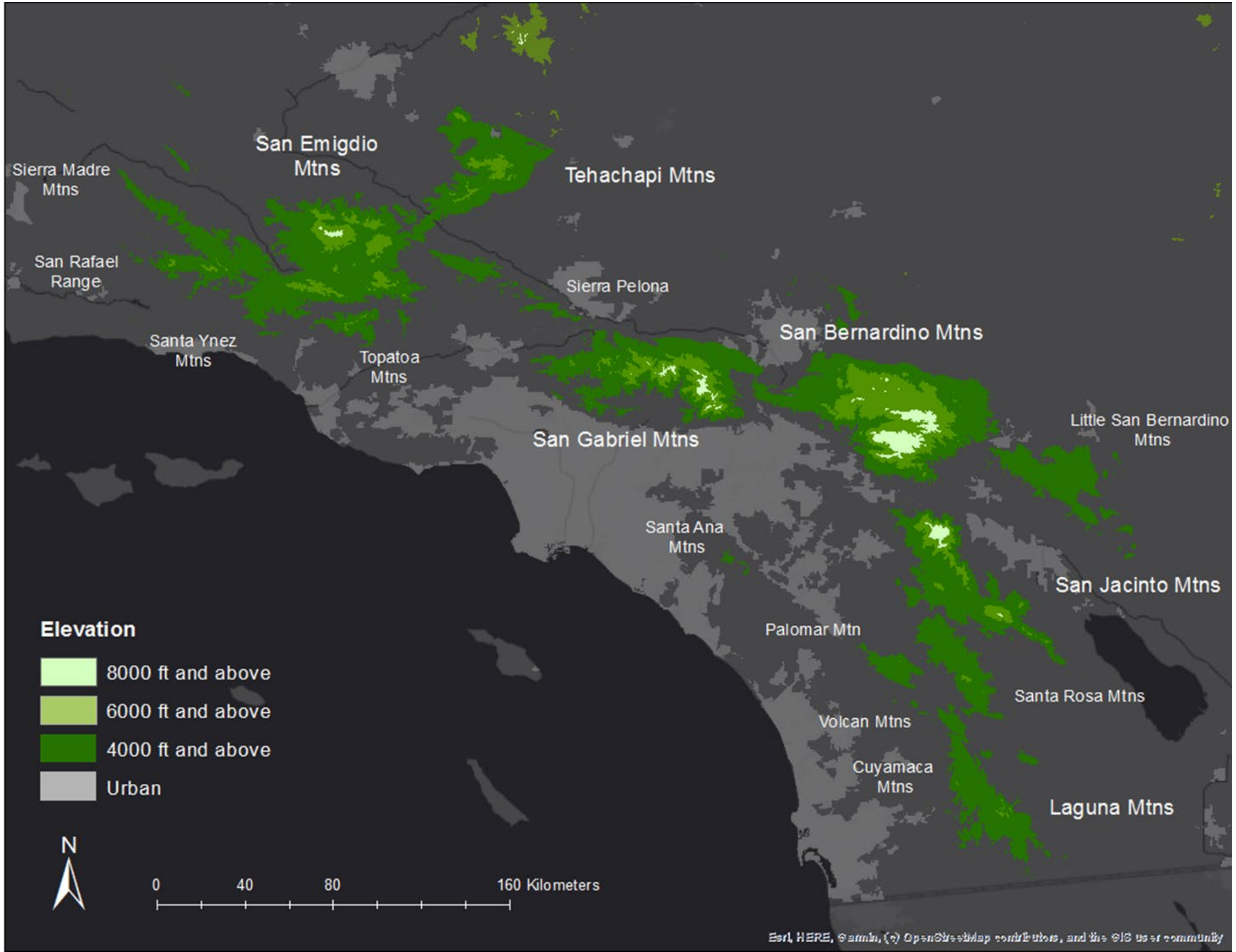
Natural range of variation in the montane conifer forests of southern California – what historical conditions can tell us about managing forests in the era of fire suppression and climate change

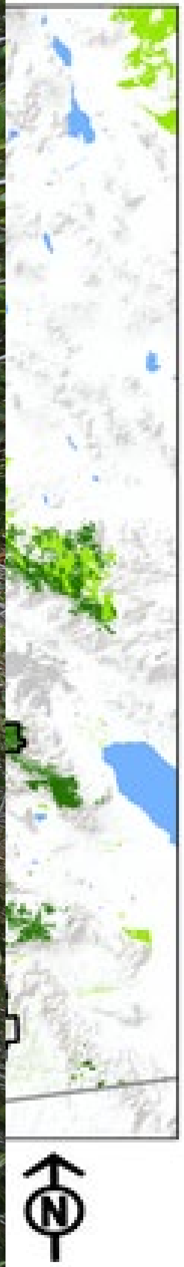
John N. Williams & Sarah Hennessy
University of California-Davis & USDA Forest Service

Collaborators: Nicole Molinari[1], Quinn Sorenson[2], Hugh Safford[2,3],
[1]USDA Forest Service; [2]University of California, Davis; [3]Vibrant Planet

Montane Sky Island Forests of Southern California

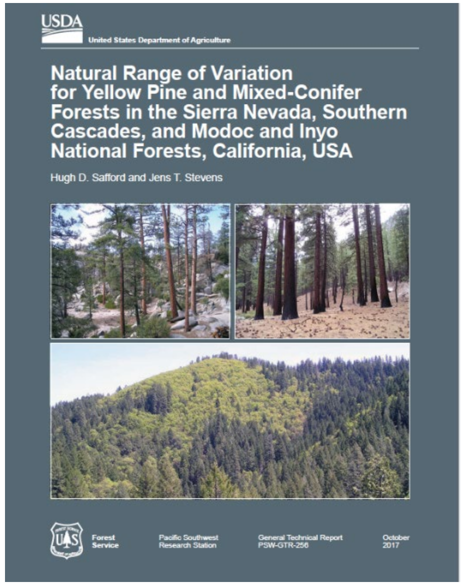


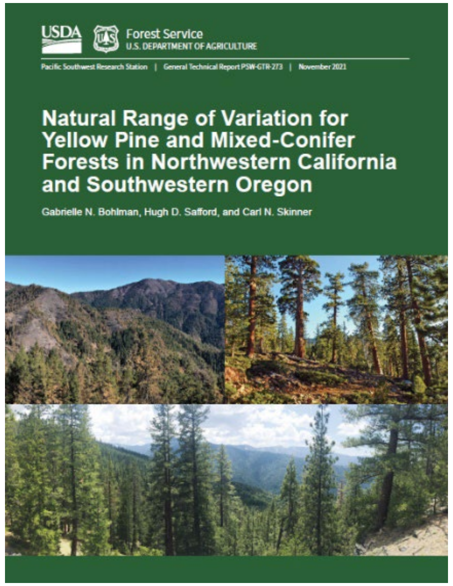
Yellov

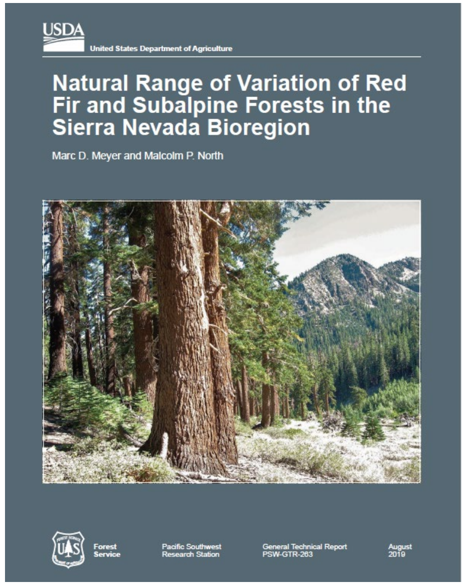


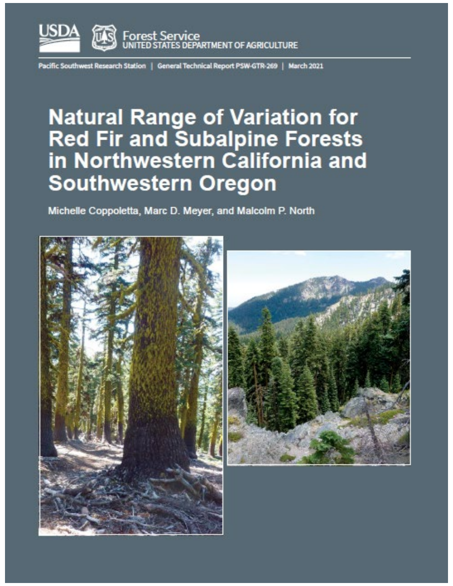
What are Natural Range of Variation (NRV) assessments and are they important?

- Baseline information on ecosystem conditions: composition; structure; function.
- Qualitative and quantitative to assess contemporary departure from “natural” **range** of conditions
- Reference for ecological restoration & recovery.
- Starting point for trends & improved estimates.







