California's wildfires: ownership matters

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We all know fire is increasing

- But why is this?
  - Is it climate?
  - Is it past management decisions?
  - Is it land use?
- And can we do anything about it?
  - Fuels
  - Houses
  - Grazing

Research Questions?

- How does ownership impact the frequency of fire?
  - Ownership can be a good proxy for management, especially for forest

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- How does firefighting impact the frequency of fire?
  - CalFire and Federal firefighters have different missions.
- How do climate variables impact the frequency of fire?
  - Temp
  - Precip/soil moisture
- Are these relationships changing over time?

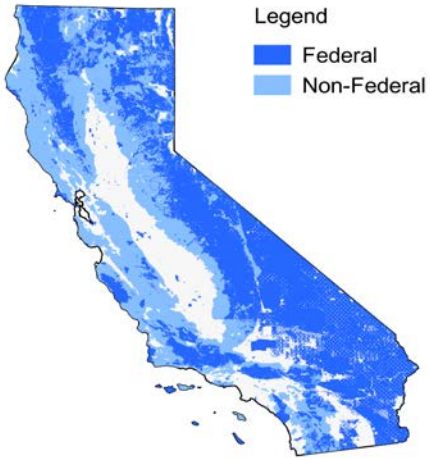
Non-Federal /State

Non-Federal /Federal

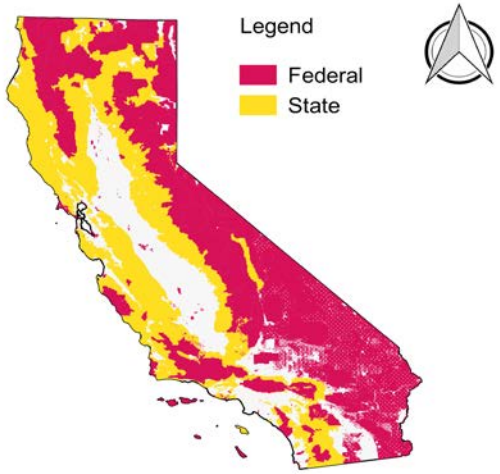
Federal /Federal

Federal /State

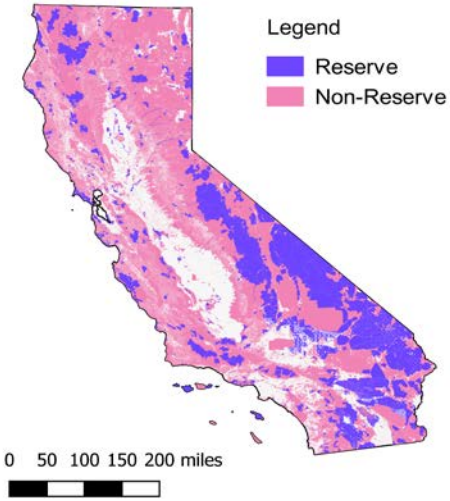
Ownership



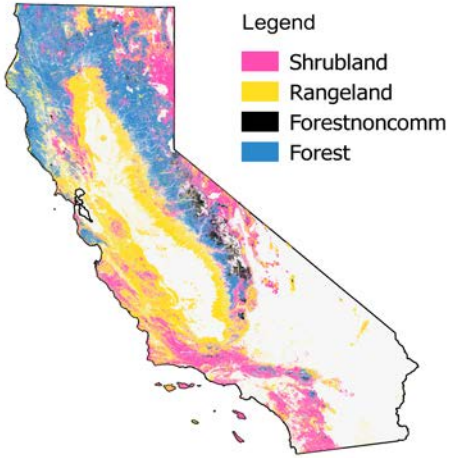
Firefighting



Reserve Status



Vegetation Type



Vegetation types with included habitat types[1].			
Forests with Commercial Species	Forests without Commercial Species	Rangelands	Shrublands
Douglas fir	Closed-Cone Pine-Cypress	Annual Grassland	Alpine-Dwarf Shrub
Eastside Pine	Jeffrey Pine	Blue Oak Woodland	Bitterbrush
Klamath Mixed Conifer	Lodgepole Pine	Blue Oak-Foothill Pine	Chamise-Redshank Chaparral
Montane Hardwood-Conifer	Subalpine Conifer	Coastal Oak Woodland	Coastal Scrub
Ponderosa Pine	Undetermined Conifer	Eucalyptus	Low Sage
Red Fir		Juniper	Mixed Chaparral
Redwood		Pasture	Montane Chaparral
Sierran Mixed Conifer		Perennial Grassland	Sagebrush
White Fir		Pinyon-Juniper	Undetermined Shrub
		Undetermined Hardwood	
		Valley Foothill Riparian	
		Valley Oak Woodland	

