Wildfires: Nexus between Management, Climate & Population Growth

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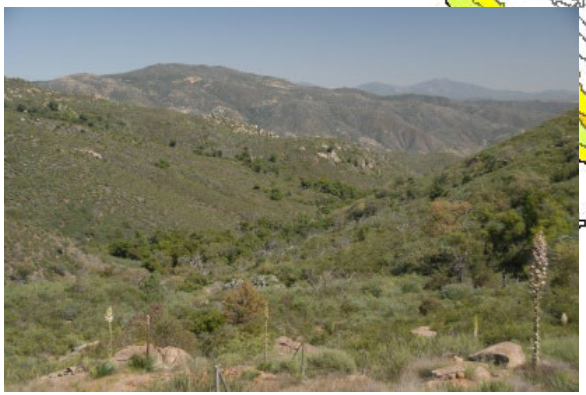
California illustrates the complexity in causes and solutions

Fires/million ha (% human)

475 (45%)



4788 (99%)

Fig. 2a

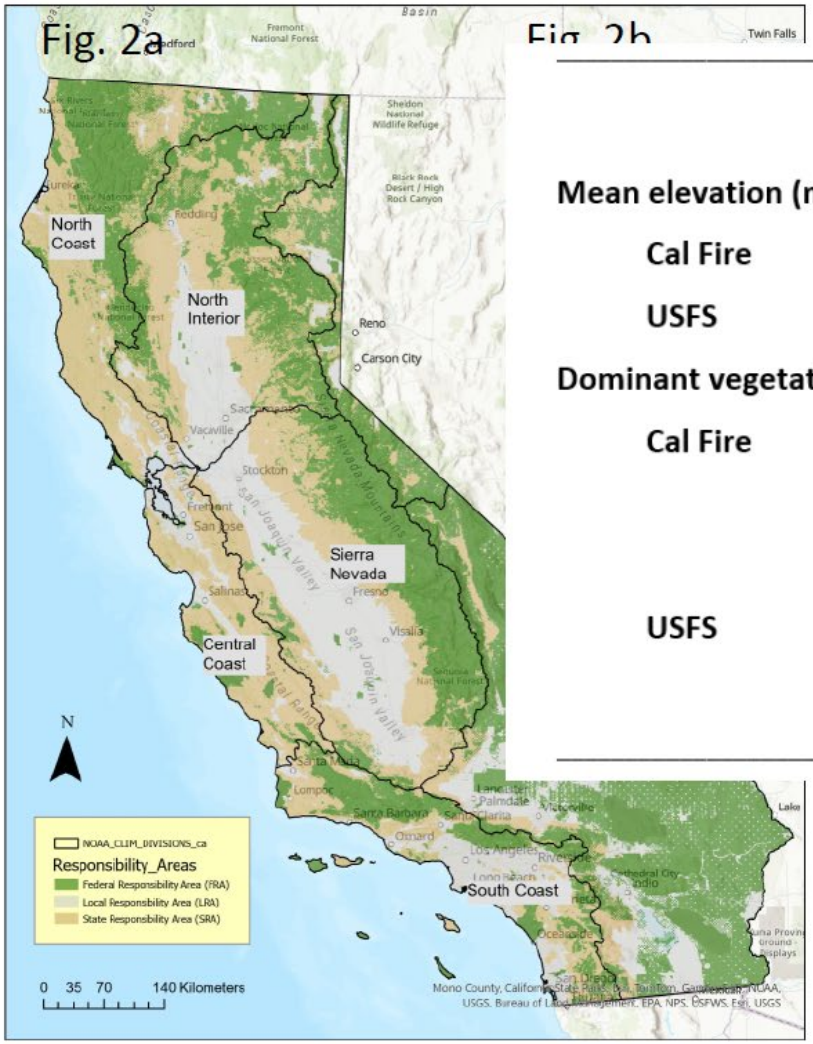


Fig. 2b

	North Coast	North Interior	Sierra Nevada	Central Coast	South Coast
Mean elevation (m)					
Cal Fire	540	740	500	430	660
USFS	1320	1800	2190	1345	1550
Dominant vegetation (%)					
Cal Fire	Conifer(52)	Conifer(35)	Grass(49)	Grass(43)	Shrub(81)
	Hrdwd(20)	Hrdwd(27)	Hrdwd(29)	Hrdwd(29)	Grass(19)
USFS	Conifer(72)	Conifer(69)	Conifer(57)	Shrub(69)	Shrub(43)
	Shrub(15)	Shrub(17)	Shrub(17)	Hrdwd(24)	Conifer(12)

Table 1. Fire frequency and area burned on state and federal lands in California

NOAA division	Cal Fire (1919–2016)		USFS (1910–2016)	
	Fire frequency (n/year/10^6 ha)	Area burned (ha/year/10^6 ha)	Fire frequency (n/year/10^6 ha)	Area burned (ha/year/10^6 ha)
North Coast	317	7780	150	7559
North Interior	421	9642	207	5914
Sierra Nevada	356	8436	169	4709
Central Coast	277	5496	66	18860
South Coast	656	15278	369	24442