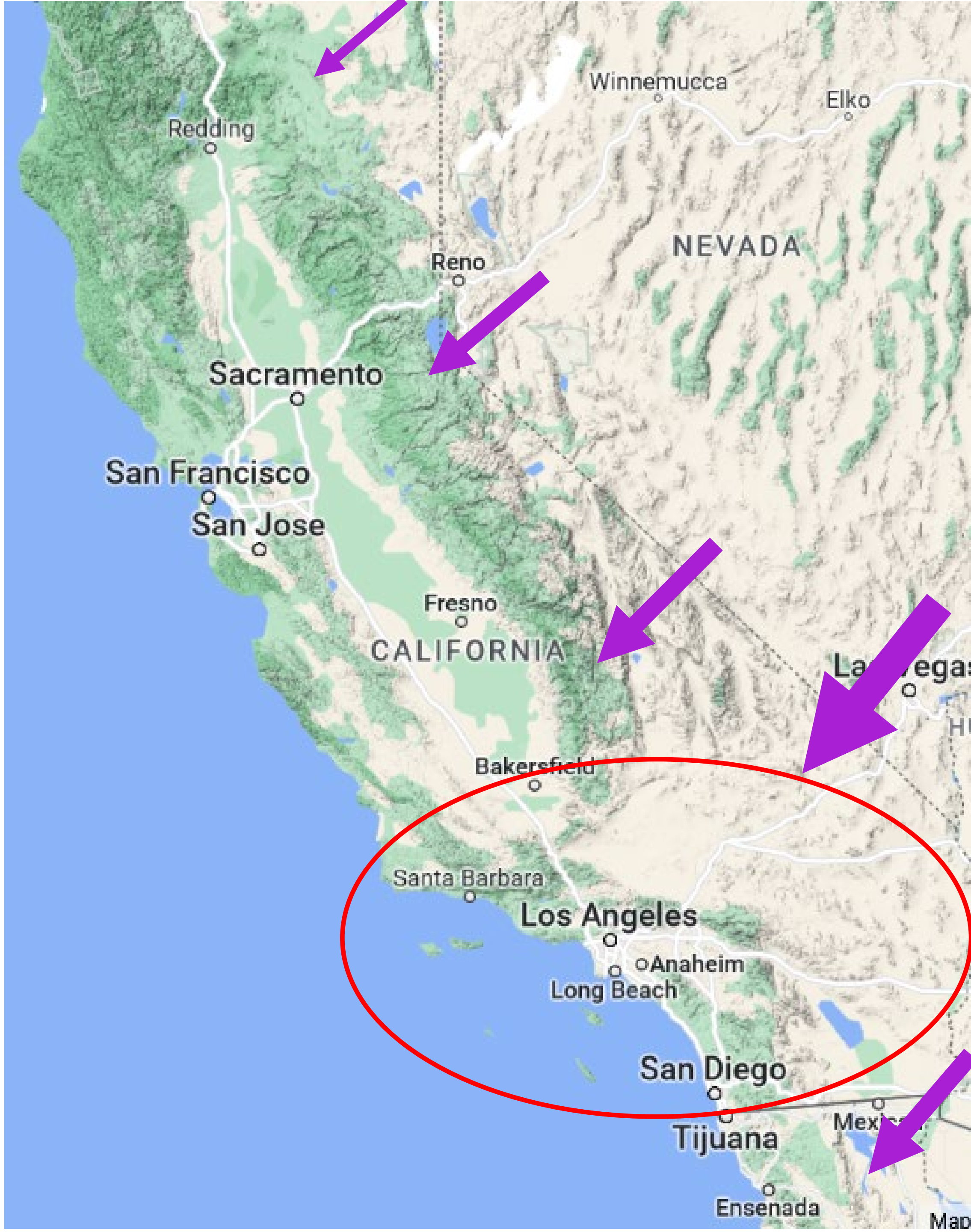


NRV period constrained by ability to look back in time

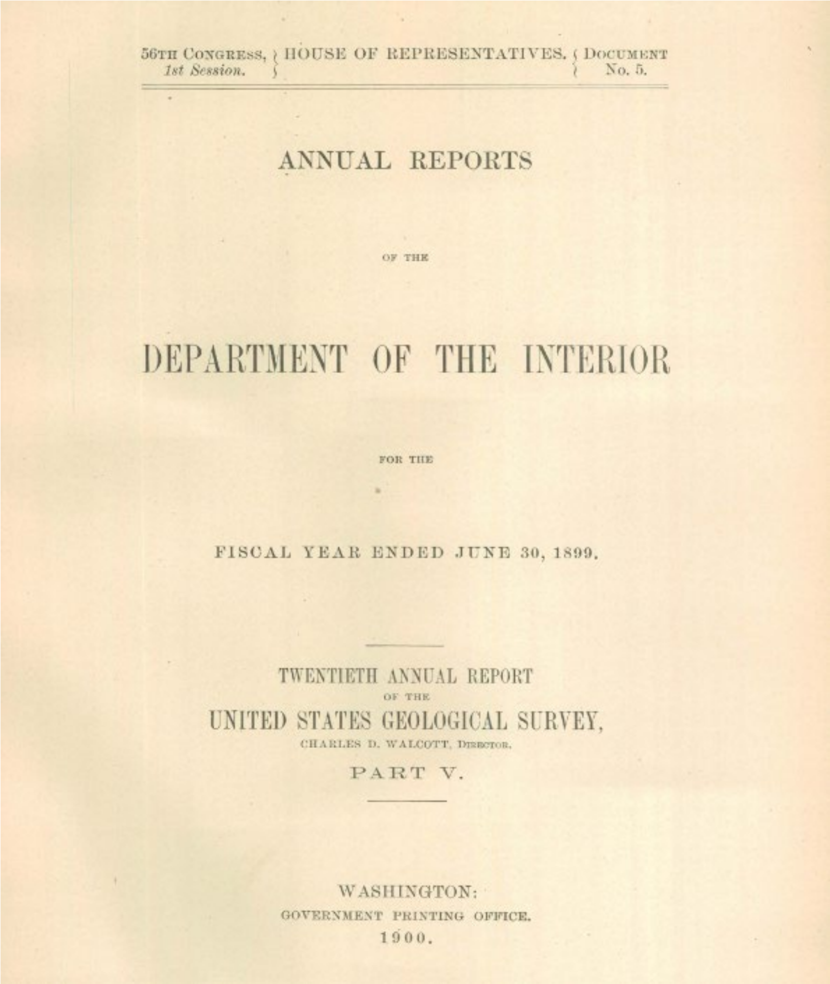
Most references limited to ~100-400 years before present, heavily biased toward more recent part of that range.

This coincides with the Little Ice Age, so not an unbiased estimate of long-term historical conditions.

We draw on historical data from study area, but also look at past/present in adjacent analogous forest types with +/-intact fire regimes → YPMC in Sierra Nevada, Sierra Juárez, Sierra San Pedro Mártir, S. Cascades.



National Forest Reserve Recon surveys of 1890s for USGS by John Leiberg



56TH CONGRESS, 1st Session. | HOUSE OF REPRESENTATIVES. | DOCUMENT No. 5.

ANNUAL REPORTS

OF THE

DEPARTMENT OF THE INTERIOR

FOR THE

FISCAL YEAR ENDED JUNE 30, 1899.

TWENTIETH ANNUAL REPORT

OF THE

UNITED STATES GEOLOGICAL SURVEY,

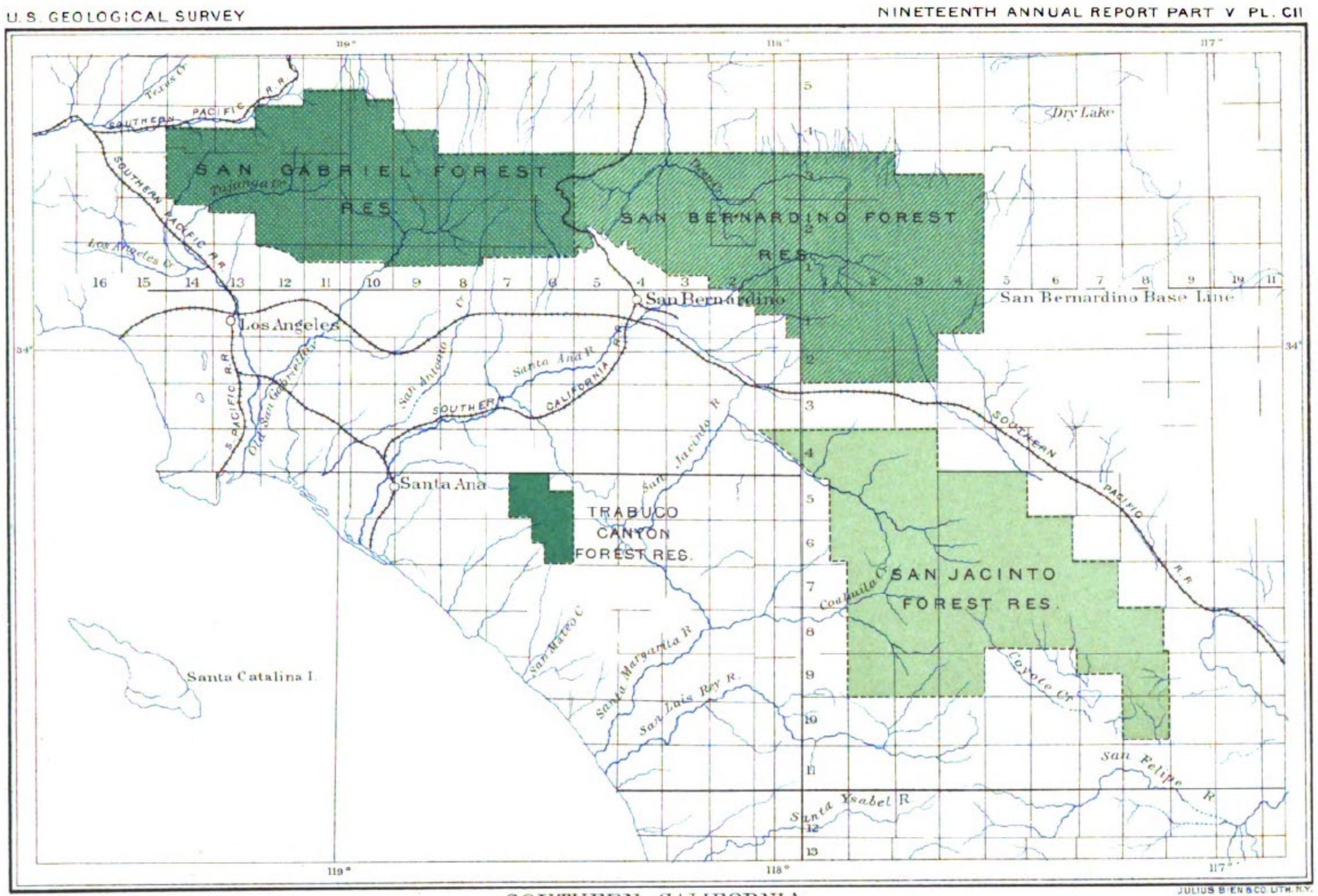
CHARLES D. WALCOTT, DIRECTOR.

PART V.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1900.



SOUTHERN CALIFORNIA

SHOWING LIMITS OF FOREST RESERVES

SCALE

0 10 20 30 40 50 MILES

Forest dimensions and variables examined

Ecological Function

Climate

Fire frequency, severity and extent

Insects & disease

Grazing & logging

Nutrient cycling & successional processes

Carbon sequestration

Species Composition

Landscape-level species composition

Trends in conifer and oak cover

Understory: shrubs, grasses

Stand Structure

Tree density, basal area

Gaps, clumps & snags

Tree seedlings & regeneration

Understory: shrubs, grasses and litter

Carbon balance

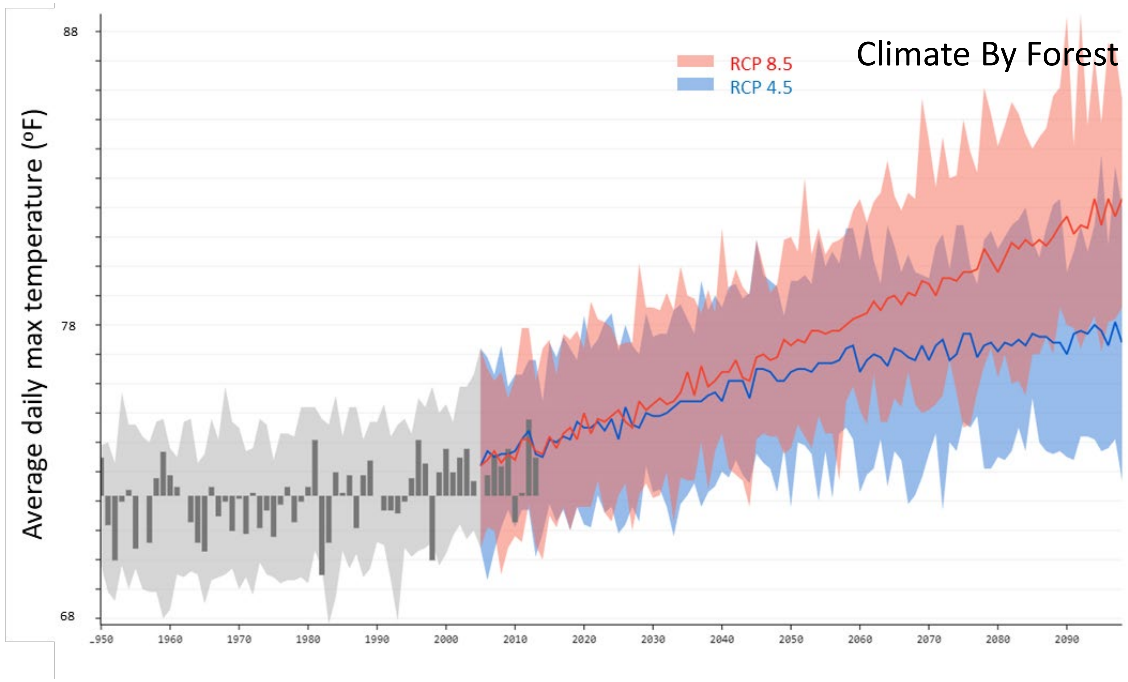
Surface fuels & litter

Climate changes and NRV

Temperature :

- 0.22° C (0.4 °F)/decade increase in mean temp since 1918 (Cordero 2011)
- min & max temp also increasing

Winter in San Bernardino NF ca. 1930. Increasing winter lows decrease depth/duration of snowpack, affecting water supply, germination & budbreak.

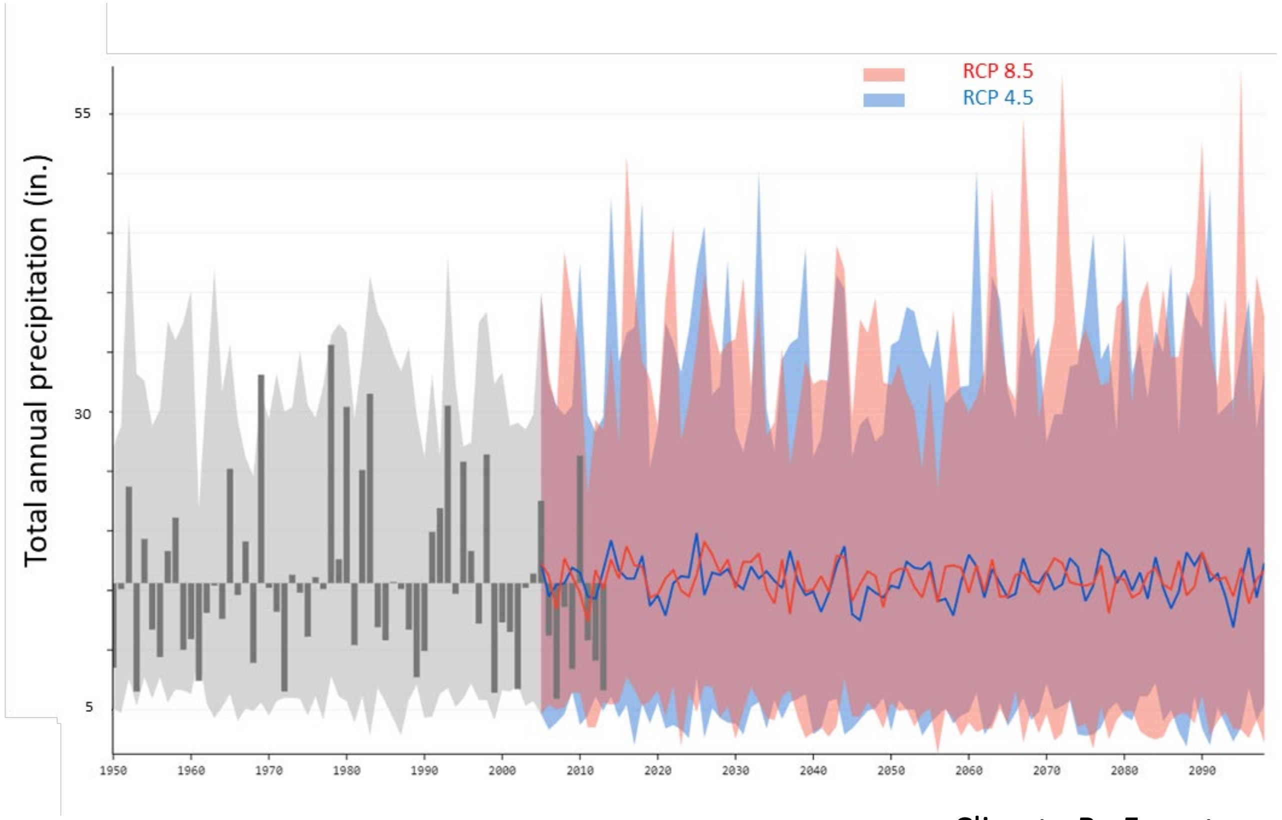


- Since 1946, # freezing months decreased (~5.5 to ~3.5)