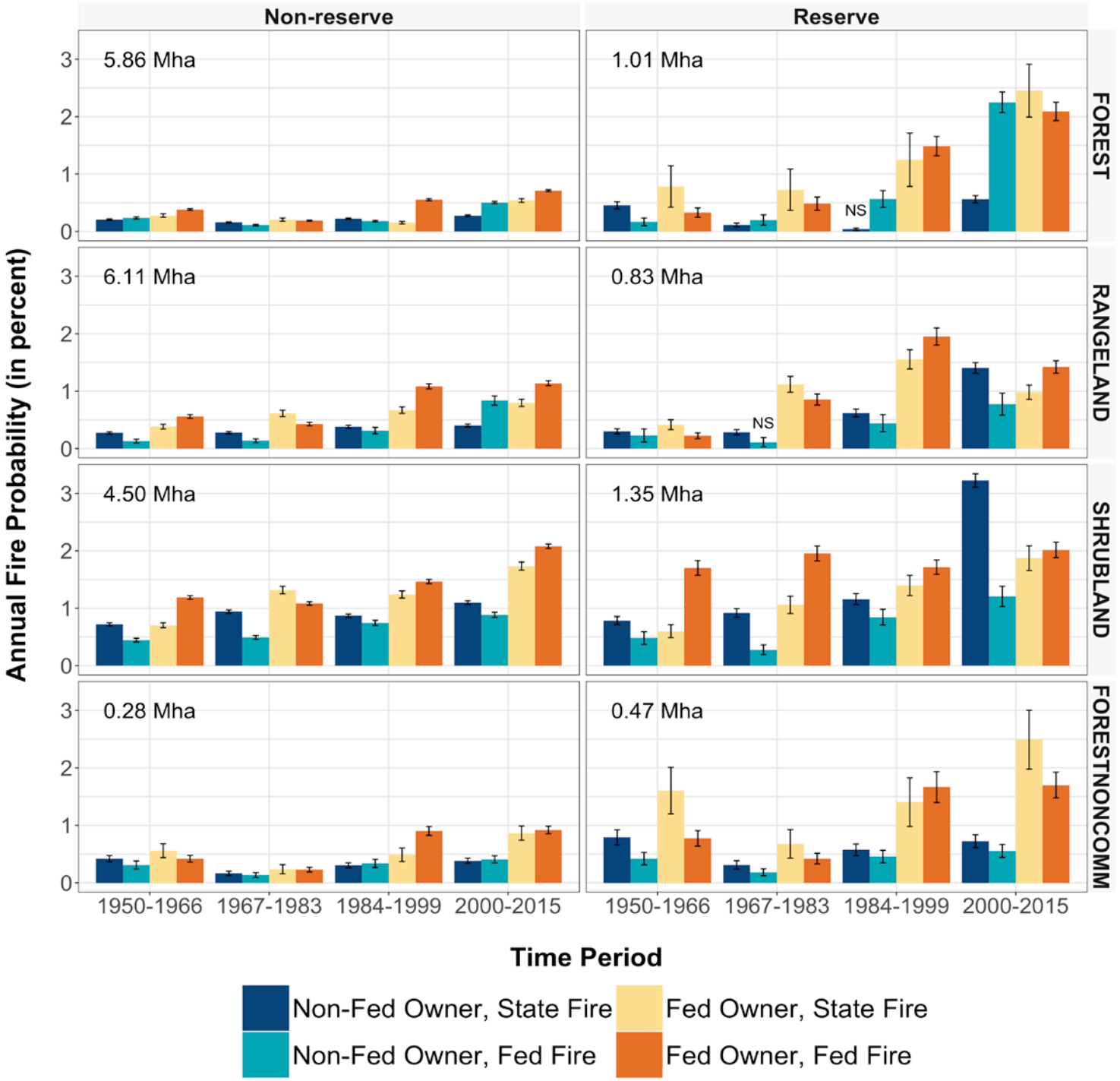

Non-reserve
Reserve
5.86 Mha
1.01 Mha
6.11 Mha
0.83 Mha
4.50 Mha
1.35 Mha
0.28 Mha
0.47 Mha
NS
NS
FOREST
RANGELAND
SHRUBLAND
FORESTNONCOMM
Annual Fire Probability (in percent)
0
1
2
3
1950-1966
1967-1983
1984-1999
2000-2015
Time Period
Non-Fed Owner, State Fire
Fed Owner, State Fire
Non-Fed Owner, Fed Fire
Fed Owner, Fed Fire

