Using Analytics for Wildfire Prediction and Management

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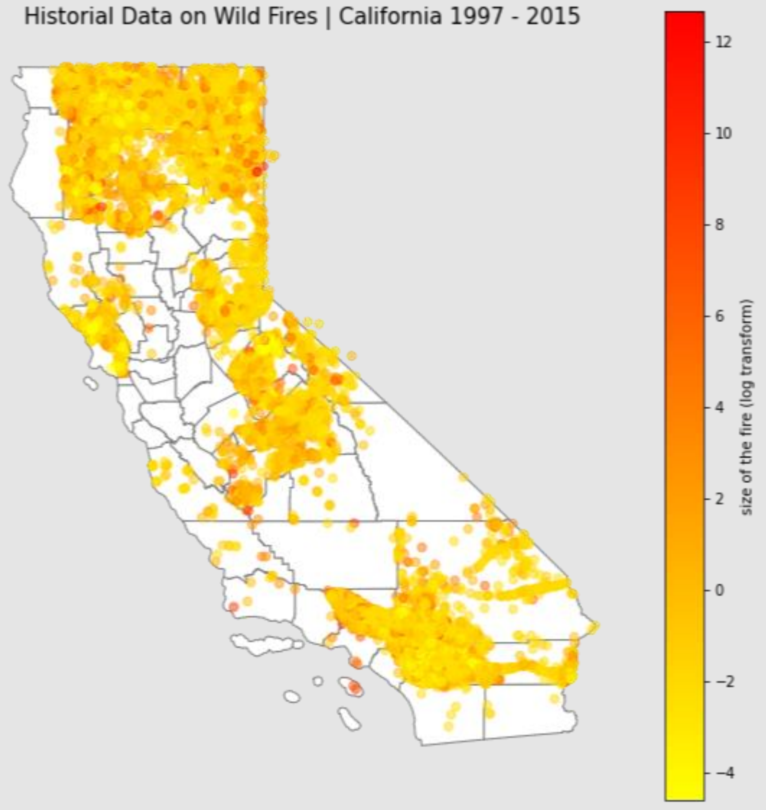
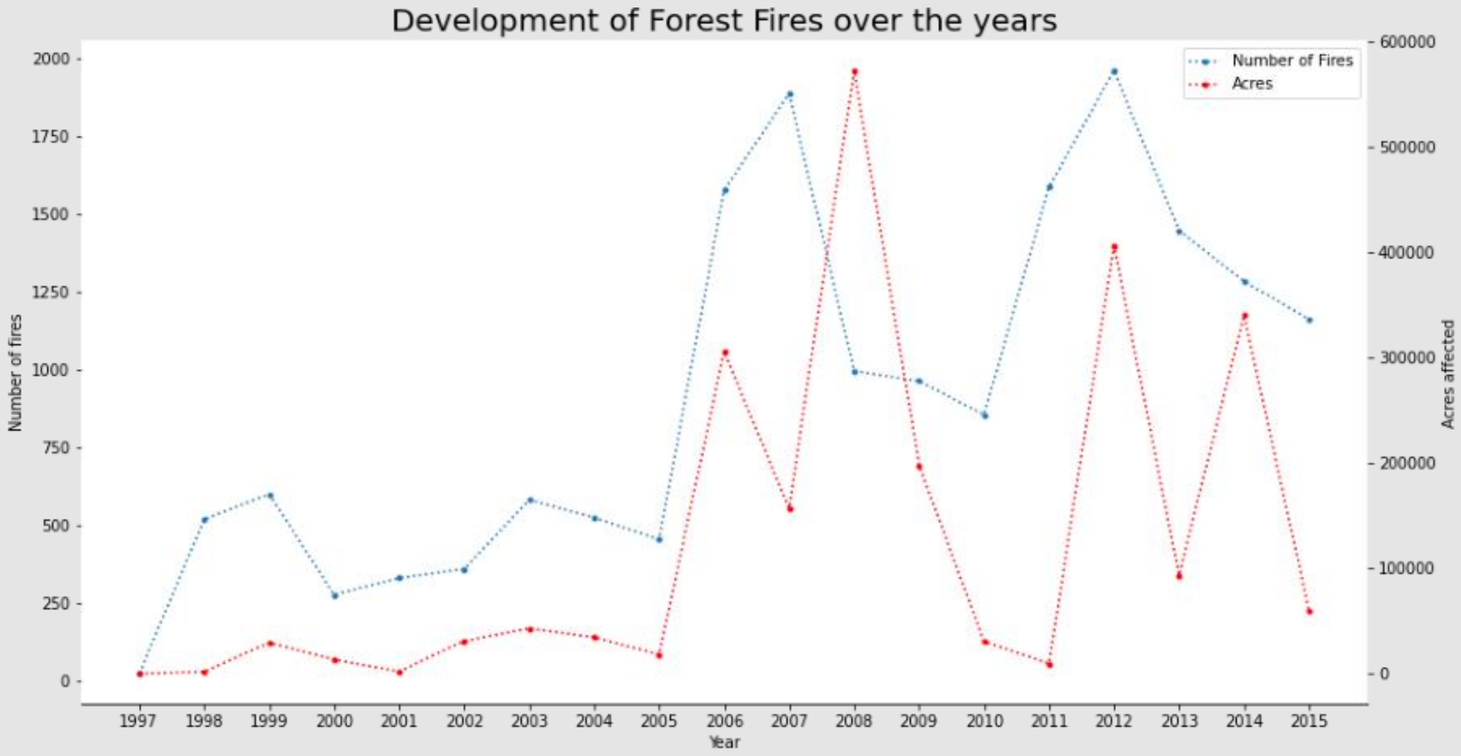
Problem + Data