Climate changes and NRV

Precipitation:

- SoCal: highest interannual precip variability in US
- El Nino Southern Oscillation
- Atmospheric rivers (Dettinger et al. 2011)
- No clear directional trend in avg, but increase in extremes



Climate By Forest

Climate changes and NRV

Drought:

- Evidence of droughts in paleorecord associated with ENSO cycling (decadal)
- Evidence of megadroughts associated with reduced ENSO variability (millennial)
- Between about 800 and 1400: AD two megadroughts lasting about 200 years and 140 years respectively

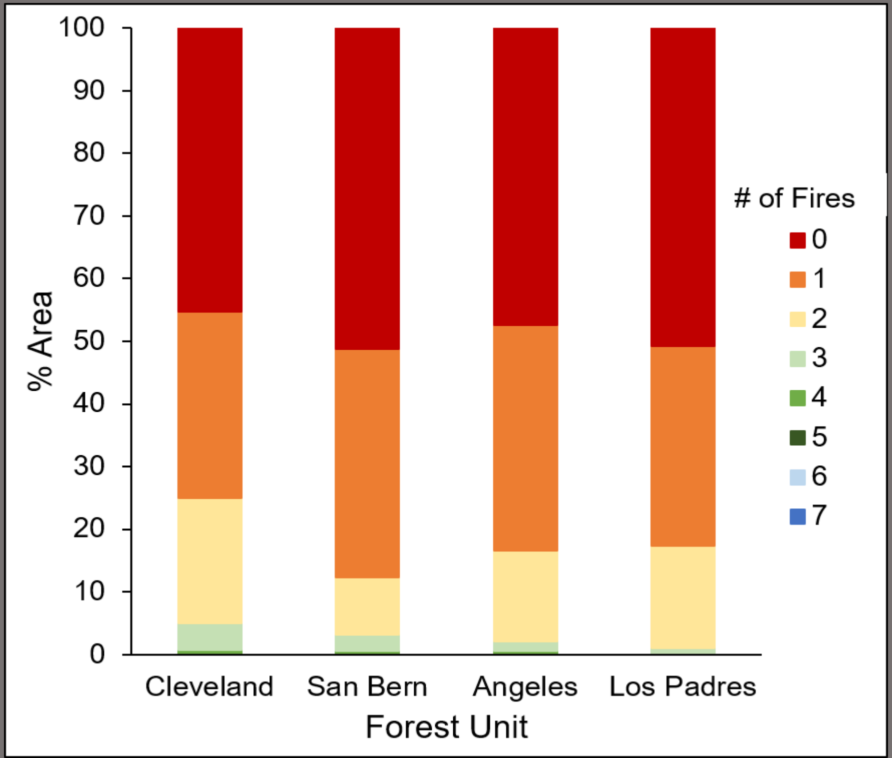
- Current changes:
  - WAS driven by low precipitation;
  - NOW by increasing temperature through evapotranspiration

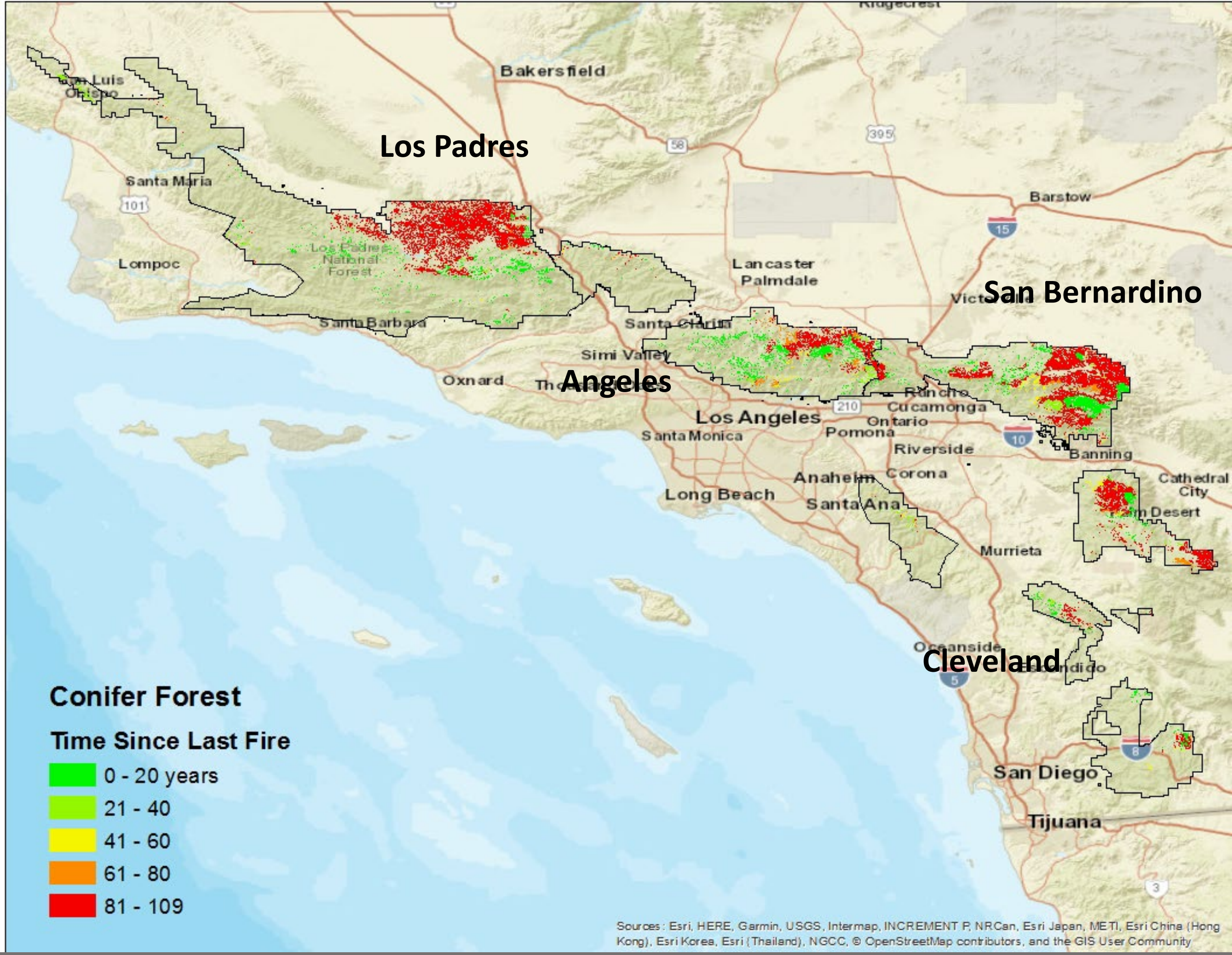
Insects & disease

- 2000-2003 western pine beetle outbreak
- ~2.8 million trees across USFS lands in SoCal

Changing fire return interval

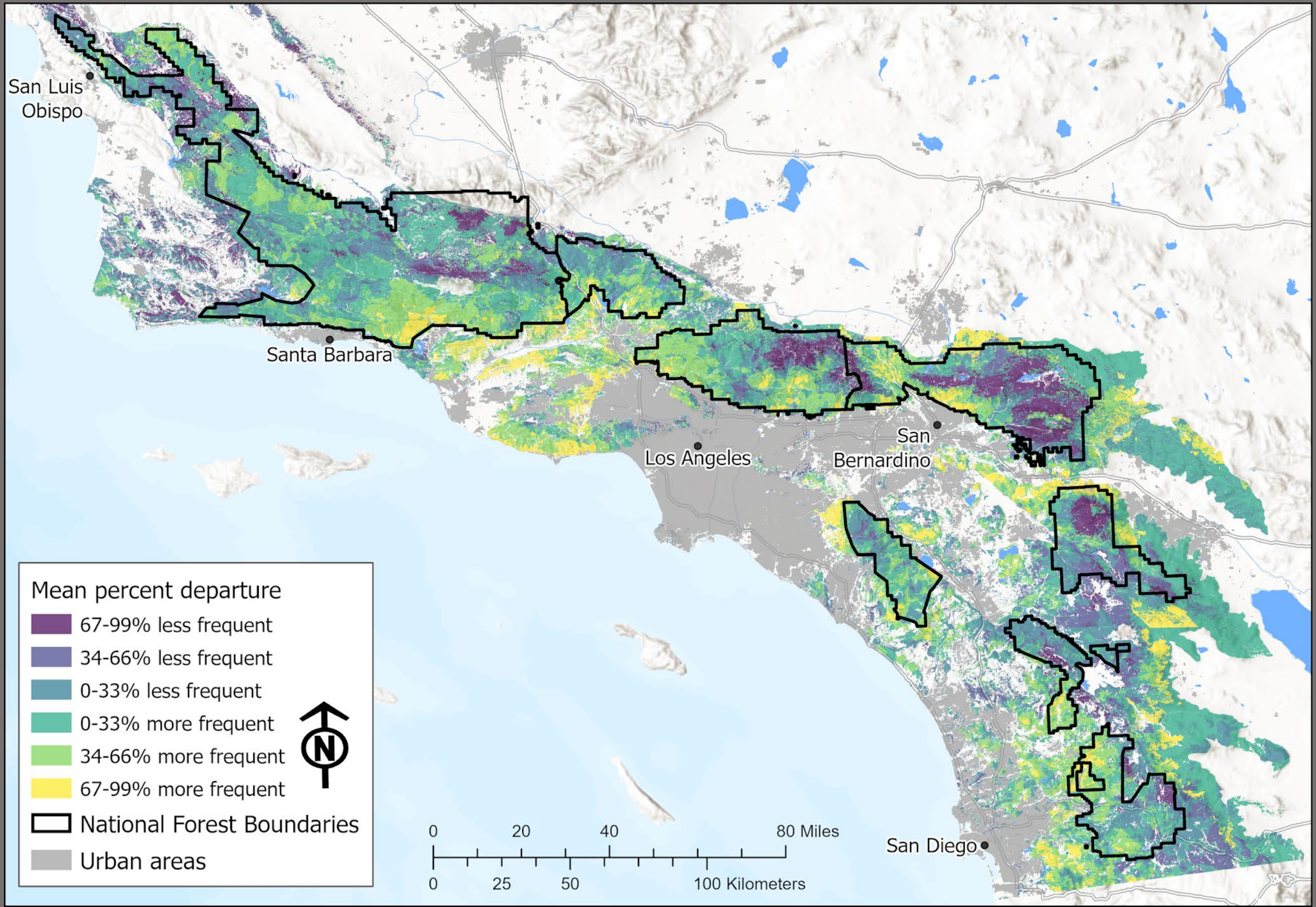
- Historical FRI = 10 - 16 yrs
- Current FRI = 78 yrs
- 50% of conifer forests have not experienced fire in > 100 years