Fig 2a

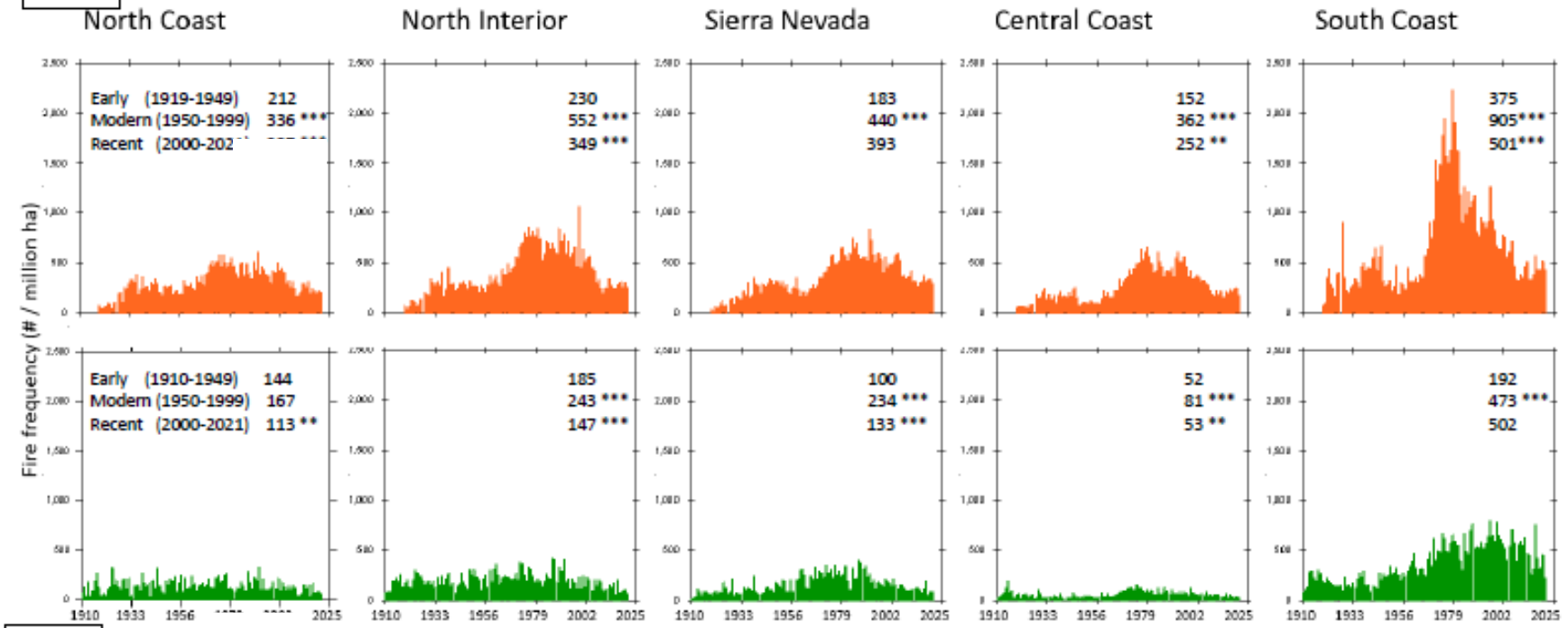
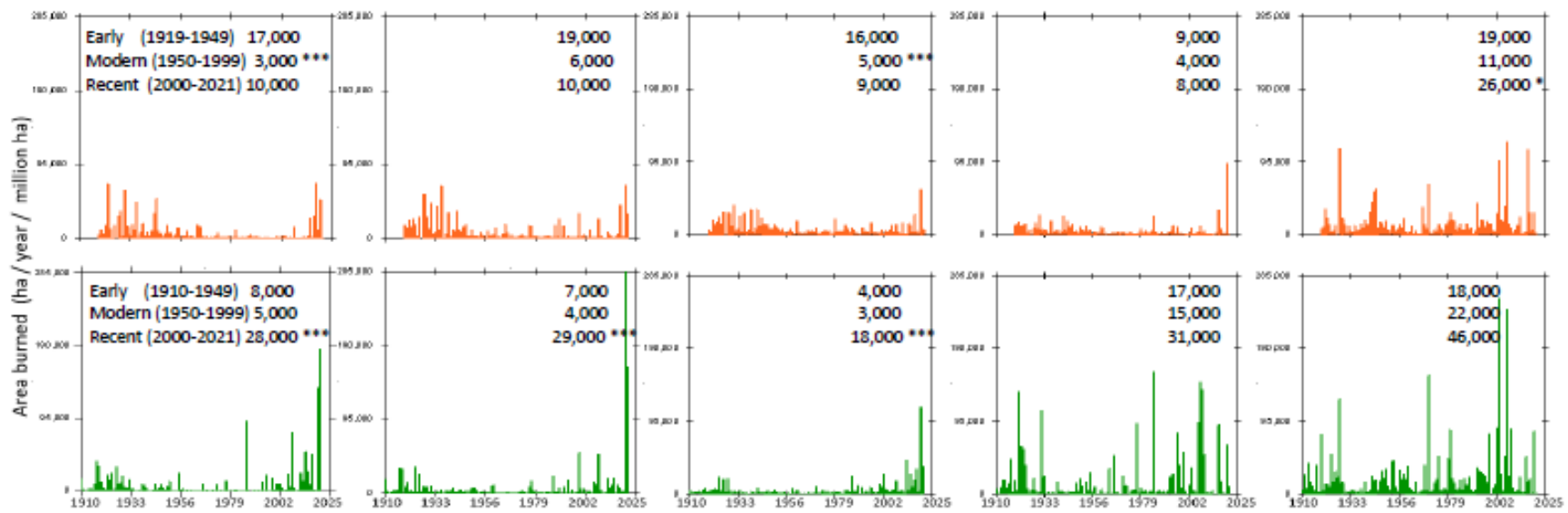