Table 1. Fire probability in time period 4 (2000-2015) and percent increase in fire probability in percent from time period 1 (1950-1965) to time period 4 (2000-2015) by vegetation type, ownership, and firefighting agency for non-reserve lands

Vegetation Type	Ownership	Firefighting	Fire Probability in percent 2000-2015	% Increase in Fire Probability from 1950-1966 to 2000-2015
FOREST	Non-Federal	State	0.28 (0.01)	33%
FOREST	Non-Federal	Federal	0.5 (0.02)	108%
FOREST	Federal	State	0.54 (0.03)	93%
FOREST	Federal	Federal	0.71 (0.02)	87%
RANGELAND	Non-Federal	State	0.4 (0.02)	48%
RANGELAND	Non-Federal	Federal	0.84 (0.08)	546%
RANGELAND	Federal	State	0.8 (0.06)	111%
RANGELAND	Federal	Federal	1.14 (0.04)	104%
SHRUBLAND	Non-Federal	State	1.1 (0.03)	53%
SHRUBLAND	Non-Federal	Federal	0.89 (0.04)	98%
SHRUBLAND	Federal	State	1.73 (0.07)	147%
SHRUBLAND	Federal	Federal	2.08 (0.04)	75%
FORESTNONCOMM	Non-Federal	State	0.38 (0.05)	-10%
FORESTNONCOMM	Non-Federal	Federal	0.41 (0.06)	32%
FORESTNONCOMM	Federal	State	0.87 (0.12)	55%
FORESTNONCOMM	Federal	Federal	0.92 (0.07)	119%

These summary statistics are suggestive but….

Balance of acres allows us to compare apples to apples

. Hectares of land where fire-fighting responsibility has been traded in the "balance of acres. arrangement for federal and state fire protection in California in selected vegetation types.			
Vegetation Type	Balanced[a] Hectares	Non-balanced Hectares	Balanced % Total
Forest	1,022,874	14,455,176	15%
Rangeland	466,626	15,997,501	7%
Shrubland	936,899	12,122,251	16%
Forestnoncomm	41,479	1,737,142	6%
a - "balanced" hectares are those where ownership and firefighting falls under different agencies, e.g. federal lands with state firefighting			

Using matching methods to find good areas to compare

1. Start with full dataset and run regression predicting ownership

2. Use this prediction to assign a probability that the point is federally owned.

3. Keep points that fall within a range of common support

4. For each non-federal point, find the federal point with a similar probability of federal ownership. Do this for each point.

5. Compare matched and unmatched datasets and check for differences in underlying variables that we think might effect fire probability

Number of matched points

Table S9. Number of points pre- and post-matching by vegetation type		
Vegetation Type	Pre-matching	Post-matching
Forest	85,286	25,510
Rangeland	49,509	11,848
Shrubland	41,606	22,162
Forest without Commercial Species	14,285	2,234

Table S7. Reduction in bias achieved by statistical matching process across ownerships for the Rangeland vegetation type. The matching process finds points that are most similar for the variables below in each ownership category and removes points that do not have a comparable point in the opposite category. This results in a reduction in the number of points in the final dataset but ensures that remaining points are as similar. One measure of similarity is the mean values for matched points, which we show here.

Variable	Matched?	Ownership		% bias	% bias reduction
		Federal	Non-Federal		
Elevation (meters)	Unmatched	1312.5	465.39	145.9	96.7
	Matched	825.18	853.49	-4.9	
Slope (degrees)	Unmatched	14.678	11.113	35.4	94.7
	Matched	12.647	12.457	1.9	
Aspect (degrees)	Unmatched	172.33	179.37	-6.8	96.5
	Matched	171.47	171.22	0.2	
Distance to road (meters)	Unmatched	10597	6244.3	62	95.6
	Matched	8270	8461.4	-2.7	
Distance to city (meters)	Unmatched	33472	17245	90.1	98.9
	Matched	23854	23681	1	
2010 Population	Unmatched	32199	67897	-23	65.2
	Matched	46183	58607	-8	
Average Maximum Temp (°C)	Unmatched	27.969	29.881	-50.9	94.5
	Matched	28.658	28.762	-2.8	
Average Soil Moisture (mm)	Unmatched	14.851	15.79	-20	56.3
	Matched	15.733	15.322	8.7	
Average Annual Precipitation (cm)	Unmatched	39.775	46.455	-24.9	76.6
	Matched	44.593	43.028	5.8	
GAP Status	Unmatched	0.35358	0.05073	81.4	95.2
	Matched	0.16768	0.18214	-3.9	

Regression framework

- Goals
  - Control for factors that might impact fire frequency
  - Ownership
  - Firefighting
  - Temp, soil moisture, precipitation
  - Ignitions likelihood – distance to towns, roads, campgrounds
- Models
  - Dependent variable is number of fires in 15 year period
  - Poisson panel regression
  - Repeated observations of each point.
  - Output – modeled average fire probability (likelihood of a fire in each year).