Safford & Van de Water, 2014
Nigro & Molinari, 2019

Changing fire return interval



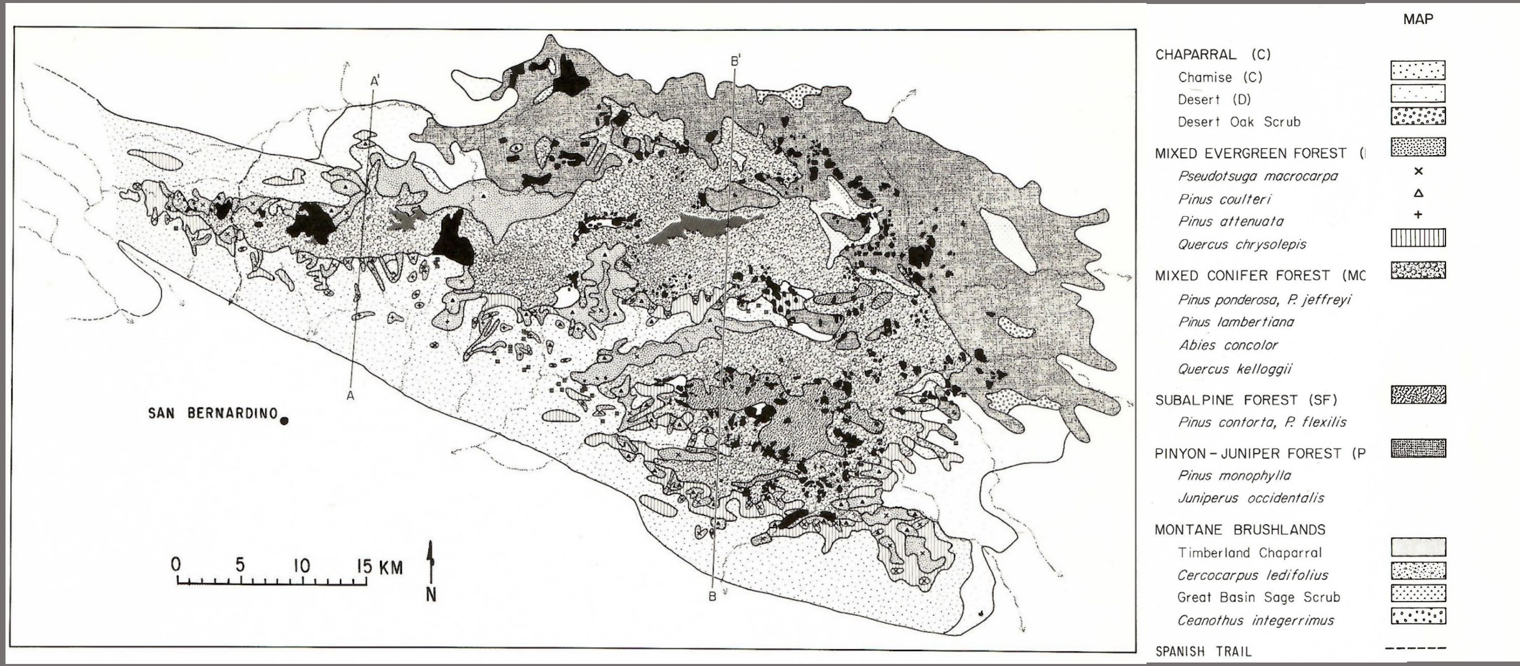
Map credit:
Megan Jennings

Changing fire severity

High Severity Patch Size:
NRV 0.2 ha
current 4.2 ha

Max patch size:
NRV 100 ha (rarely larger)
current 824 ha

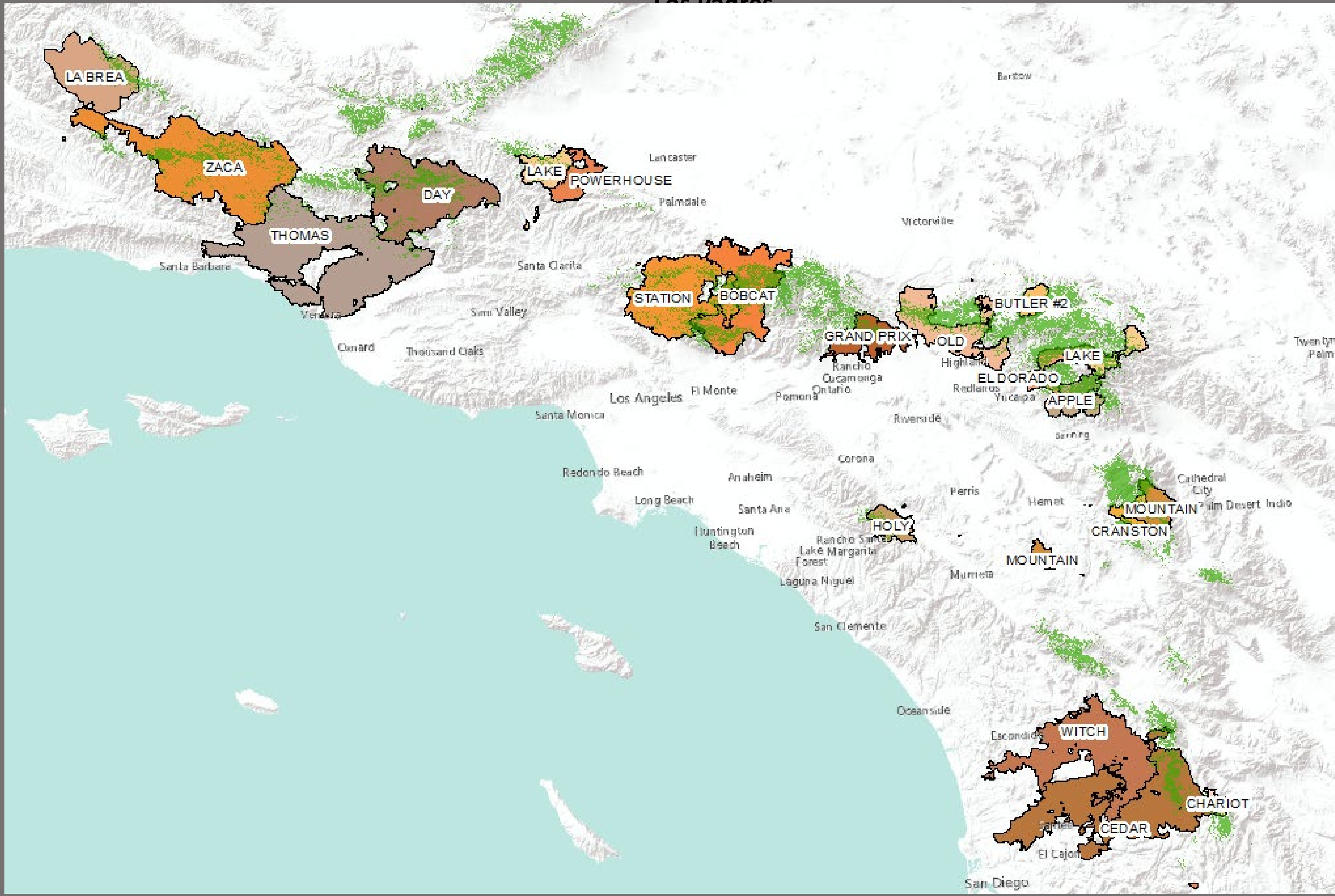
% High Severity Burn Area:
NRV 3-16%
current 24%



Nigro & Molinari, *2019*

Minnich 1988

Changing fire extent



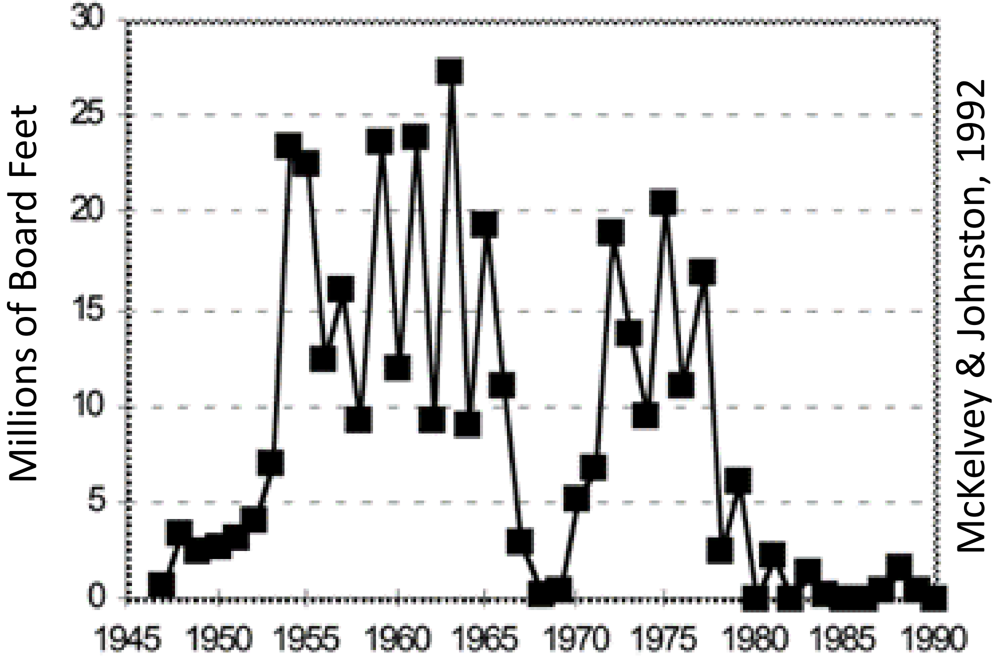
Fire size

NRV 210–456 ha
current 761 ha

Nigro & Molinari, 2019

Grazing & logging

- Not NRV, but sheep grazing prevalent in late 1800s, early 1900s during earliest NRV surveys.
- Pressure from SoCal to limit grazing and logging led to creation of National Forest Reserves
  → became Angeles, Cleveland, San Bern NFs.
- Early technology limitations and later closing of sawmills reduced incentives for logging.



McKelvey & Johnston, 1992

Successional Processes

- Dominant ir

"After
in aga
evider
timbe
at the

"In a b
the ru
anoth
relatio

Photo: slworking2

Carbon Balance

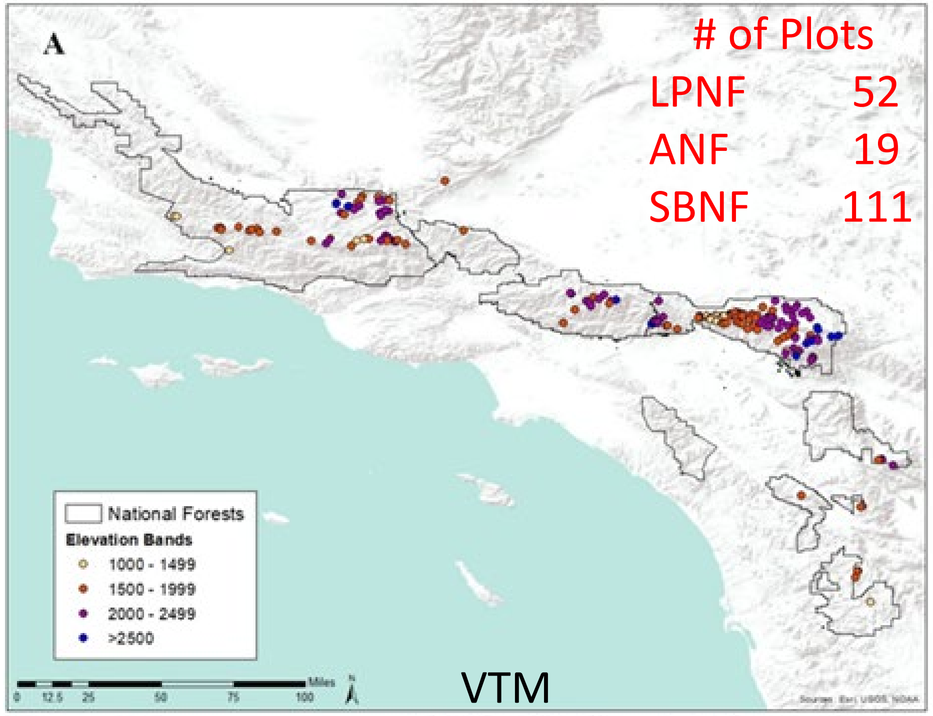
National Forest	Forested Carbon Stocks 2020 (Tg C)	Forested area (ha)	Shrubland Aboveground Carbon (Tg C)	Shrubland area (ha)	NF area in shrubland (%)
Angeles	4.8±2.1	47,533	0.34 ± 0.02	123,777	54
Cleveland	0.6±0.4	6,218	0.41±0.02	123,837	54
Los Padres	25.3±7.0	230,869	1.10 ± 0.07	282,173	34
San Bernardino	13.9±5.3	119,211	0.29 ± 0.03	90,959	26

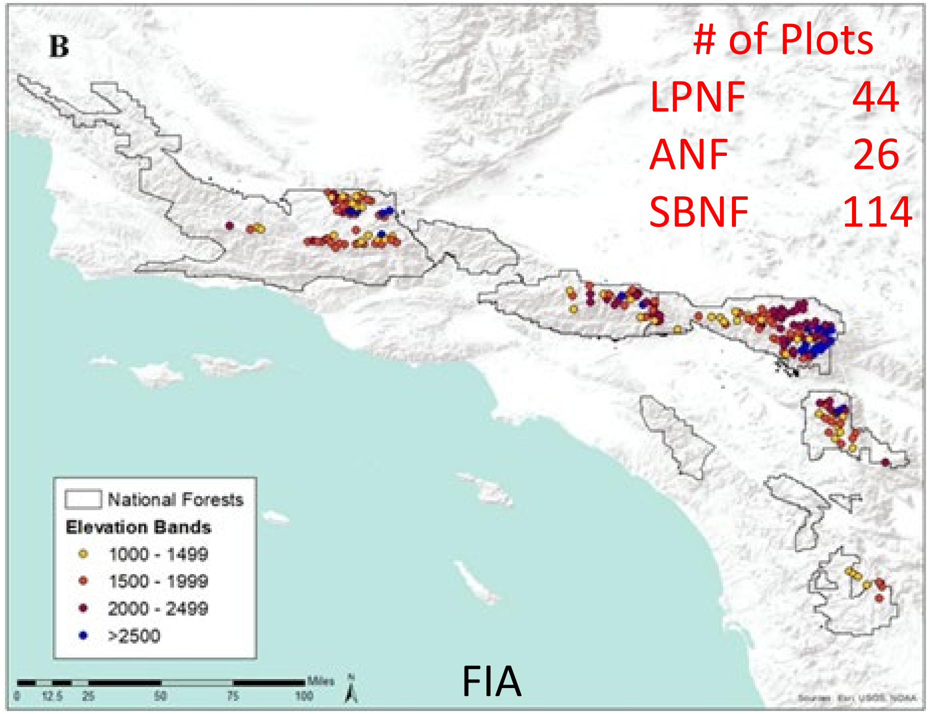
Two Important Datasets for Comparison

Vegetation Type Map (**VTM**) survey of 1920's & 30's ("Wieslander Data"): Extensive plot network across CA with pictures, consistent methodology.