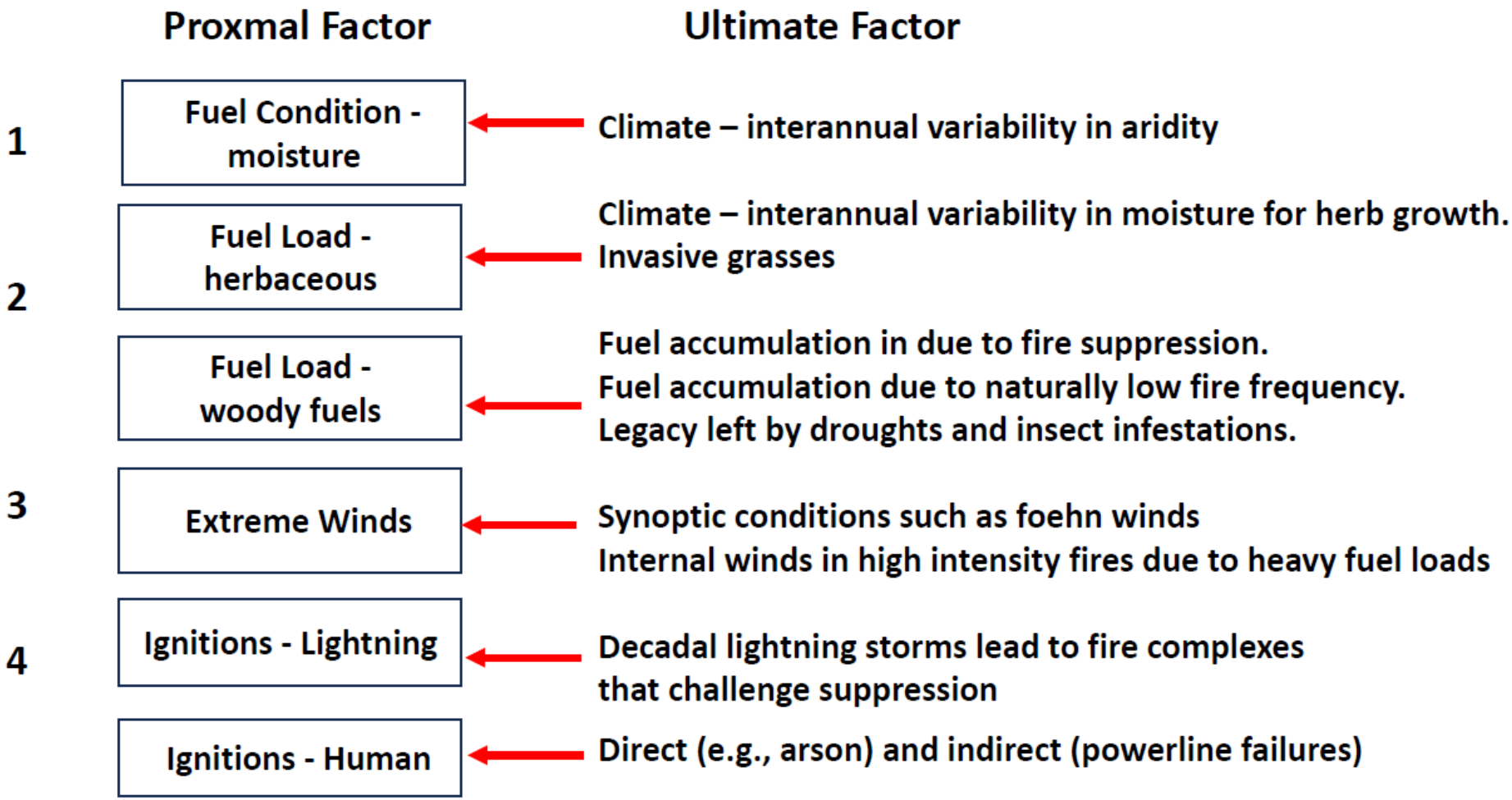
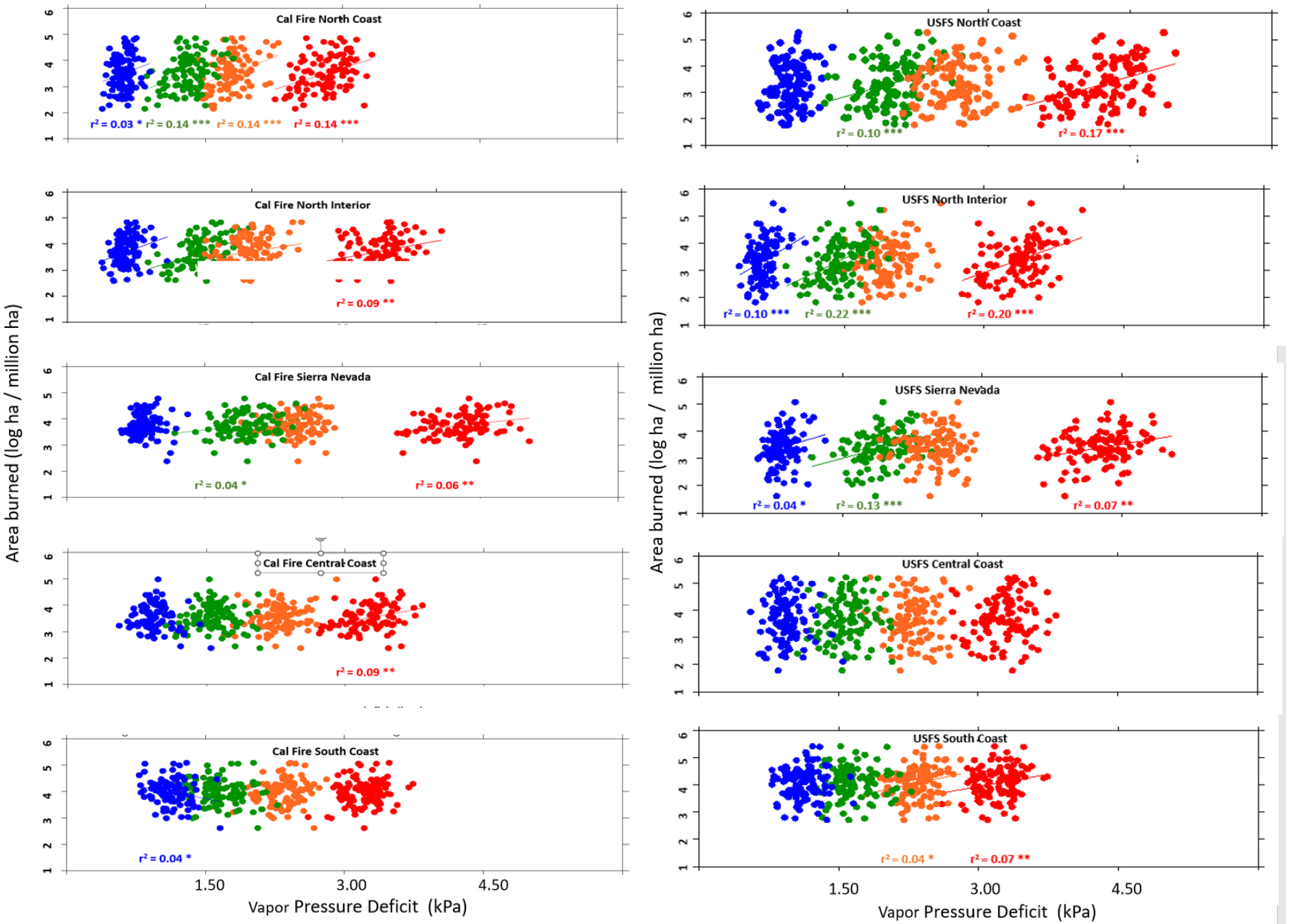
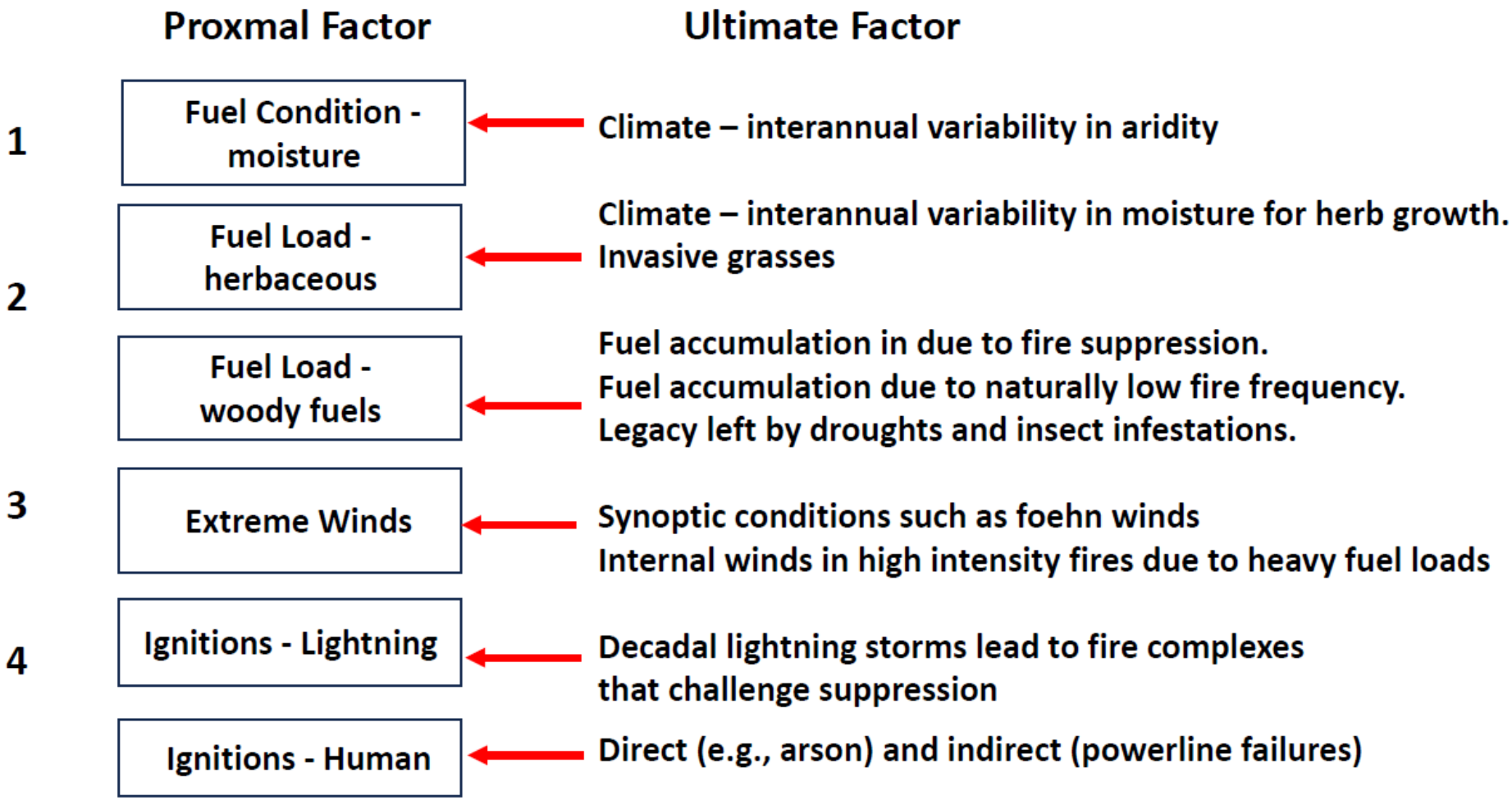

