

PREDICTING WILDFIRE CAUSES

Supervised Learning Capstone

Matt Francis



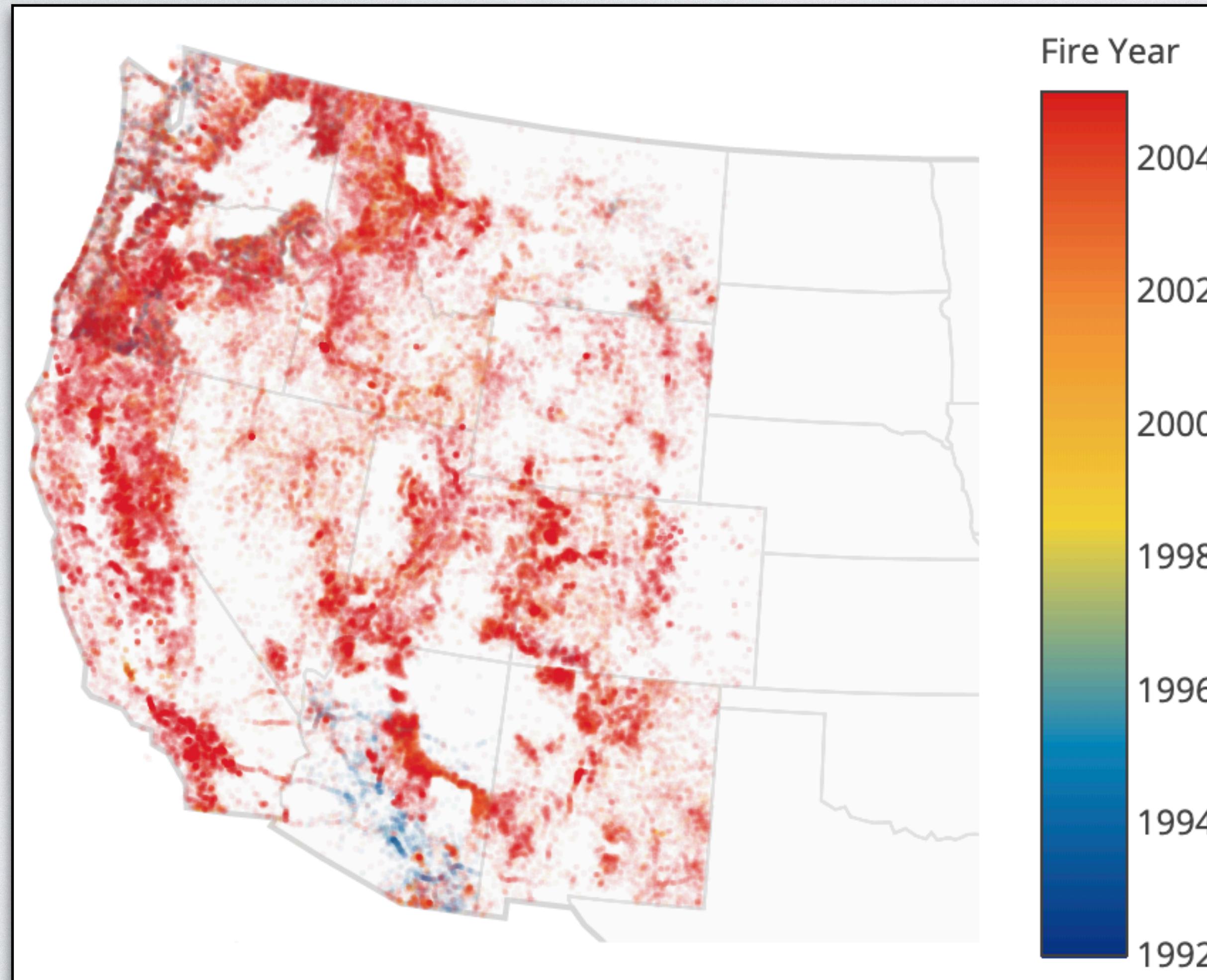
MOTIVATION

- Human-caused fires accounted for between 43 and 59% of all wildfires in the western US from 1992-2015.
- While wildfires can be beneficial to the ecosystem, they also pose serious threats to lives, property, and infrastructure.
- Cause prediction can:
 - Assist investigators bring arsonists to justice
 - Inform the public of the actual causes of wildfires
 - Act as a catalyst for abatement strategies