Wildfire + Weather Observations

California counties, 1993-2015





Objectives

Allocate proper resources to wildfires

Predict fire size at time of ignition with classification models

Find risk of wildfire in a geographic area

Use survival regression to estimate time before next fire

Estimate impact of analytics on wildfire management

Identify savings from handling fires early before they grow too large

Predicting Fire Size

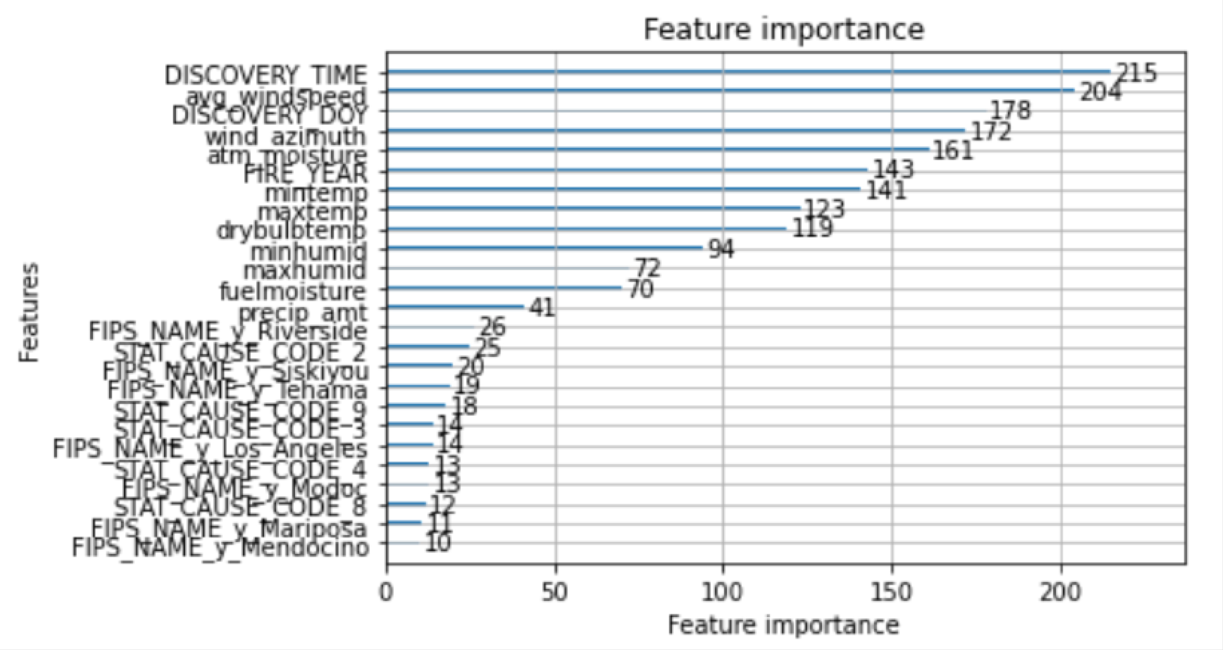
Gradient Boosting

Most important variables:

- Discovery Time and Day of Year
- Wind Speed and Direction
- Humidity and temperature

Metrics:

- Accuracy: 0.6564
- AUC: 0.6438
- Recall: 0.78



Estimating Fire Risk

CPH Regression to predict "survival" of a county: 0.649 out-of-sample C-index

Important variables are min and max windspeed and temperature

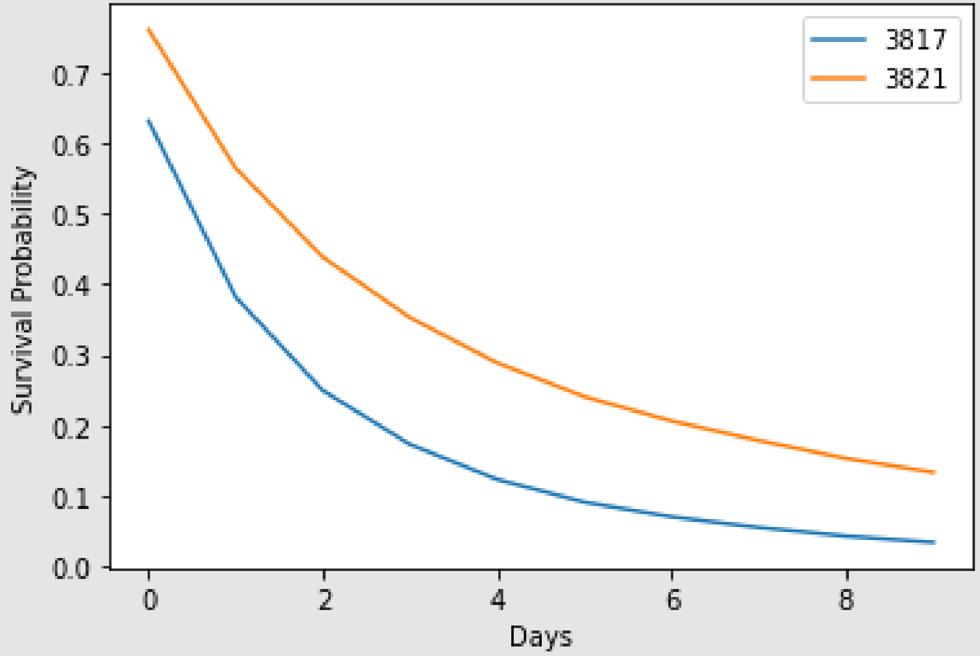
#3821: 9/27/11 in Siskiyou County

- Lower temps and windspeeds
- True time until next fire = 4 days

#3817: 9/15/11 in Siskiyou County

- High temp and windspeed
- True time until next fire = 1 day

Predicted Probability of No Fire



Quantifying Impact

Cost of missing a big fire (FN): $4 million

Cost of mismanagement (FP): $1 million

Baseline model: 122 FN → $488M

Our model: 19 FN + 106 FP → $182M

Annual savings[1] of **$300 million**

	Small fire	**Big fire**
Send resources for a small fire	Fire handled effectively	Difficulties handling fire; High costs & damage as fire spreads (False Negative)
Send resources for a big fire	Unneeded resources are wasted (False Positive)	Fire handled effectively

[1]Calculated from all fire observations in 2015

Conclusions and Insights

- ✓Predicting fire size is a complicated and noisy problem
- ✓Weather information is valuable for predicting fire size and survival time, but additional data sources could improve predictions
- ✓Huge potential cost savings + health & ecological benefits can come from proper resource management