North Coast
North Interior
Sierra Nevada
Central Coast
South Coast
Fire frequency (# / million ha)
Early (1919-1949) 212
Modern (1950-1999) 336 ***
Recent (2000-202
230
552 ***
349 ***
183
440 ***
393
152
362 ***
252 **
375
905***
501***
Early (1910-1949) 144
Modern (1950-1999) 167
Recent (2000-2021) 113 **
185
243 ***
147 ***
100
234 ***
133 ***
52
81 ***
53 **
192
473 ***
502
1910 1933 1956 1979 2002 2025

Fig 2b


North Coast
North Interior
Sierra Nevada
Central Coast
South Coast
Area burned (ha / year / million ha)
Early (1919-1949) 17,000
Modern (1950-1999) 3,000 ***
Recent (2000-2021) 10,000
19,000
6,000
10,000
16,000
5,000 ***
9,000
9,000
4,000
8,000
19,000
11,000
26,000 *
Early (1910-1949) 8,000
Modern (1950-1999) 5,000
Recent (2000-2021) 28,000 ***
7,000
4,000
29,000 ***
4,000
3,000
18,000 ***
17,000
15,000
31,000
18,000
22,000
46,000
1910 1933 1956 1979 2002 2025


Proxmal Factor
Ultimate Factor
1
Fuel Condition - moisture
Climate – interannual variability in aridity
2
Fuel Load - herbaceous
Climate – interannual variability in moisture for herb growth.
Invasive grasses
Fuel Load - woody fuels
Fuel accumulation in due to fire suppression.
Fuel accumulation due to naturally low fire frequency.
Legacy left by droughts and insect infestations.
3
Extreme Winds
Synoptic conditions such as foehn winds
Internal winds in high intensity fires due to heavy fuel loads
4
Ignitions - Lightning
Decadal lightning storms lead to fire complexes that challenge suppression
Ignitions - Human
Direct (e.g., arson) and indirect (powerline failures)


Cal Fire North Coast
r² = 0.03 * r² = 0.14 *** r² = 0.14 *** r² = 0.14 ***
Cal Fire North Interior
r² = 0.09 **
Cal Fire Sierra Nevada
r² = 0.04 * r² = 0.06 **
Cal Fire Central Coast
r² = 0.09 **
Cal Fire South Coast
r² = 0.04 *
USFS North Coast
r² = 0.10 *** r² = 0.17 ***
USFS North Interior
r² = 0.10 *** r² = 0.22 *** r² = 0.20 ***
USFS Sierra Nevada
r² = 0.04 * r² = 0.13 *** r² = 0.07 **
USFS Central Coast
USFS South Coast
r² = 0.04 * r² = 0.07 **
1 2 3 4 5 6
1.50 3.00 4.50
Area burned (log ha / million ha)
Vapor Pressure Deficit (kPa)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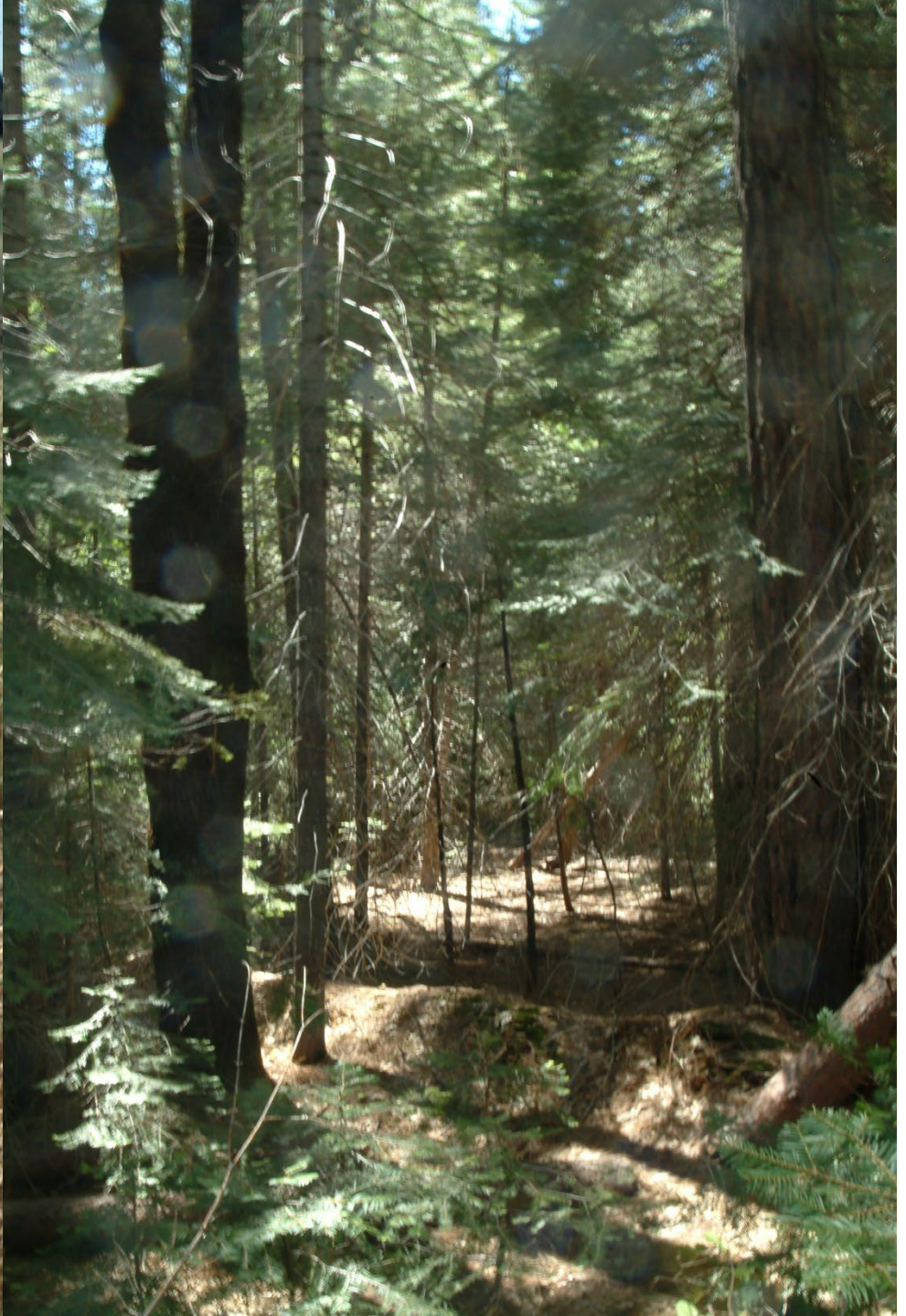


Table 1. Multiple regression models of **a)** fire frequency and **b)** area burned with adjusted-r^2 ; variable with highest r^2 presented first, for correlated variables only highest r^2 retained; variables included # of ignitions by source, all climate parameters: seasonal temperature (mean and max), precipitation, VPD, PDSI and annual PDSI in prior years. Conclusions summarize the importance of aridity, shading indicates conditions conducive to grass growth.