GOAL

Fires of the western US: 1992 - 2015



- Use supervised learning algorithms to predict the cause of forest fires in the western US

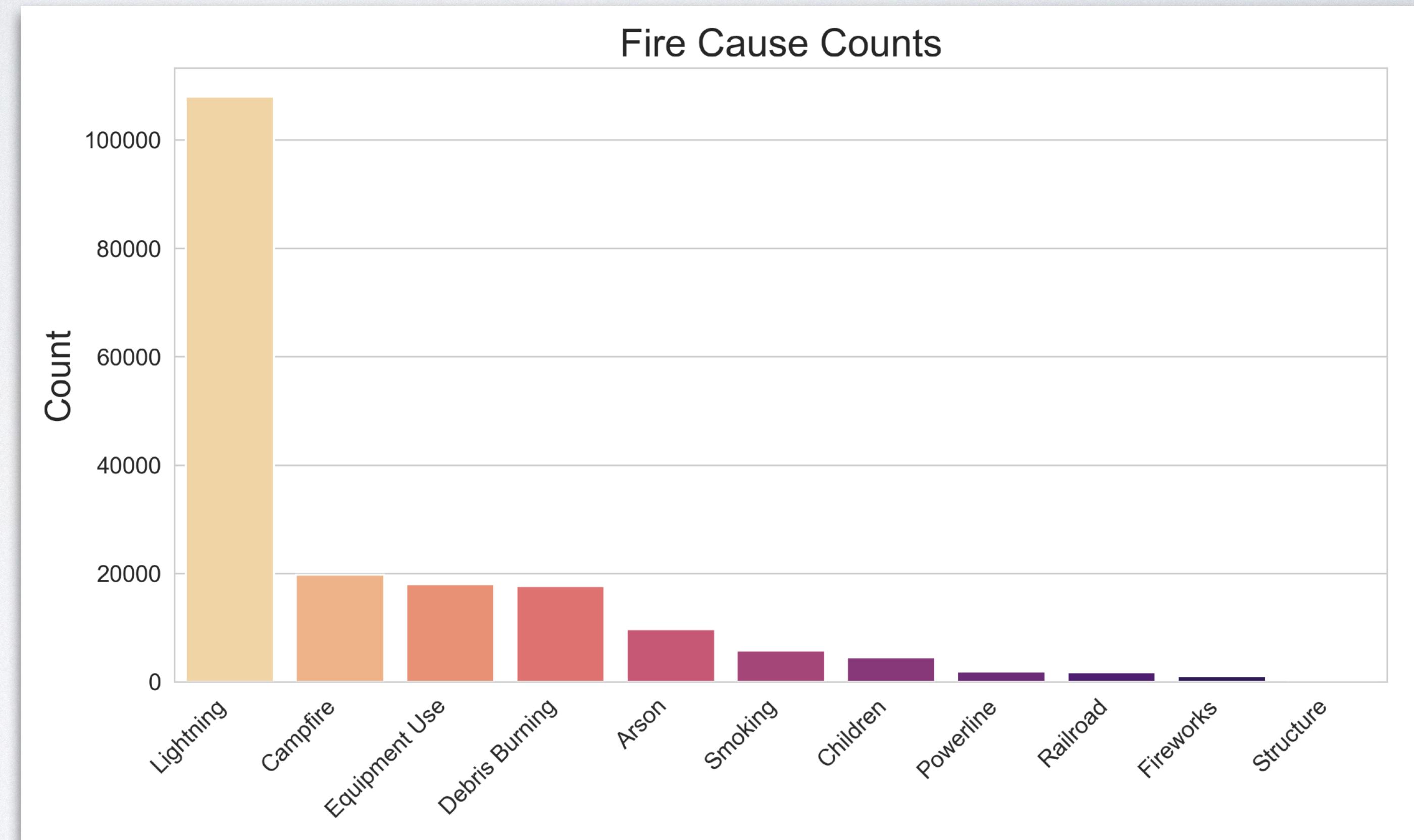
OUTLINE

- Data set
- Model setup
- Class imbalance strategies
- Imbalanced model metrics
- Baseline models
- Models on augmented data
- Results
- Future work