Appendix

Big vs. Small fires

- Big fires: >= 2 acres, small fires < 2 acres
  - Why? 2 acres is the size of about 12 average lots in California, which we anticipate would take time to contain
- Drop everything < 0.5 acres
  - Why? All fires in our dataset under 0.5 acres took less than 1 day to contain, and 90% of fires under 0.5 acres were contained within 5 hours

Cost explanations

From the NWCG, the cost of using one unit each of all available firefighting crews and equipment for one day ≈ $250,000. We assume that a small fire will require 1 unit of all available firefighting crews and equipment, and a big fire will require 4 units of all available firefighting crews and equipment on average. Therefore, the treatment for a fire predicted to be small would cost $250,000 and the treatment of a fire predicted to be big would cost $1M.

Cost estimation false negatives:

To get true net false negative cost, we would normally take the cost of improperly treating big fires (big fires receiving small fires' resources) and subtract the cost of properly treating big fires (big fires receiving big fires' resources). We must make a significant assumption here that properly treated big fires and properly treated small fires incur *no* damage costs. CA historical fire data indicates that the total cost of wildfire-related property damage was estimated to be $3.061 billion in 2015. Technically, this figure contains damage amounts for big and small fires. However, small fires cause a very small amount of damage compared to the biggest wildfires. Therefore, we make the assumption for the purposes of this analysis that most of the $3.061 billion damage is generated by big fires.

We use $3 billion as a conservative estimate of the *total* impact of big fires. Since we lost about 83% of wildfire observations while merging weather and wildfire data, we are only considering about 1/6 of all California wildfires. Our test set, comprised of fires in 2015, has 122 fires that were classified as big fires. We therefore estimated the damage caused by a big wildfire initially treated with a small fire's resources to be around $3 billion/ (6*122), which is roughly $4 million per fire.

Cost estimation false positives:

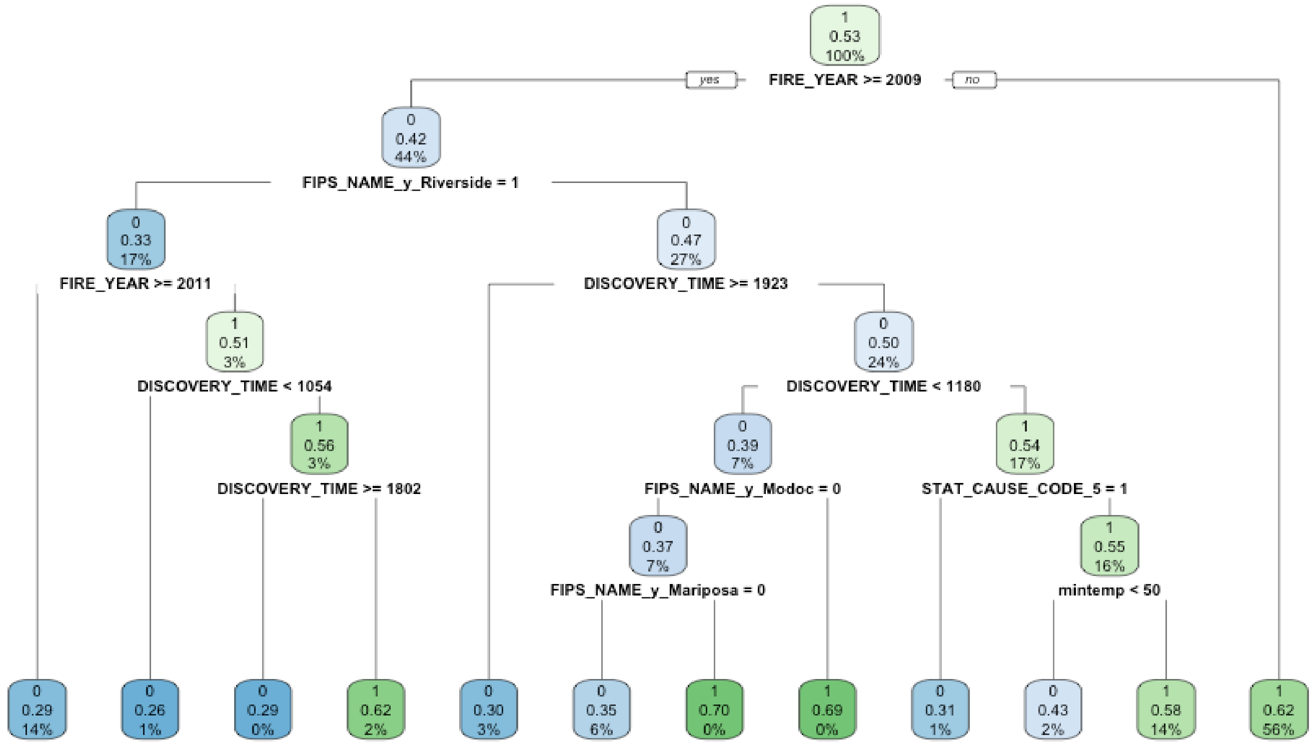
From our resource cost calculations above, we estimate that it costs $1 million to pay for the resources required by a big fire. If the fire we are allocating resources for is actually a small fire, we also incur an opportunity cost, as those resources are wasted and cannot be re-allocated quickly to an actual big fire. We estimate this opportunity cost as $1M as well.

