But SoCal is seeing increasingly negative departures (too much fire)

Different historical vegetation maps show different patterns.

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From Past to Present: Revised Estimates of Historical Burned Areas and Emissions in California and Modern Deviations from Pre-Euroamerican Settlement Fire Frequencies

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Thanks!

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