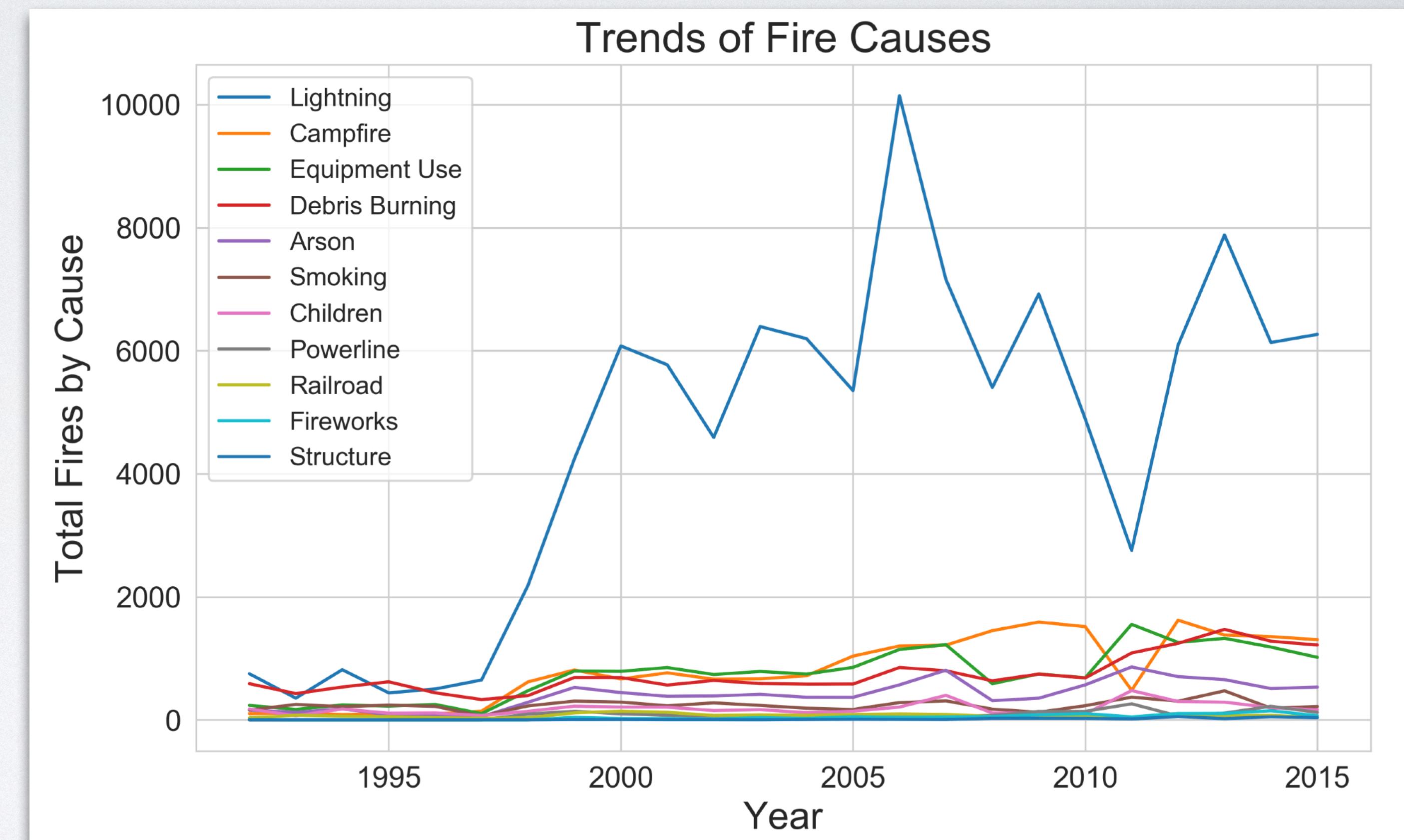
DATA SET

- Nationally compiled [forest fire database](#) from 1992 - 2015
- 1.88 million total fires recorded
- Types of data:
 - Reporting agencies
 - Report metadata
 - Fire names
 - Dates
 - Size
 - Geography