True positive cost = $1M + $0 damage	False positive cost = $1M + $1M opportunity cost
False negative cost = $250k + $4M damage	True negative cost = $250k + $0 damage

Other models

Model	Test Accuracy	Test AUC	Test False Negative Rate (rate of missing big fires)
Logistic Regression	0.5614	0.6161	0.1580
CART	0.5931	0.6210	0.1679
Random Forests	0.6498	0.6391	0.2470
Boosted Trees	0.6564	0.6438	0.2216

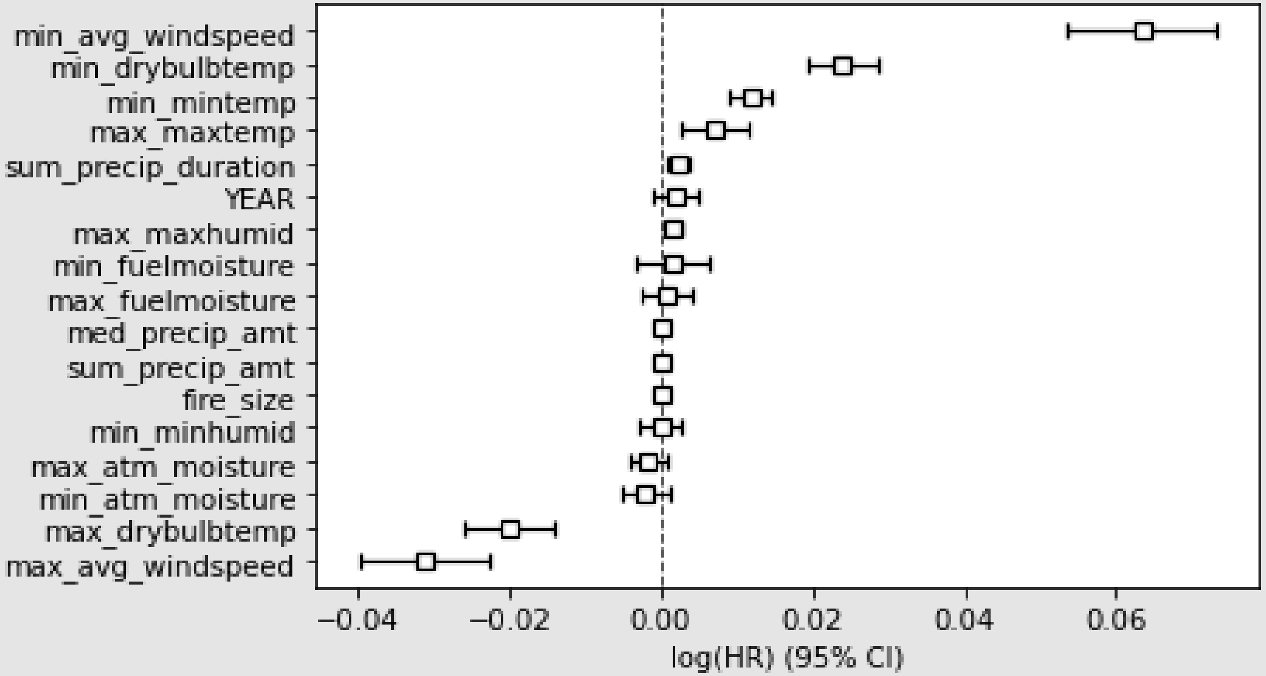
Other models



Classification Report for Boosting model

	precision	recall	f1-score	support
0	0.66	0.51	0.57	752
1	0.66	0.78	0.71	907
accuracy			0.66	1659
macro avg	0.66	0.64	0.64	1659
weighted avg	0.66	0.66	0.65	1659

Other plots



min_avg_windspeed
min_drybulbtemp
min_mintemp
max_maxtemp
sum_precip_duration
YEAR
max_maxhumid
min_fuelmoisture
max_fuelmoisture
med_precip_amt
sum_precip_amt
fire_size
min_minhumid
max_atm_moisture
min_atm_moisture
max_drybulbtemp
max_avg_windspeed
−0.04
−0.02
0.00
0.02
0.04
0.06
log(HR) (95% CI)

Other plots

Baseline

1	County	DayOfYeai	Real_size	Pred_size	TP	FP	FN	TN	total cost
2	El Dorado	150	0	0	0	0	0	1	0
3	El Dorado	157	0	0	0	0	0	1	0
4	El Dorado	163	1	0	0	0	1	0	4000000
5	El Dorado	166	1	0	0	0	1	0	4000000
6	El Dorado	168	0	0	0	0	0	1	0
7	El Dorado	168	1	0	0	0	1	0	4000000
8	El Dorado	170	0	0	0	0	0	1	0
9	El Dorado	170	0	0	0	0	0	1	0
10	El Dorado	171	1	0	0	0	1	0	4000000