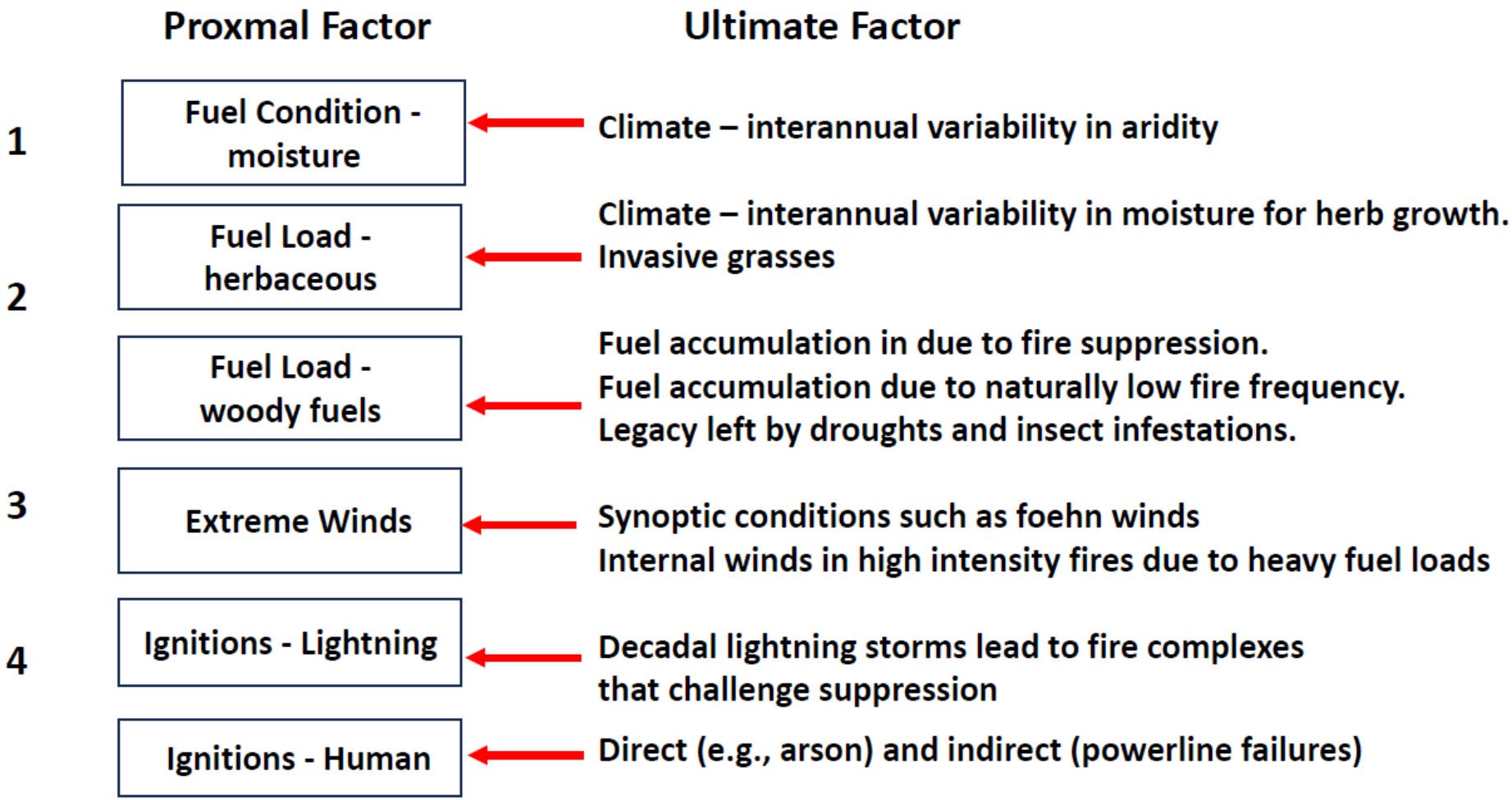
a)

	Early (1910/1919 – 1969)		Late (1970 – 2021)		Conclusions 1910/1919 – 1969	1970 – 2021
North Coast						
CAL:	+ TMNa	(r^2=0.246, *P*<0.001)	- TMNsu	(r^2=0.080, *P*=0.024)	Hi aut aridity	Lo sum aridity
USFS:	+ TMNa	(r^2=0.066, *P*=0.026)	+ VPDsp	(r^2=0.118, *P*=0.007)	Hi aut aridity	Hi spg aridity
North Interior						
CAL:	+ TMNa +TMNsu	(r^2=0.259, *P*<0.001)	- TMNsu	(r^2=0.259, *P*<0.001)	Hi sum, aut aridity	Lo sum aridity
USFS:	+ TMNsu	(r^2=0.176, *P*=0.001)	- PPTsp	(r^2=0.105, *P*=0.007)	Hi sum aridity	Hi spr aridity
Sierra Nevada						
CAL:	+ PDSI(-5yr ave)	(r^2=0.124, *P*=0.007)	+ PDSI(-2yr ave)	(r^2=0.145, *P*=0.003)	Lo prior 5-yr aridity	Lo prior 2-yr aridity
USFS:	+ TMNa	(r^2=0.128, *P*=0.003)	- PPTwss	(r^2=0.093, *P*=0.016)	Hi aut aridity	Hi w,sp,su aridity
Central Coast						
CAL:			+ PDSI(-2yr ave)	(r^2=0.068, *P*=0.035)		Lo prior 2-yr aridity
USFS:			+ PDSI(-yr1)	(r^2=0.148, *P*=0.003)		Lo prior yr aridity
South Coast						
CAL:	+ PDSIwssa	(r^2=0.112, *P*=0.010)	+ PDSI(-5yr ave)	(r^2=0312, *P*<0.001)	Lo prior 5-yr aridity	Lo prior 5-yr aridity
USFS:	- PDSI(-5yr ave) + TMNa	(r^2=0.202, *P*<0.001)	+ PDSI(-yr1)	(r^2=0.187, *P*<0.001)	Hi prior 5-yr aridity + Hi a arid	Lo prior 5-yr aridity

What was going on upstream? Thousands of landslides.

USGS

Matthew A. Thomas and Jason Kean (USGS unpublished)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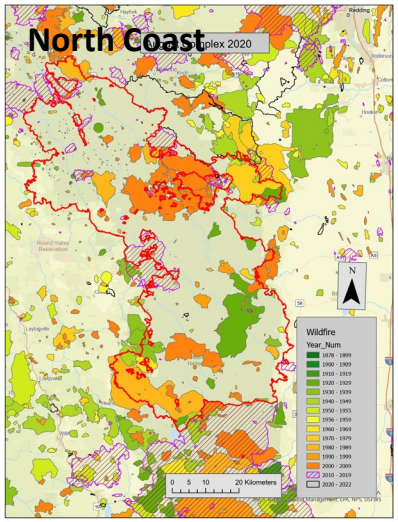
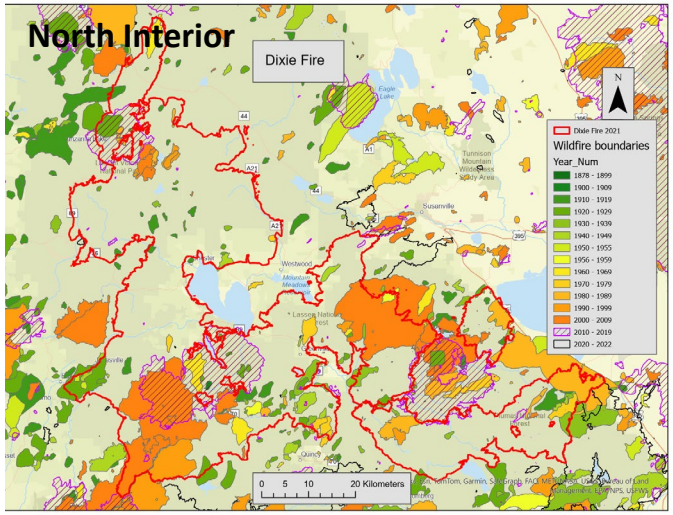
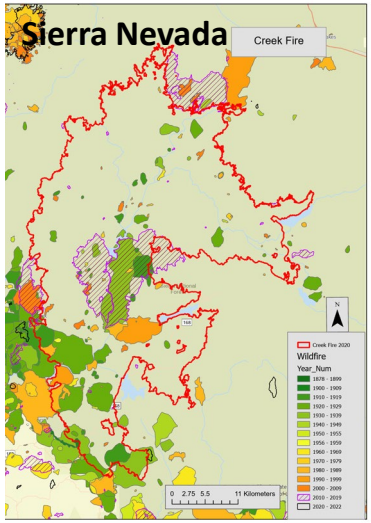
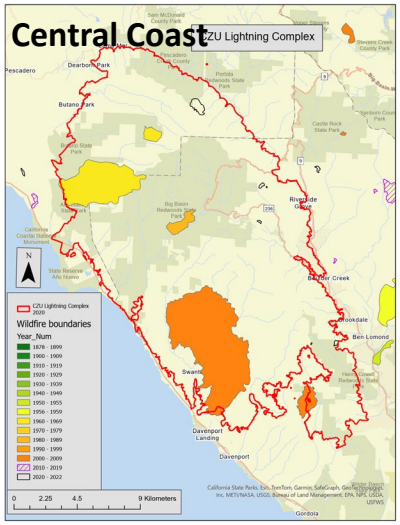
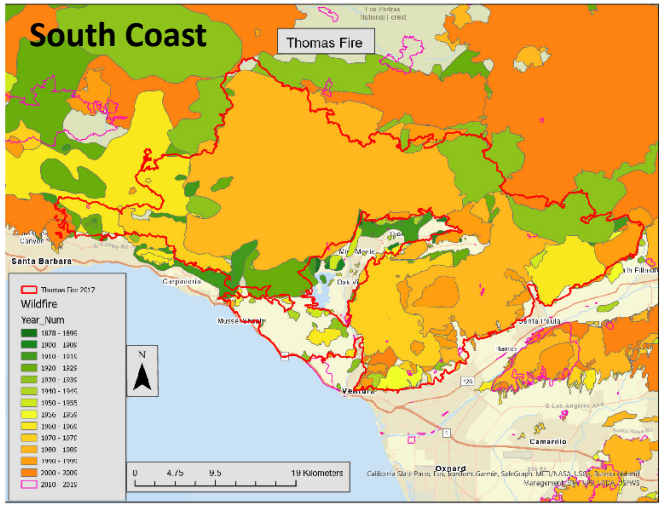
Red outline = perimeter of largest fire ever recorded
Colored areas = previous fires since 1910