DATA SET

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MODEL SETUP

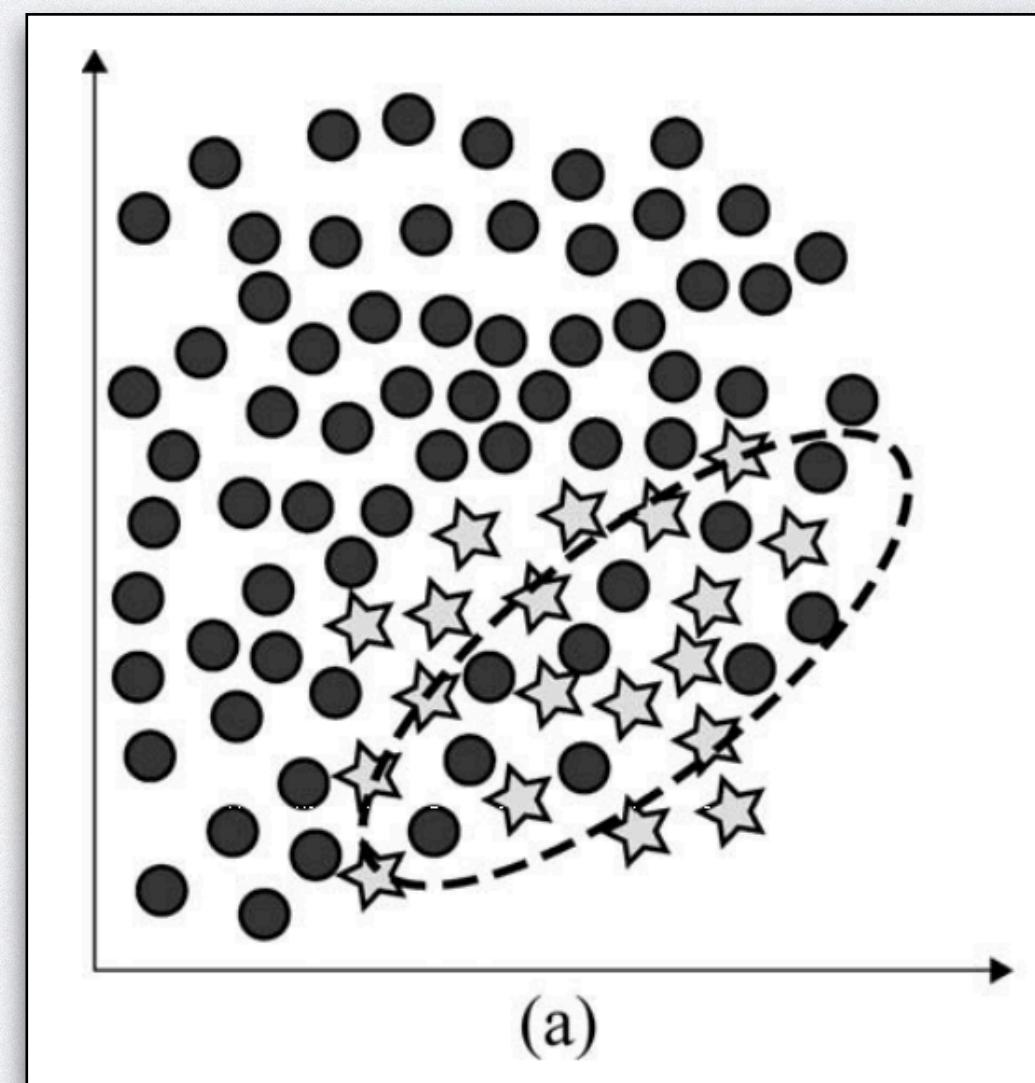
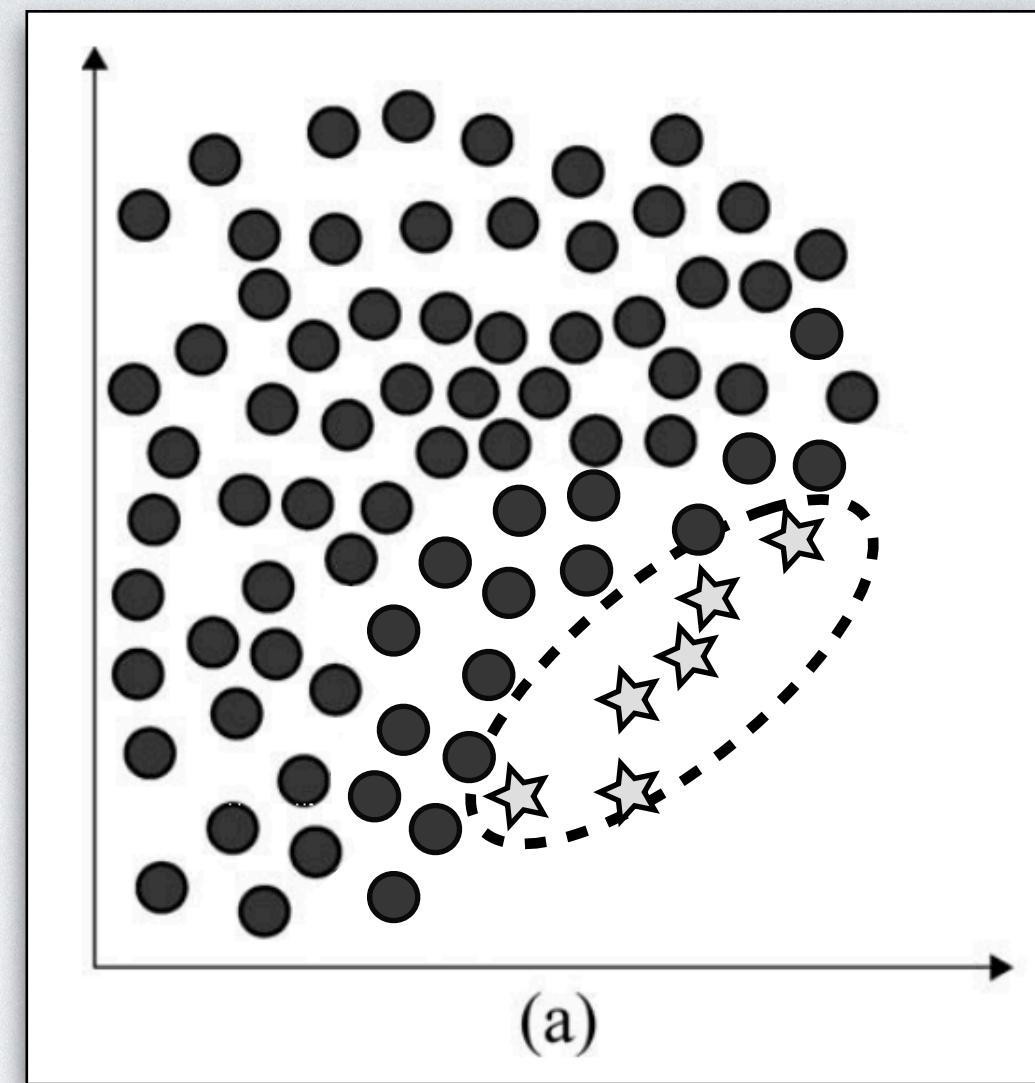
| Feature | Description | Type |
|-----------------|---------------------------------------|-------------|
| STAT_CAUSE_CODE | Fire cause | Categorical |
| DISC_MONTH | Month fire started | Categorical |
| DISCOVERY_TIME | Time fire started or was reported | Continuous |
| FIRE_LENGTH | Length (days) fire burned uncontained | Continuous |
| FIRE_SIZE_CLASS | Final size of fire, binned | Categorical |
| STATE | State fire started in | Categorical |
| FULL_FIPS | County fire started in | Categorical |
| OWNER_DESCR | Landowner type where fire started | Categorical |