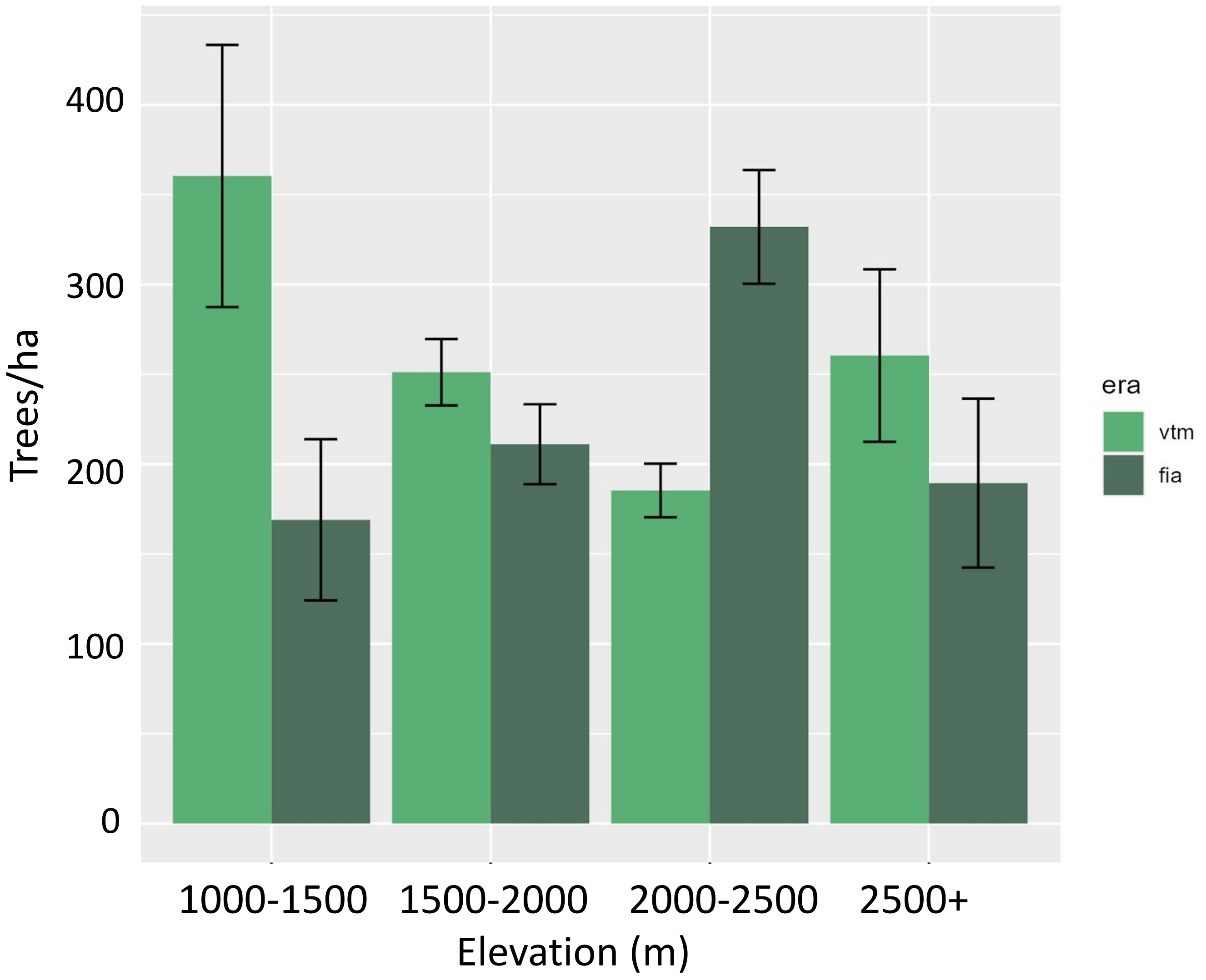
USFS Forest Inventory and Analysis (**FIA**) program: Active plot network across US (data from 2006 or later), uses common stand exam methodology.

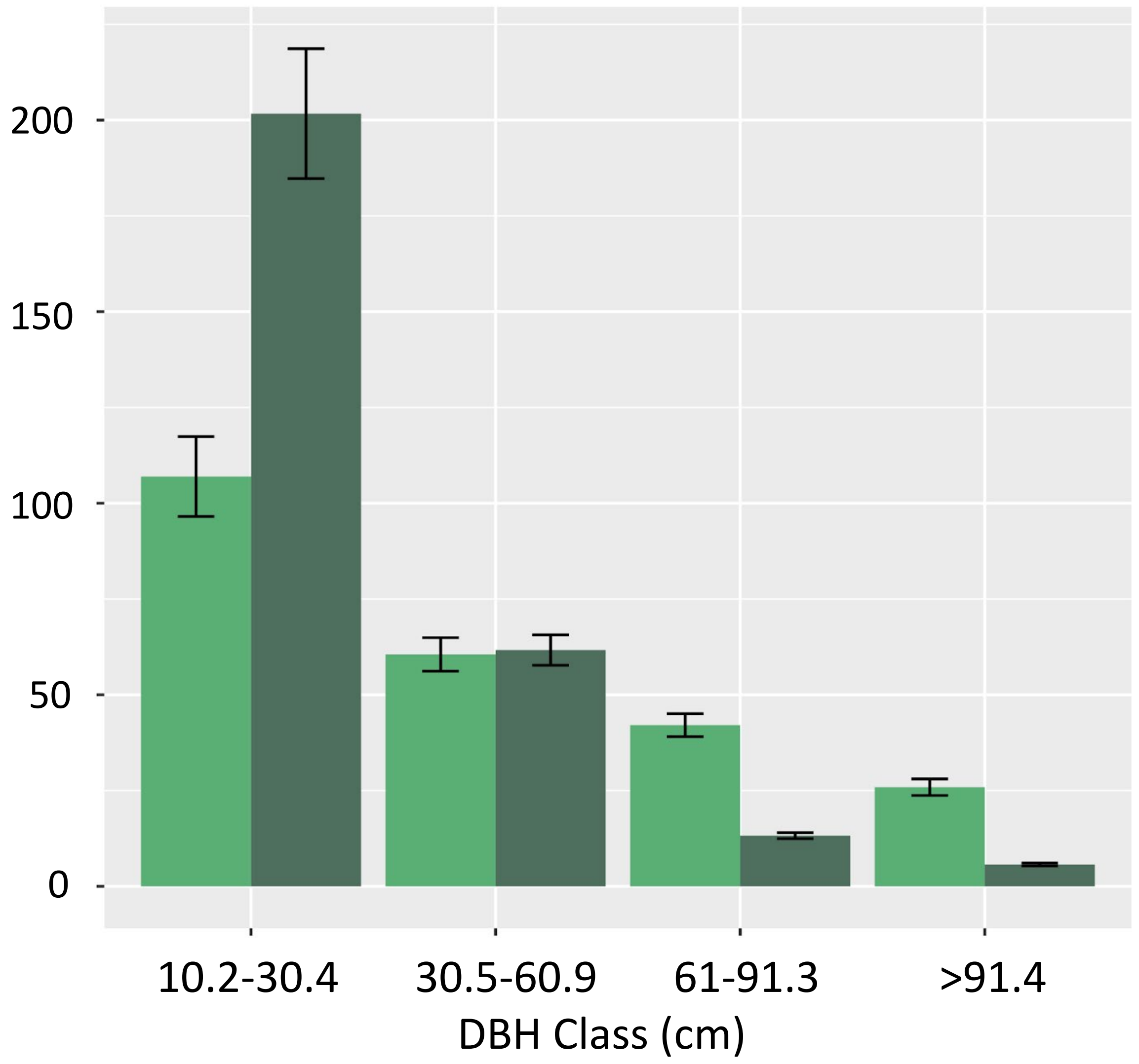
We compared stand structure, species composition and fuels data for VTM and FIA plots in ***Angeles, Los Padres,*** *and* ***San Bernardino National Forests*** *to estimate NRV and current conditions and likely future trends.*





Tree Density

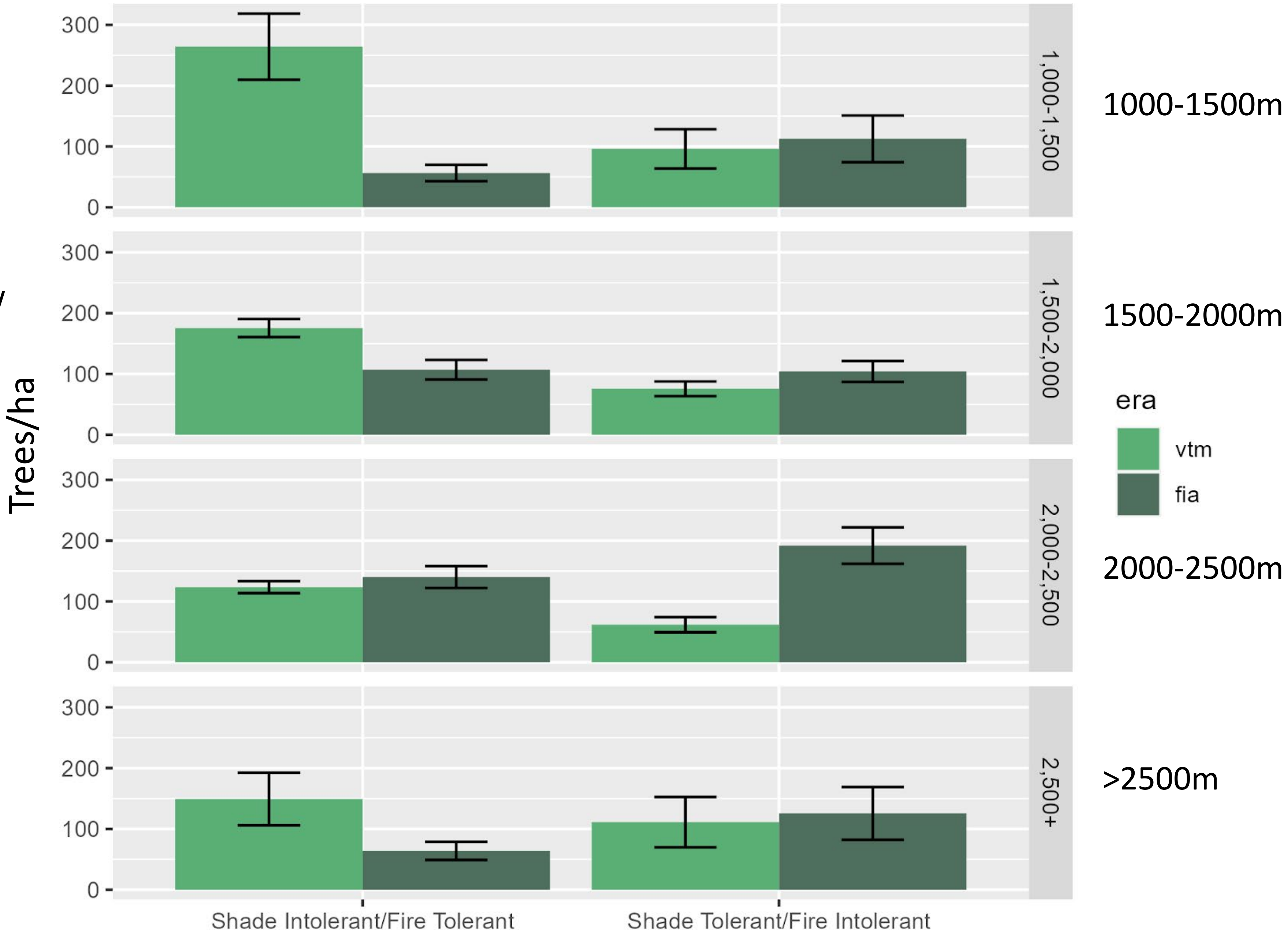




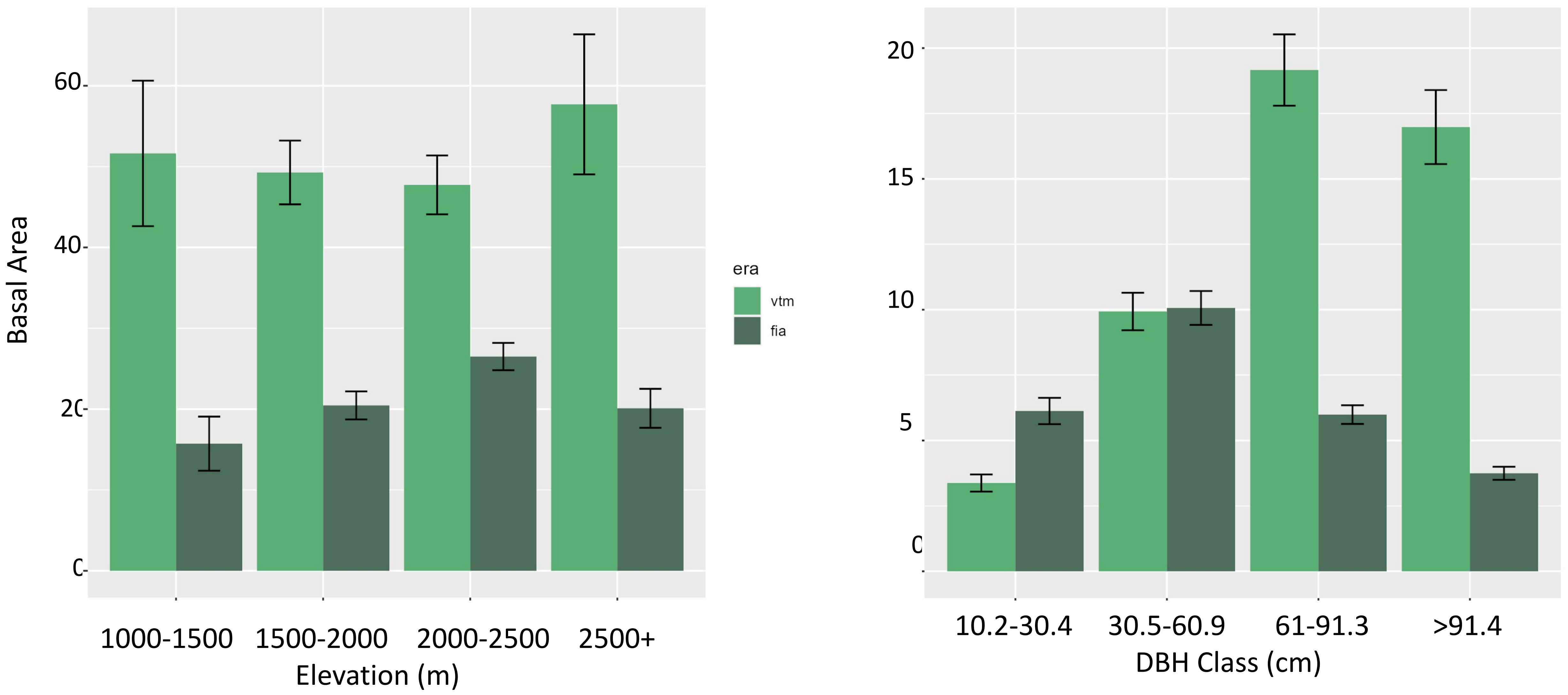
Functional Changes in Tree Species Composition & Density

As tree density increases in the absence of fire, especially among smaller diameter stems, regeneration of shade intolerant species (e.g., yellow pine) decreases.