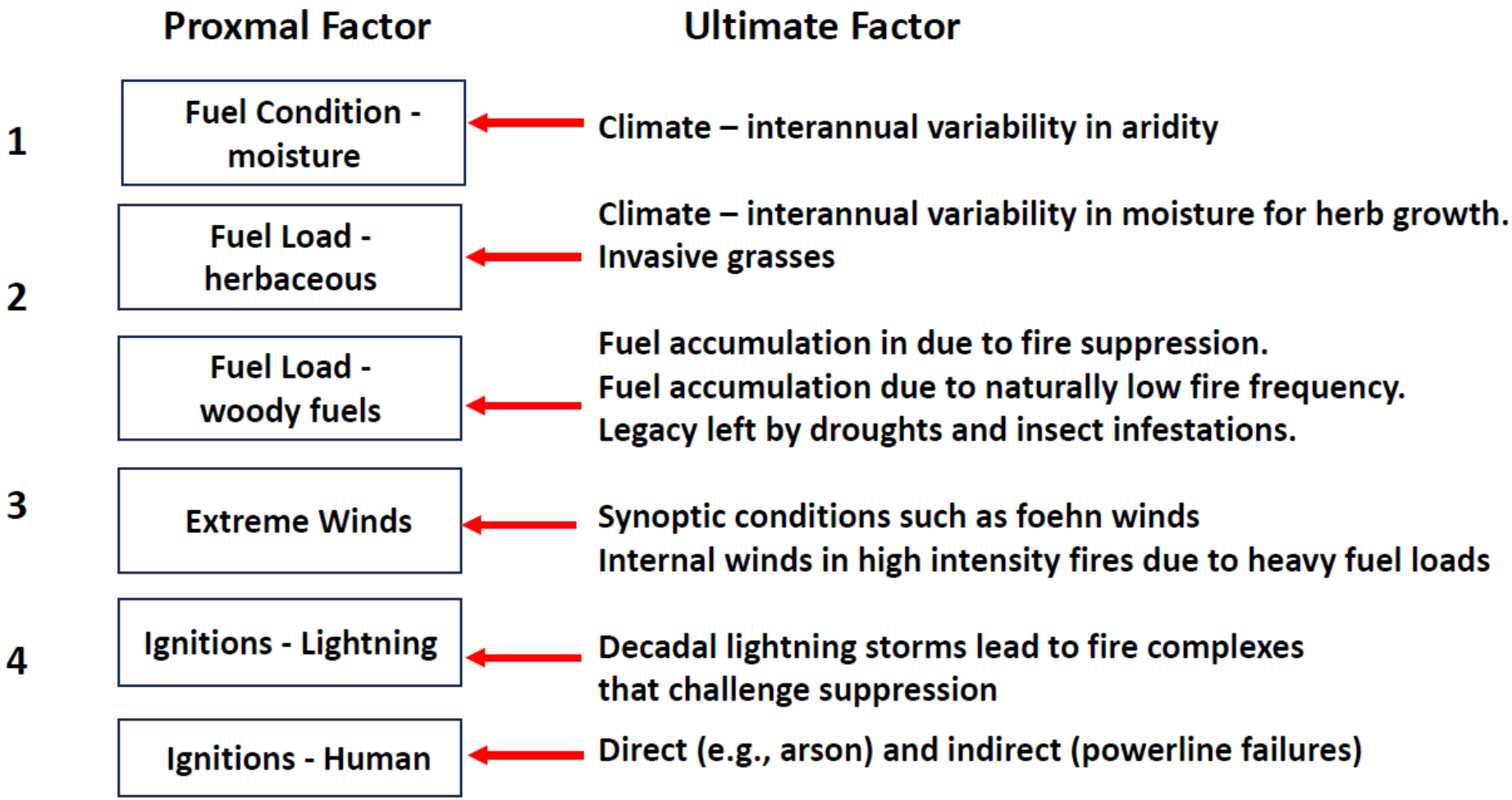








Region	Largest fire	Year	Size ha	Area unburned since 1910 (%)	Fire rotation interval (yr)
NC	August Cmplx	2020	417,933	66	130
NI	Dixie	2021	389,890	67	111
SN	Creek	2020	157,738	77	129
CC	CZU	2020	160,422	86	82
SC	Thomas	2017	114,040	8	53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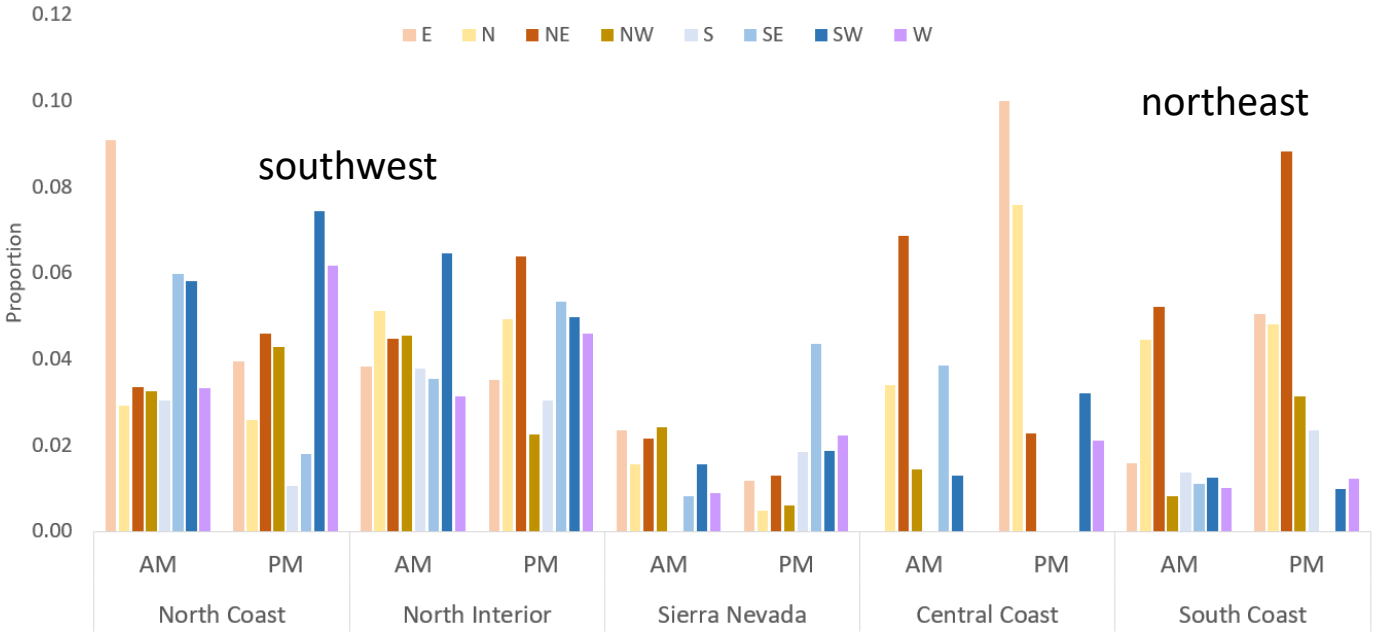