11	El Dorado	175	1	0	0	0	1	0	4000000
12	El Dorado	175	1	0	0	0	1	0	4000000
13	El Dorado	183	1	0	0	0	1	0	4000000
14	El Dorado	184	1	0	0	0	1	0	4000000
15	El Dorado	197	1	0	0	0	1	0	4000000
16	El Dorado	203	0	0	0	0	0	1	0
17	Riverside	106	1	0	0	0	1	0	4000000
18	Riverside	106	1	0	0	0	1	0	4000000
19	Riverside	106	0	0	0	0	0	1	0
20	Riverside	108	1	0	0	0	1	0	4000000
21	Riverside	116	0	0	0	0	0	1	0

cost of FP	1000000
cost of FN	4000000
total cost	488000000

GBM

1	County	DayOfYeai	Real_size	Pred_size	TP	FP	FN	TN	total cost
2	El Dorado	150	0	1	0	1	0	0	1000000
3	El Dorado	157	0	1	0	1	0	0	1000000
4	El Dorado	163	1	1	1	0	0	0	0
5	El Dorado	166	1	1	1	0	0	0	0
6	El Dorado	168	0	1	0	1	0	0	1000000
7	El Dorado	168	1	1	1	0	0	0	0
8	El Dorado	170	0	1	0	1	0	0	1000000
9	El Dorado	170	0	1	0	1	0	0	1000000
10	El Dorado	171	1	1	1	0	0	0	0
11	El Dorado	175	1	1	1	0	0	0	0
12	El Dorado	175	1	1	1	0	0	0	0
13	El Dorado	183	1	1	1	0	0	0	0
14	El Dorado	184	1	1	1	0	0	0	0
15	El Dorado	197	1	1	1	0	0	0	0
16	El Dorado	203	0	1	0	1	0	0	1000000
17	Riverside	103	1	1	1	0	0	0	0
18	Riverside	106	1	0	0	0	1	0	4000000
19	Riverside	106	1	0	0	0	1	0	4000000
20	Riverside	106	0	1	0	1	0	0	1000000
21	Riverside	108	1	1	1	0	0	0	0

cost of FP	1000000
cost of FN	4000000
total cost	182000000

Image sources

- Icons made by Freepik from www.flaticon.com
- California by Michael Thompson from the Noun Project