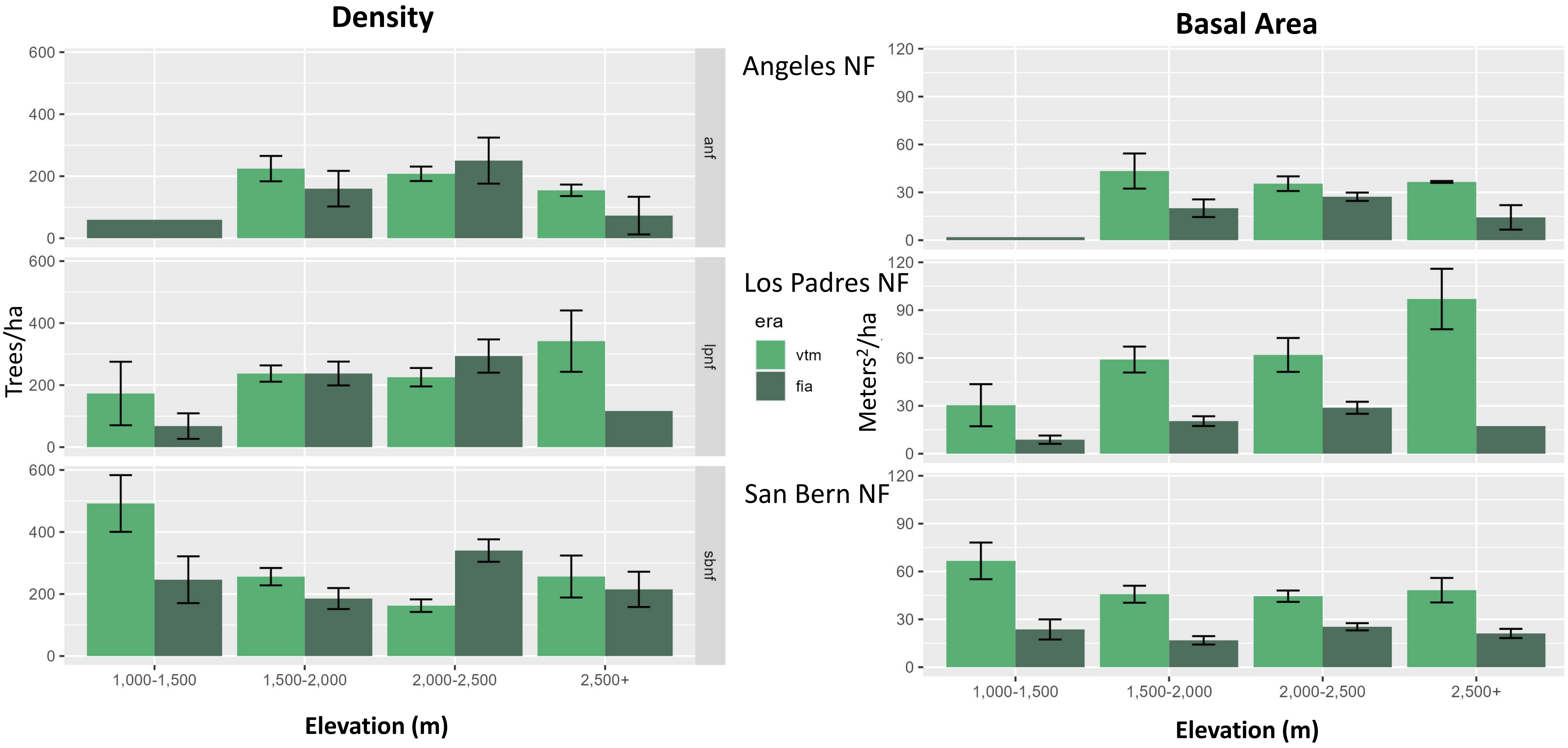
This allows shade tolerant, but fire intolerant species to increase in density, increasing understory and ladder fuels and making the forest more susceptible to stand-replacing high severity fire.



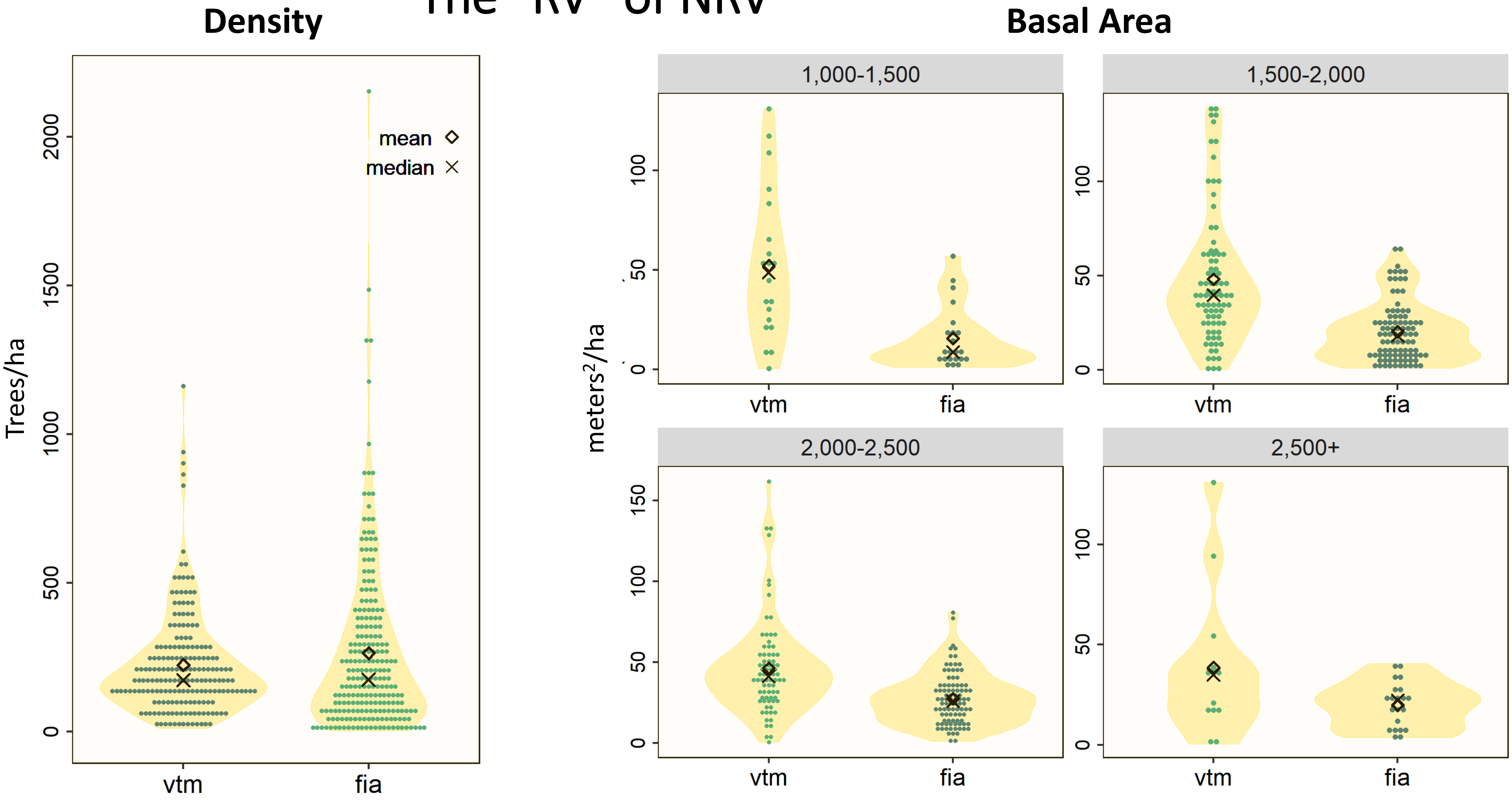
Basal area (m^2/ha)