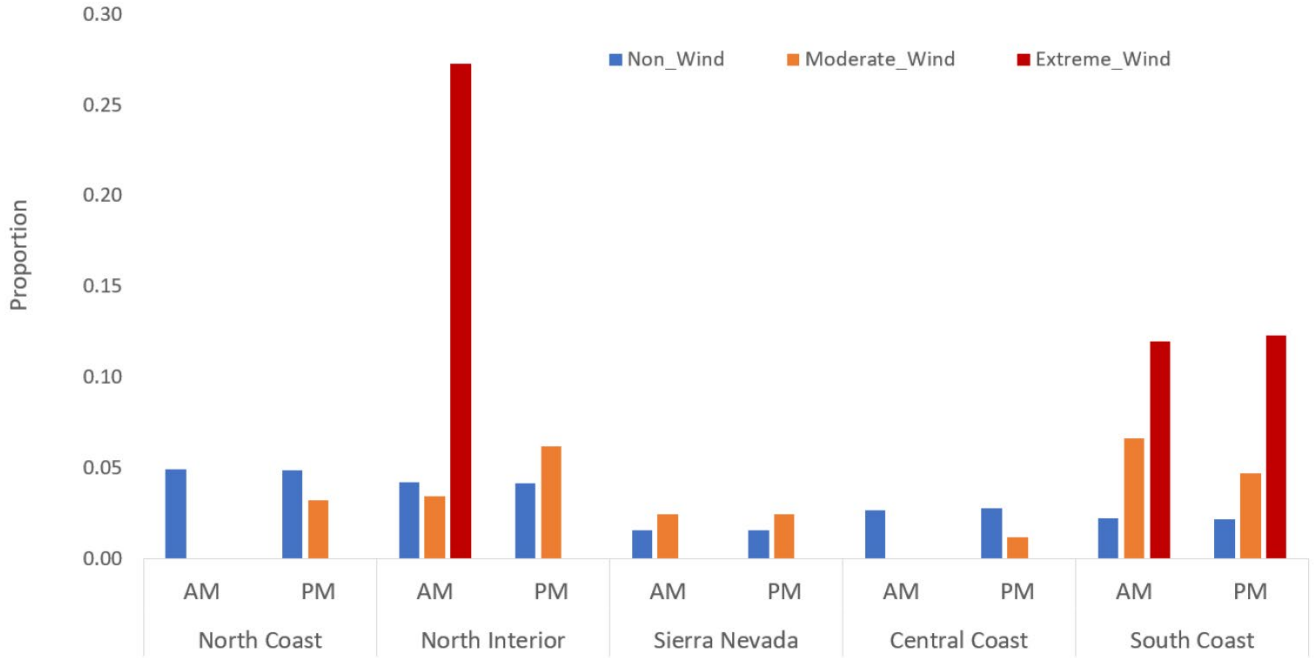
Area burned by fires >5,000 ha

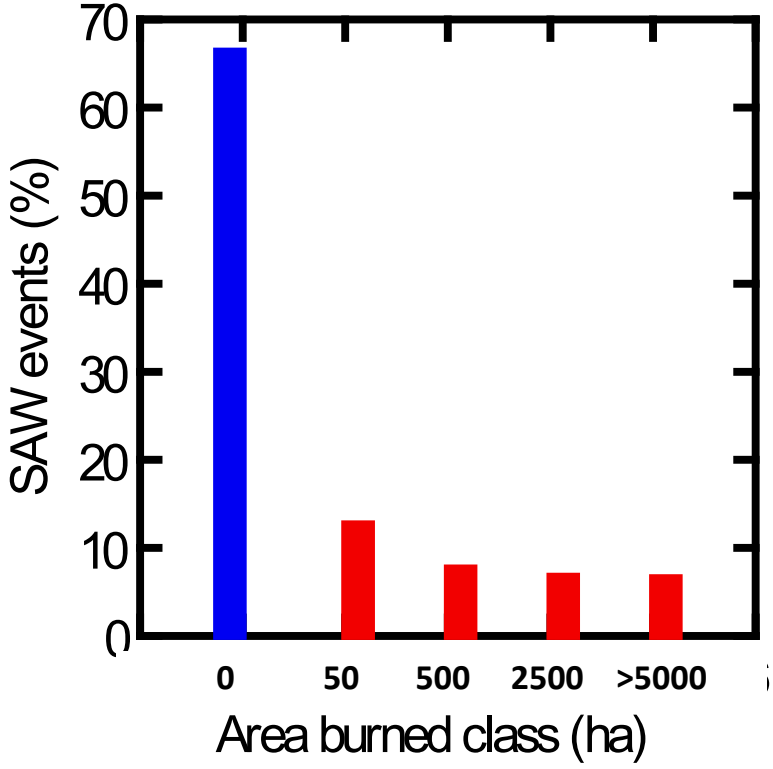
a) Wind direction for am and pm

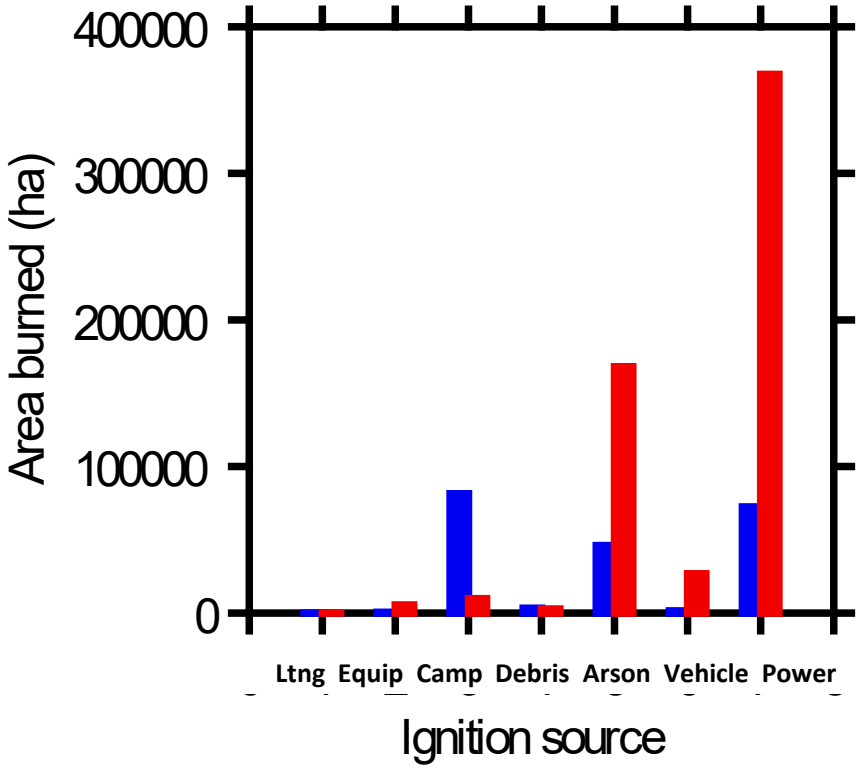


b) By wind severity



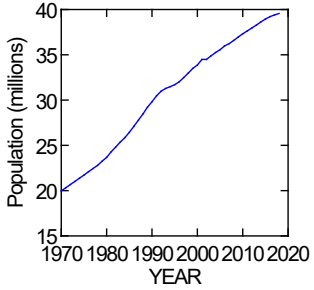
Santa Ana Winds (SAW)