Table 3. Marginal effect of federal ownership, federal firefighting, reserve status, and climate on annual fire probability (AFP). Marginal effects are calculated from period 1 (1950-1966) to period 4 (2000-2015); all other variables in model are held at their means. Standard errors are calculated using the delta method.

	Percentage point change in AFP	Std. Error	Z-statistic	p-value
Forest				
Effect of federal ownership	0.15	0.01	13.79	$p < 0.01$
Effect of federal firefighting	0.14	0.01	12.92	$p < 0.01$
Effect of reserved status	0.54	0.04	13.17	$p < 0.01$
Effect of temperature[1]	0.03	0.00	14.47	$p < 0.01$
Effect of soil moisture	-0.03	0.00	-14.51	$p < 0.01$
Effect of precipitation	0.00	0.00	-8.59	$p < 0.01$
Rangelands				
Effect of federal ownership	0.30	0.03	11.87	$p < 0.01$
Effect of federal firefighting	0.17	0.03	6.31	$p < 0.01$
Effect of reserved status	0.18	0.03	6.27	$p < 0.01$
Effect of temperature[1]	0.02	0.00	5.20	$p < 0.01$
Effect of soil moisture	-0.02	0.00	-8.16	$p < 0.01$
Effect of precipitation	0.00	0.00	12.54	$p < 0.01$
Shrublands				
Effect of federal ownership	0.22	0.03	8.59	$p < 0.01$
Effect of federal firefighting	0.26	0.03	10.05	$p < 0.01$
Effect of reserved status	0.07	0.03	2.23	0.03
Effect of temperature[1]	0.05	0.00	15.54	$p < 0.01$
Effect of soil moisture	-0.06	0.00	-20.17	$p < 0.01$
Effect of precipitation	0.00	0.00	0.91	0.37

Table 4. Marginal effect of federal ownership and federal firefighting annual fire probability per time period for non-reserved lands. All other values are held at their means; standard errors are calculated using the delta methods. P-values are in parenthesis.

	Time Period					
	1967-1983		**1984-1999**		**2000-2015**	
Forests						
Effect of federal ownership	0.07	($p < 0.01$)	0.22	($p < 0.01$)	0.21	($p < 0.01$)
Effect of federal firefighting	-0.01	(0.43)	0.21	($p < 0.01$)	0.32	($p < 0.01$)
Rangelands						
Effect of federal ownership	0.35	($p < 0.01$)	0.53	($p < 0.01$)	0.15	(0.01)
Effect of federal firefighting	0.04	($p < 0.01$)	-0.11	($p < 0.01$)	0.27	($p < 0.01$)
Shrublands						
Effect of federal ownership	0.25	($p < 0.01$)	0.18	($p < 0.01$)	0.32	($p < 0.01$)
Effect of federal firefighting	-0.05	(0.23)	0.37	($p < 0.01$)	0.39	($p < 0.01$)
Forests without Commercial Species						
Effect of federal ownership	0.03	(0.54)	0.28	($p < 0.01$)	0.37	($p < 0.01$)
Effect of federal firefighting	0.01	(0.83)	0.31	($p < 0.01$)	0.16	(0.08)

Lessons learned

- For nearly every time period, and every vegetation type fire probabilities were higher on federal land than non-federal land
- For nearly every time period, and every vegetation type fire probabilities were higher where federal firefighters were responsible.
- However, there were differences in trends of ownership and fire fighting over time
  - Forest were always increasing
  - Shrublands and rangelands and inverse patters
- Ownership and fire fighting have larger impacts on fire probabilities than temperature
  - Of course climate is more complex than simply

Future Research

- We need to compare grazed to non-grazed sites
  - Research starting now – we need to develop dataset of grazing
  - Any ideas would be very much appreciated
- We need to look at severity as well as frequency
  - It may be that severity and frequency are related in complex ways
  - Good severity data back to 1980's

Thank you

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