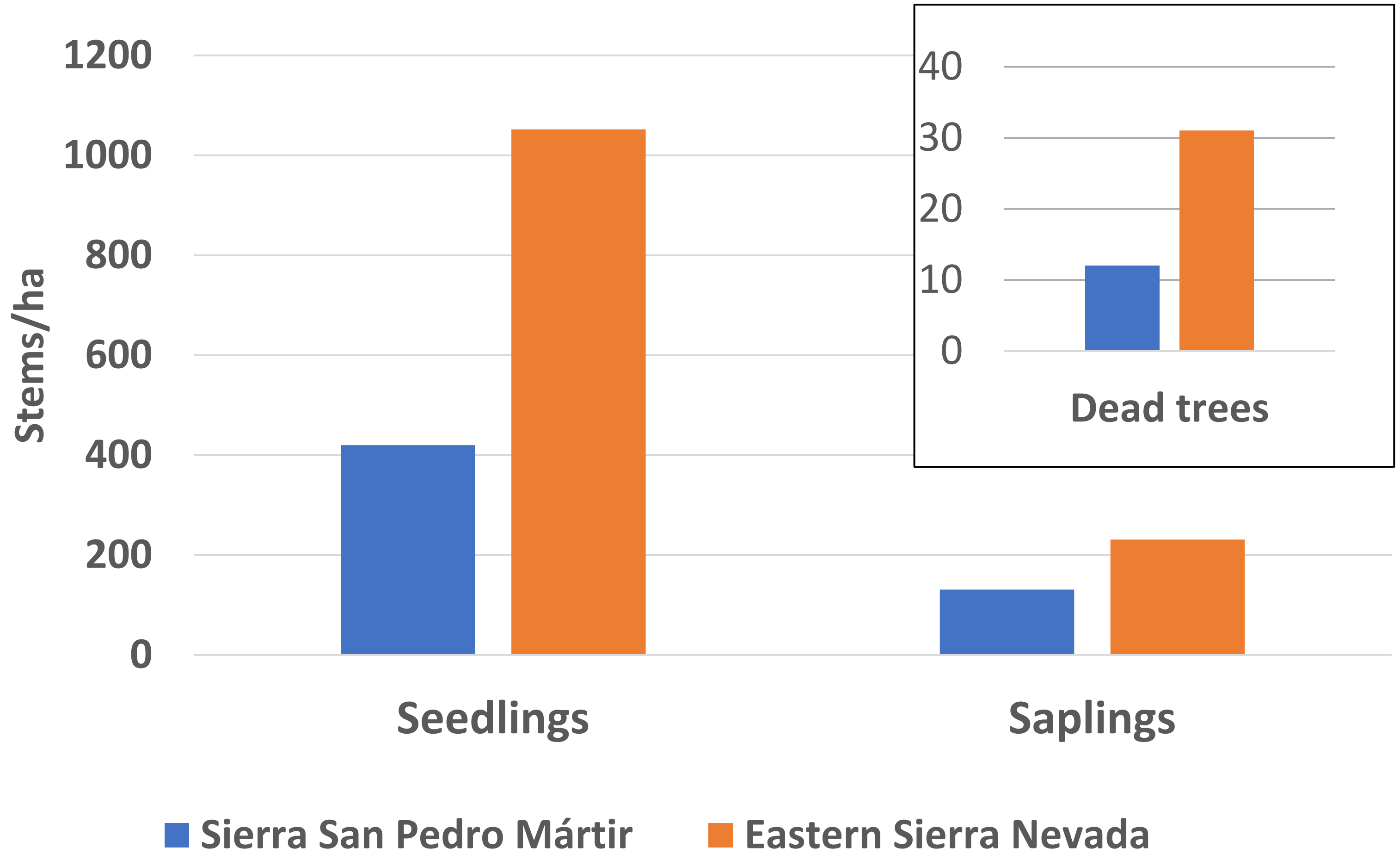
Regional Differences



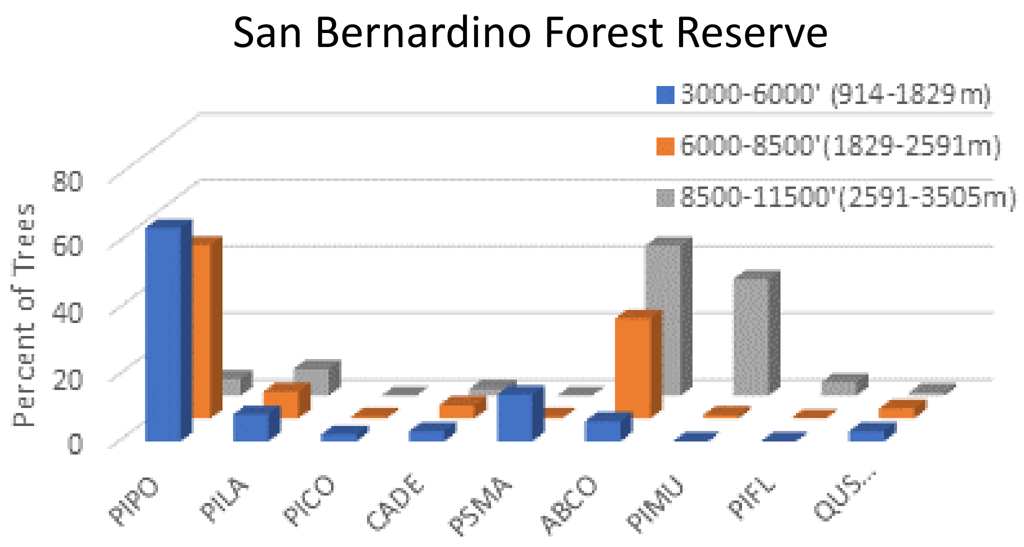
The "RV" of NRV

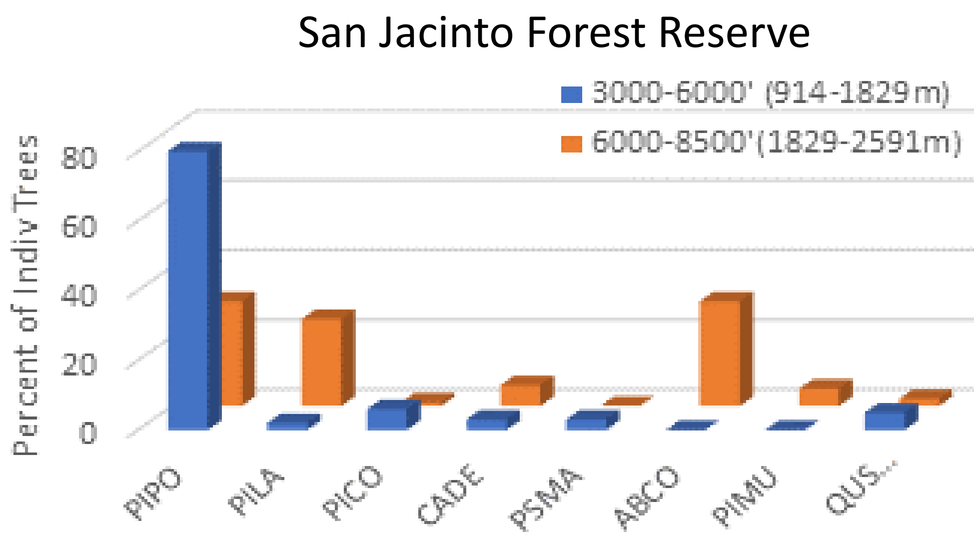

Density
Basal Area
mean
median
Trees/ha
0
500
1000
1500
2000
vtm
fia
1,000-1,500
1,500-2,000
2,000-2,500
2,500+
meters^2/ha
0
50
100
150

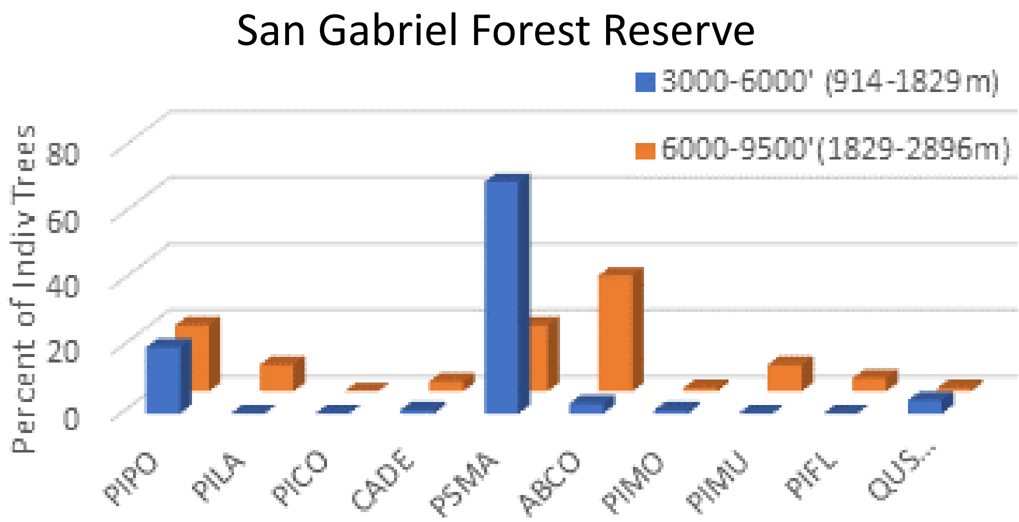
Seedlings, Saplings & Dead Trees
Estimates from adiacent forests with +/- intact fire regimes