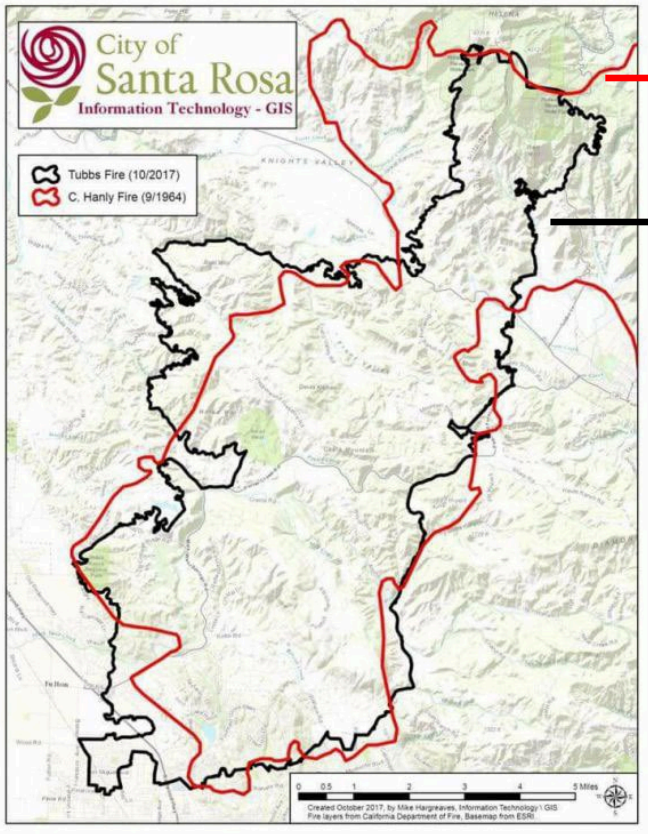
Since the year 2000, the area burned in California due to powerline failures has increase 5x over the previous two decades

Largely driven by population growth



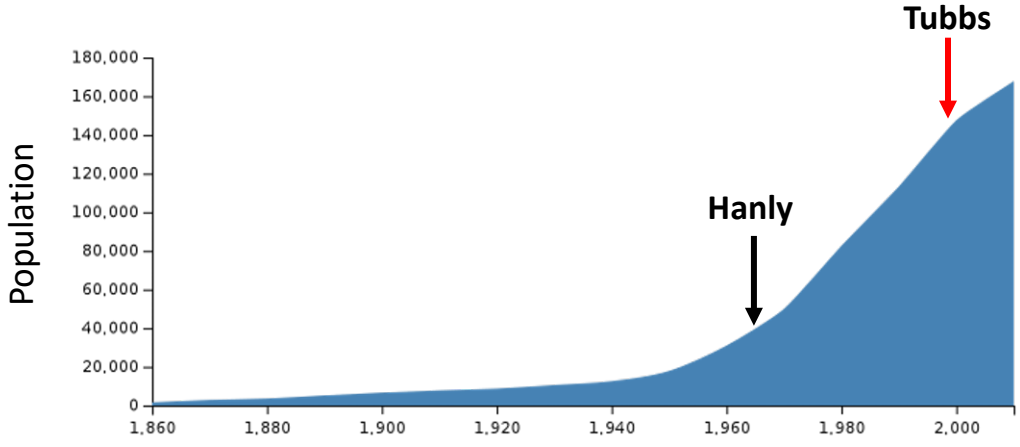
The 5 Principles of South Coast Wind-Dominated Fires

1) ***People:*** This is more a people problem than a fuel problem. 100% of these fires are ignited by people and increased fire activity since 2000 may be accounted for by the additional 5.5 million people; population growth may be a greater threat than global warming for these types of fires.
2) *Prevention*: Rather than focusing on fuel treatments we need put much greater emphasis on fire prevention. However, it is not just a numbers issue; ignitions have declined radically since the mid-1980s, but area burned has increased. In the last decade the majority of large fires have been ignited by powerline failures. Option: shut down power grid during high wind events.
3) *Plannning*: Community planning needs to give fire similar recognition as other hazards. We have limited ability to control earthquakes and floods, so we have zoning restrictions. Fires have been perceived as controllable, but history reveals we are vulnerable. There is a need for greater focus on *fire-zoning* and consideration of replacing community planning with regional planning.
4) *Protection*: Focus needs to be on the 'house out', i.e., greatest effort near homes and less as one moves further into the wildlands. Reducing fuels within 100' is important for defensible space, however, most homes burn from embers and thus reducing litter on roofs, adequate eve vent covers, double-pane windows and roof sprinklers may make a difference.
5) *Prediction*: Real time prediction of wind patterns and communicating that information to fire-fighting agencies and homeowners could save lives.

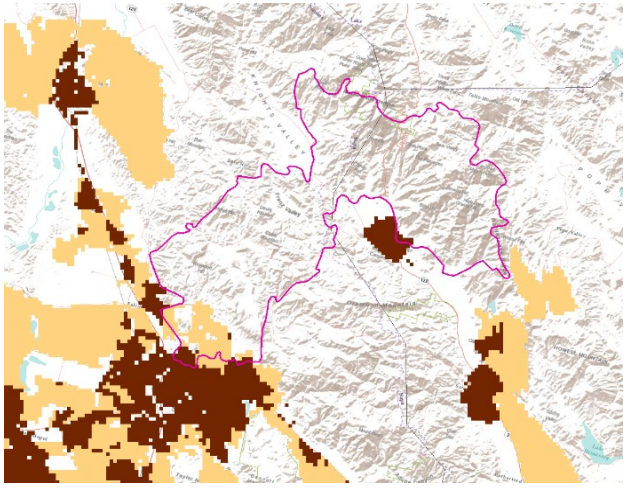


1964 **Hanly Fire** 83,000 acres
(no fatalities/~100 structures lost)

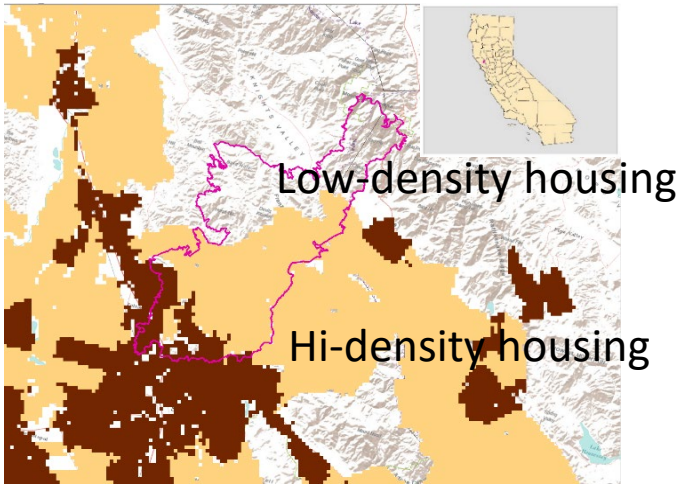
2017 **Tubbs Fire** 36,800 acres
(22 fatalities / 5,643 structures lost)



1964 Hanly Fire



2017 Tubbs Fire



USGS science for a changing world

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NATIONAL PARK SERVICE
Department of the Interior

FOREST SERVICE
US
DEPARTMENT OF AGRICULTURE

Joint Fire Science Program

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CAL FIRE
SINCE 1885

FIRE
ORANGE COUNTY
CALIFORNIA
AUTHORITY

MHDP
USGS Hazards Project

Photo: JE Keeley