Tree species composition – ca. 1900

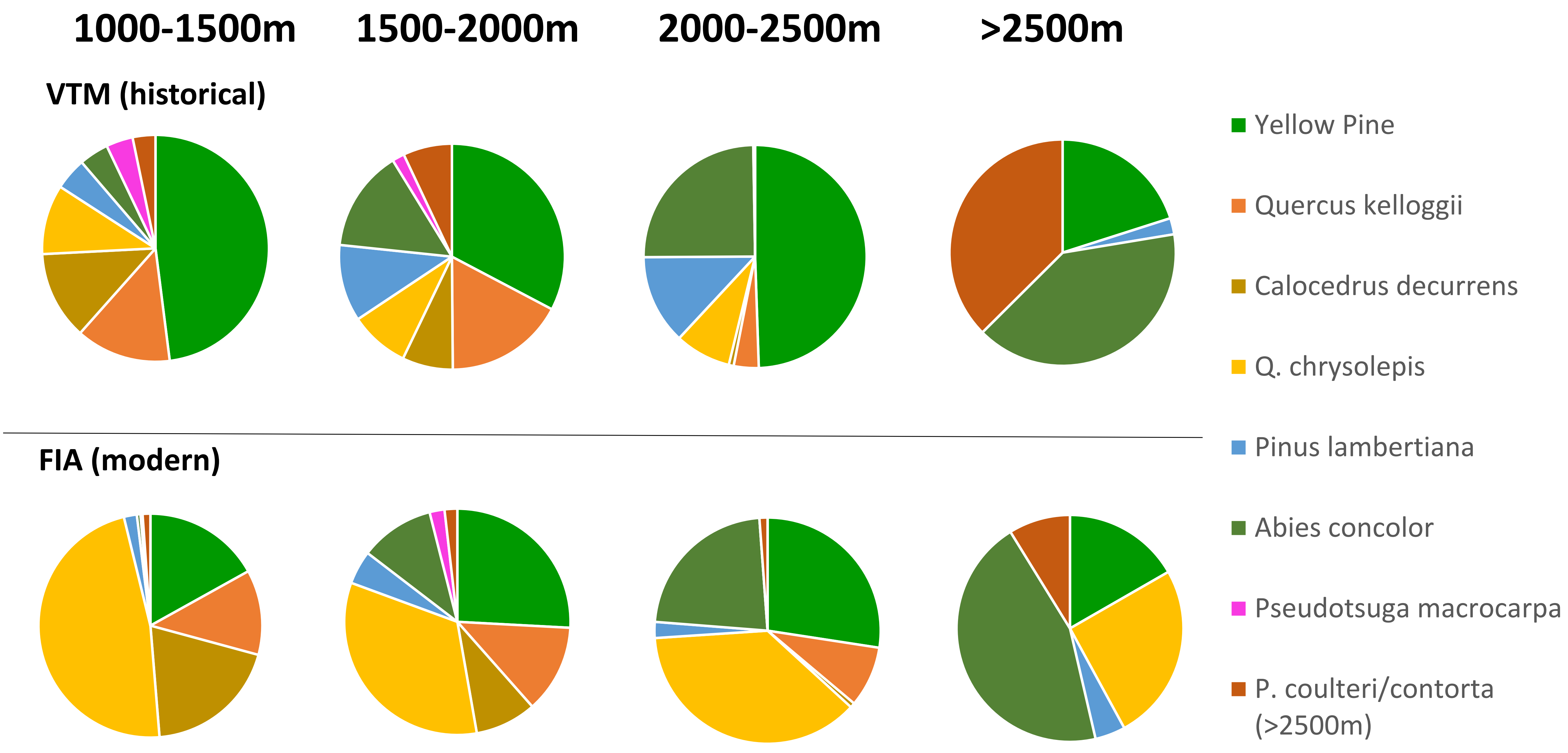




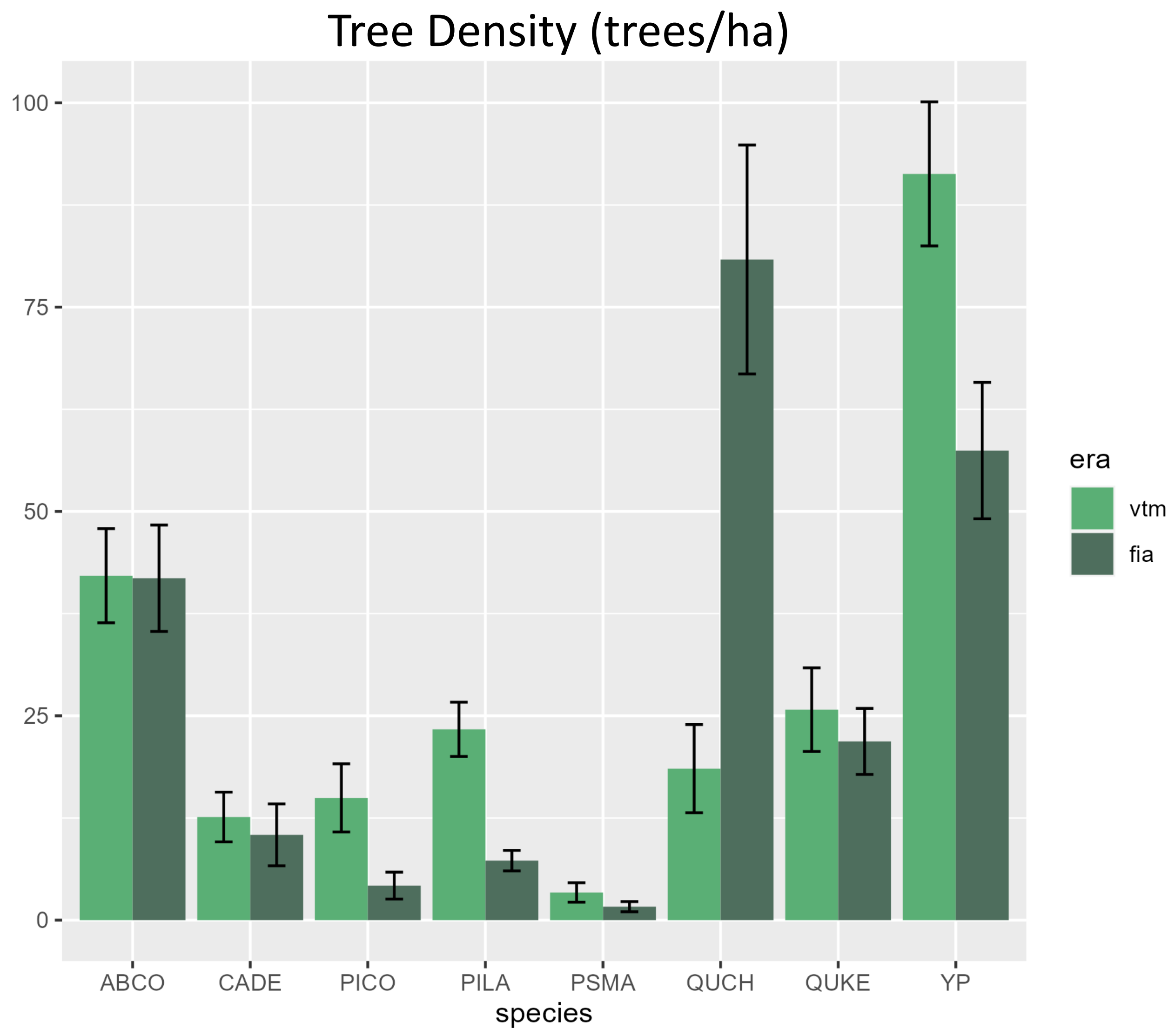


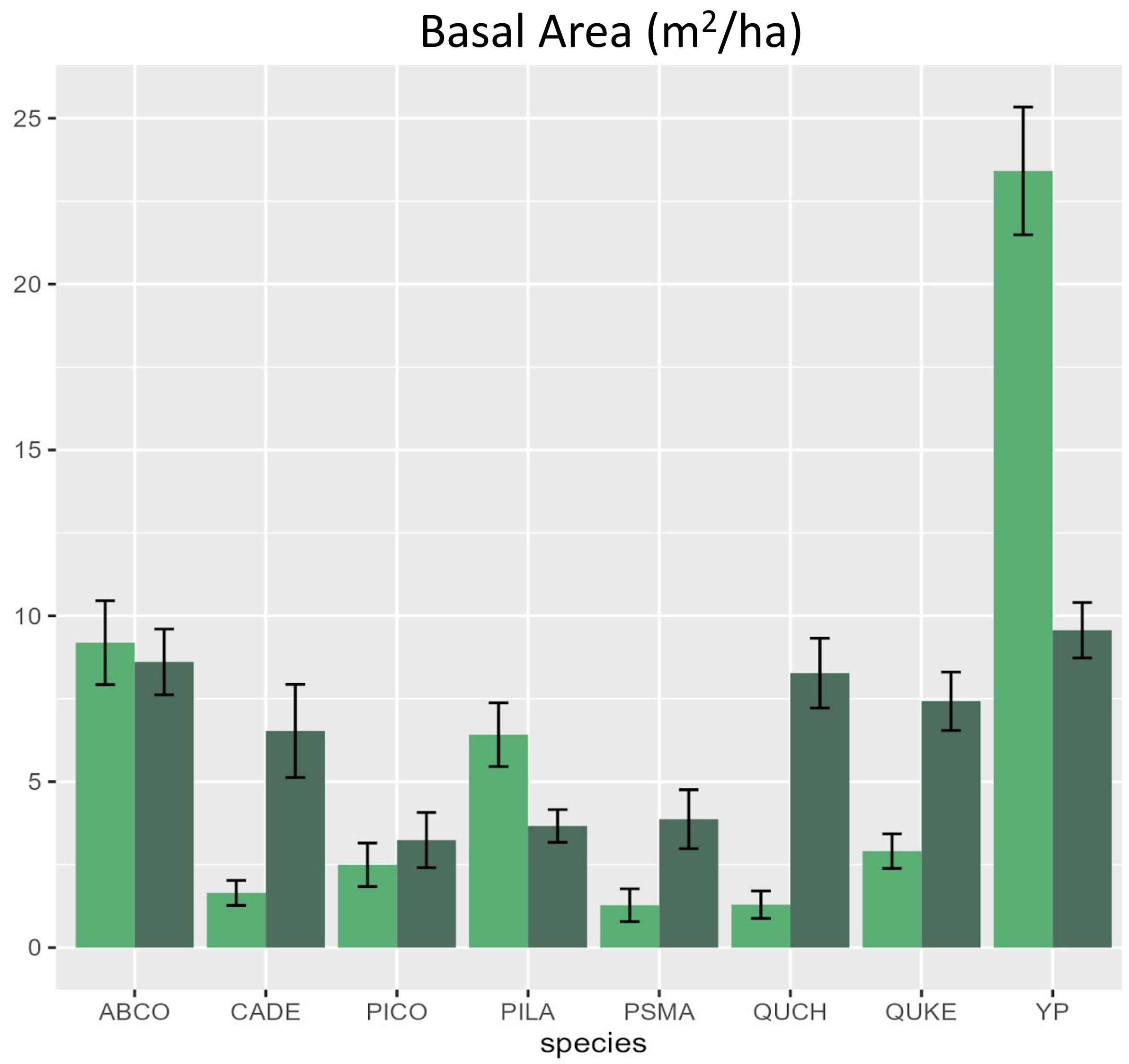
PIPO – *Pinus ponderosa*
PILA – *P. lambertiana*
PICO – *P. coulteri*
CADE – *Calocedrus decurrens*
PSMA – *Pseudotsuga macrocarpa*
ABCO – *Abies concolor*
PIMO – *P. monophylla*
PIMU – *P. contorta (P. murrayana)*
PIFL – *P. flexilis*
QUSP – *Quercus species* (all)

Changes in Tree Species Composition Across Elevation

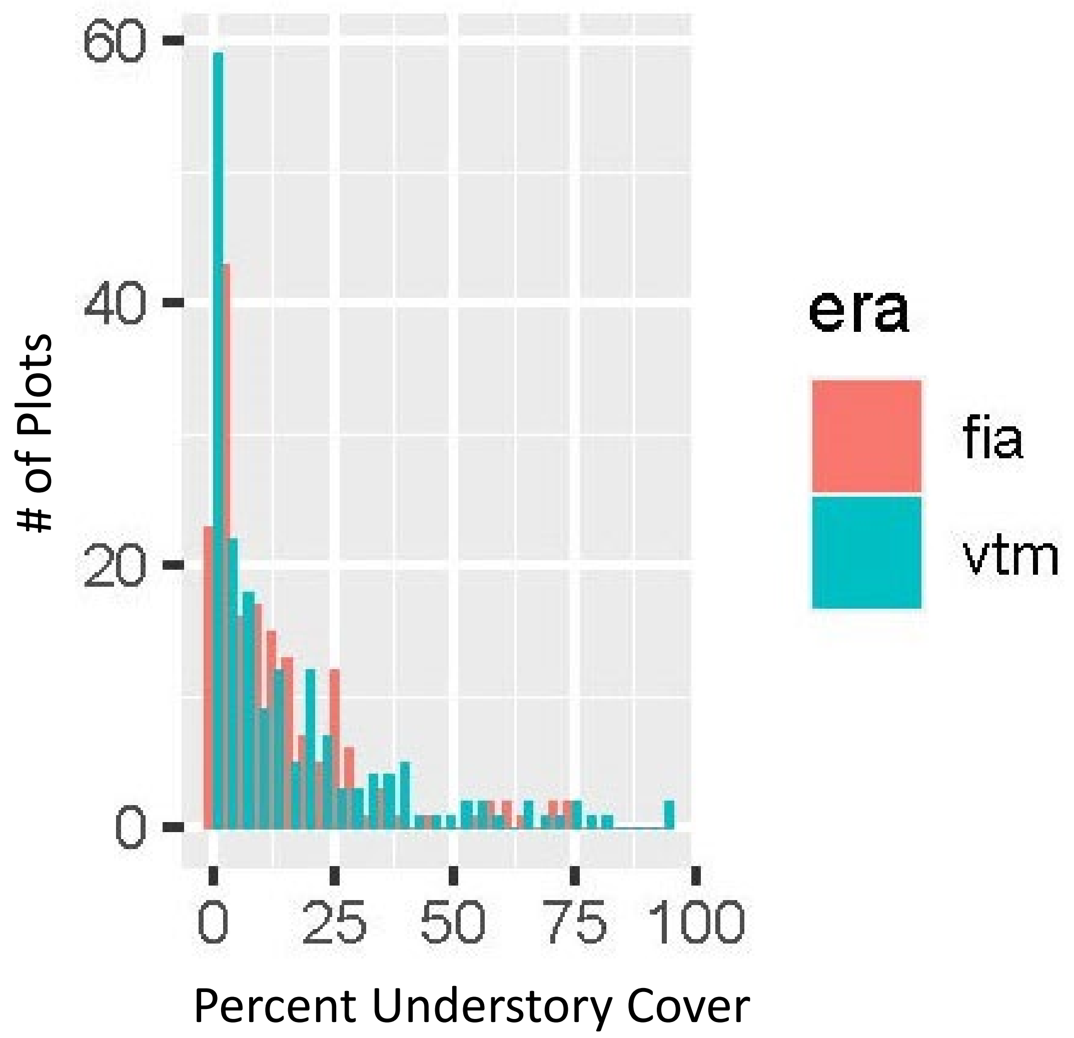


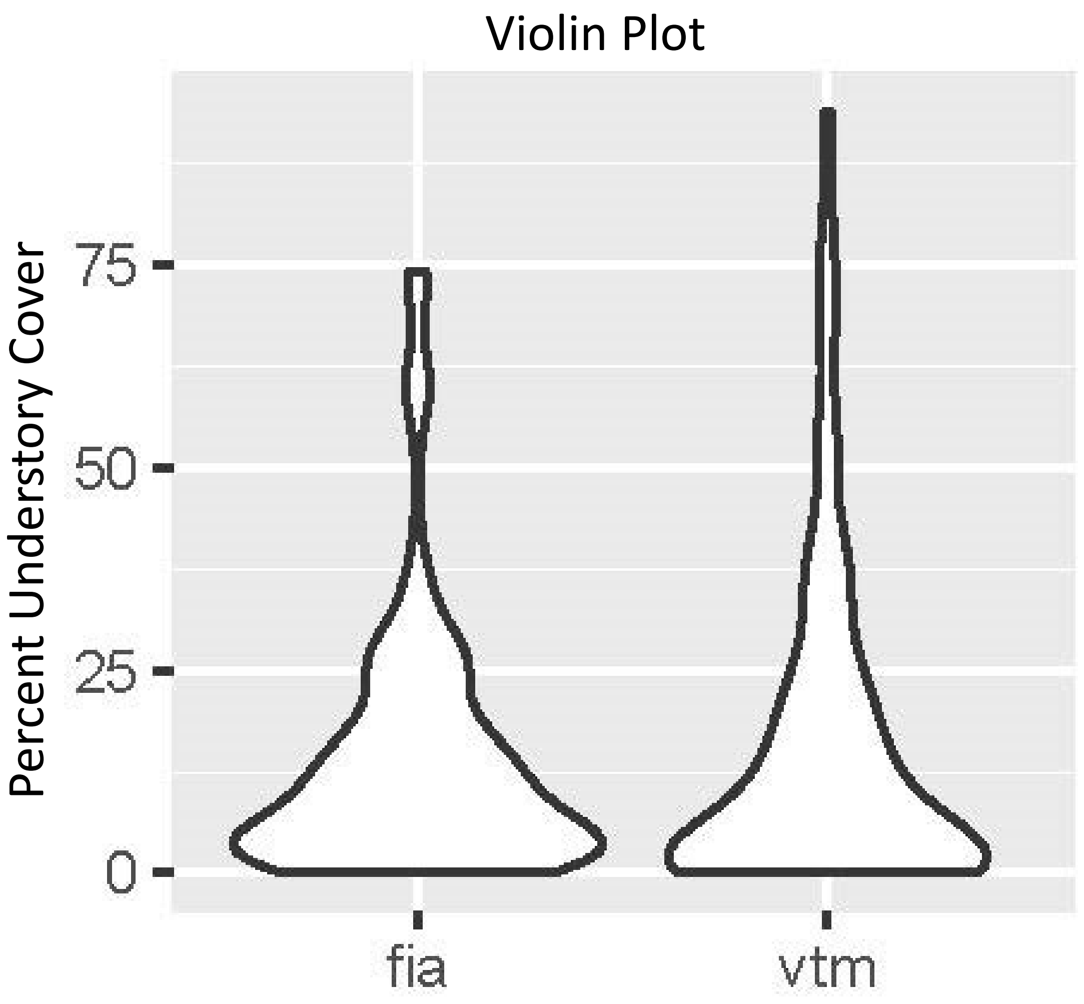
Tree species and stand structural changes: NRV to Present





Minimal Shrub Layer Changes





Surface Fuels
Estimates from adjacent forests with +/- intact fire regimes

Fuels	SSPM 1998		SSPM 2013			Eastern Sierra Nevada 2013		
Fuels (t/ha)	**mean**	**se**	**mean**	**median**	**se**	**mean**	**median**	**se**
1-hour	0.11	0.03	0.56	0.28	0.07	0.26	0.15	0.04
10-hour	0.85	0.16	1.24	0.96	0.11	1.54	1.31	0.14
100-hour	1.2	0.27	2.9	2.31	0.33	3.03	2.31	0.43
≥1000-hour (cwd)	13.64	3.84	28.9	4.8	6.8	25.1	5.9	5.9
Total fuels	15.8	3.91	33.6	10.4	6.9	29.7	11	6

	Sierra San Pedro Mártir			Eastern Sierra Nevada		
	mean	**median**	**se**	**mean**	**median**	**se**
Litter depth (cm)	**2.96**	2.62	0.27	**3.63**	3.33	0.25
Duff depth (cm)	**1.18**	0.81	0.16	**1.21**	0.71	0.17

Stephens 2004; Dunbar-Irwin & Safford 2016

Conclusions

- NRVs are best-guess estimates, depend on available records & data. We relied heavily on Leiberg & VTM.
- Climate models converge on warming, ambiguous about precipitation. Extremes likely to be more extreme.
- SoCal fire return intervals for YPMC increased dramatically: from 10-16 yrs in NRV → to 78 yrs today.
- Wildfire – same story: big fires are bigger, percent area burning at high severity increased relative to NRV

VTM vs FIA

- Tree density increasing since NRV – mostly at lower elevations and among smaller diameter classes. Density of large dia. classes has decreased.
- Basal area decreased since NRV – largely result of loss of large dia. trees.
- Tree species shifting from shade intolerant pines to shade tolerant conifers and oaks. Implications for fire tolerance.
- Fuels: NRV record sparse; likely increase in fine fuels with suppression - based on adjacent YPMC forests.

Thank you!

Nicole Molinari, Quinn Sorenson, Hugh Safford

CAL FIRE – California Climate Investments Grant

Wieslander Survey - San Bernardino NF, ca. 1930

Thomas Fire (282,000 acres) - Los Padres NF, 2017

John Williams: jnwill@ucdavis.edu

Sarah Hennessy: sarah.hennessy@usda.gov