Data shape: (188,018, 8)

Train / Test Split: (75%, 25%)

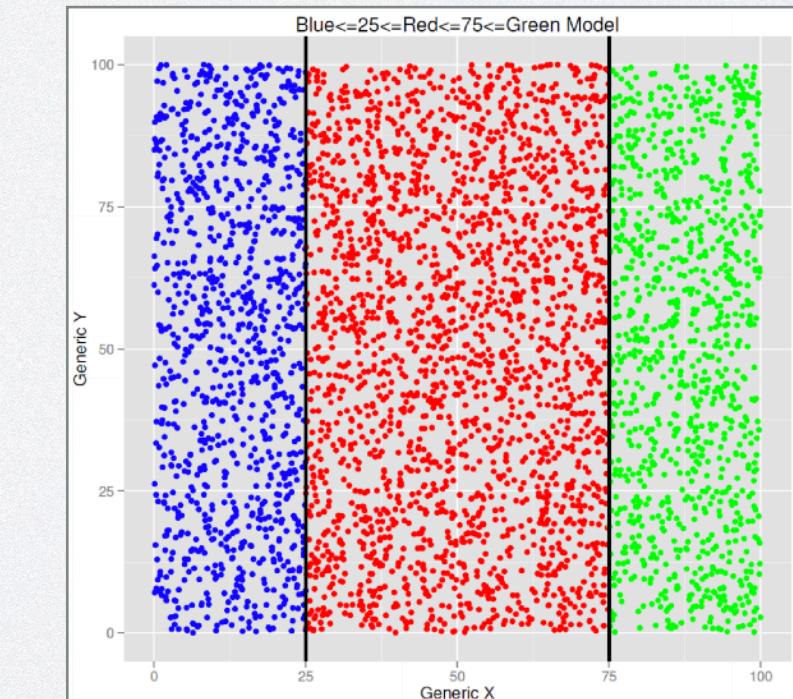
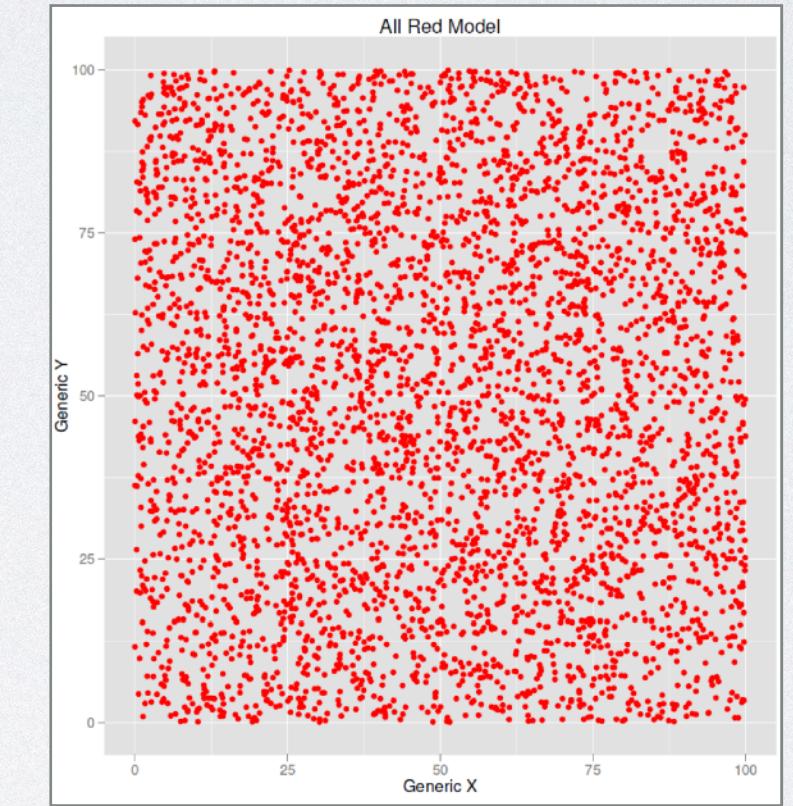
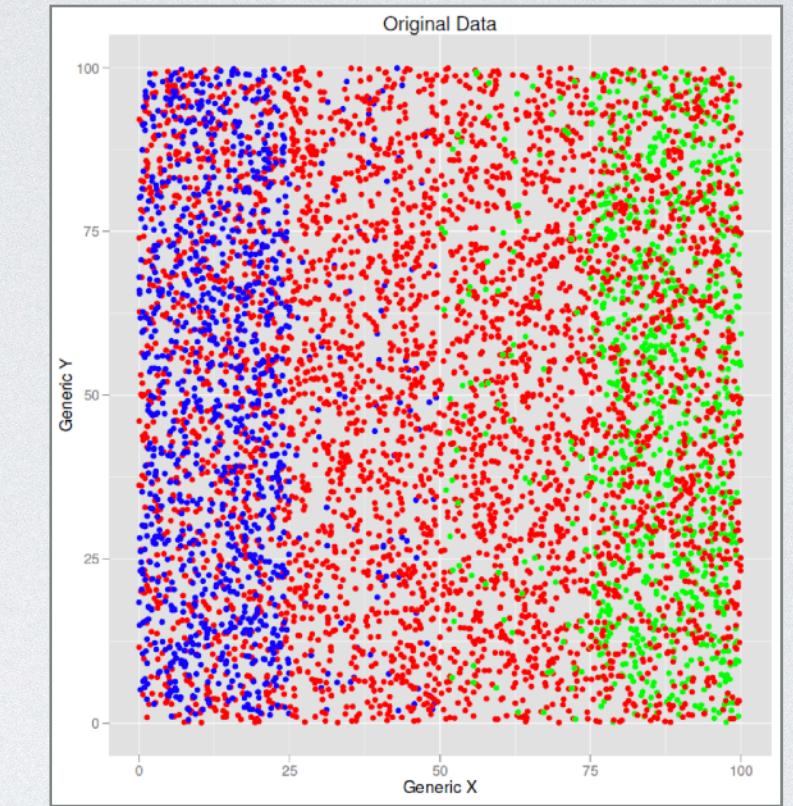
CLASS IMBALANCE

- Why class imbalance is bad:
 - Small minority classes lead to limited training losses when misclassified
 - Significant class overlap can lead to poor class boundaries
- Two main ways to deal with class imbalance:
 - Data space manipulations
 - Algorithm modifications (e.g., Fig. 3)



MODEL METRICS

- Accuracy is not useful
- Overview of imbalanced metrics ([see §2.2](#))
 - Balanced accuracy
 - Arith. avg. of recall of each class
 - Geometric mean
 - Geom. avg. of recall of each class
 - Weighted F1
 - Class weighted average of precision & recall
 - Will only consider this metric
- Computation time



**Given
this
input
data**

**These
two
models
have the
same
accuracy
score**

MODEL METRICS

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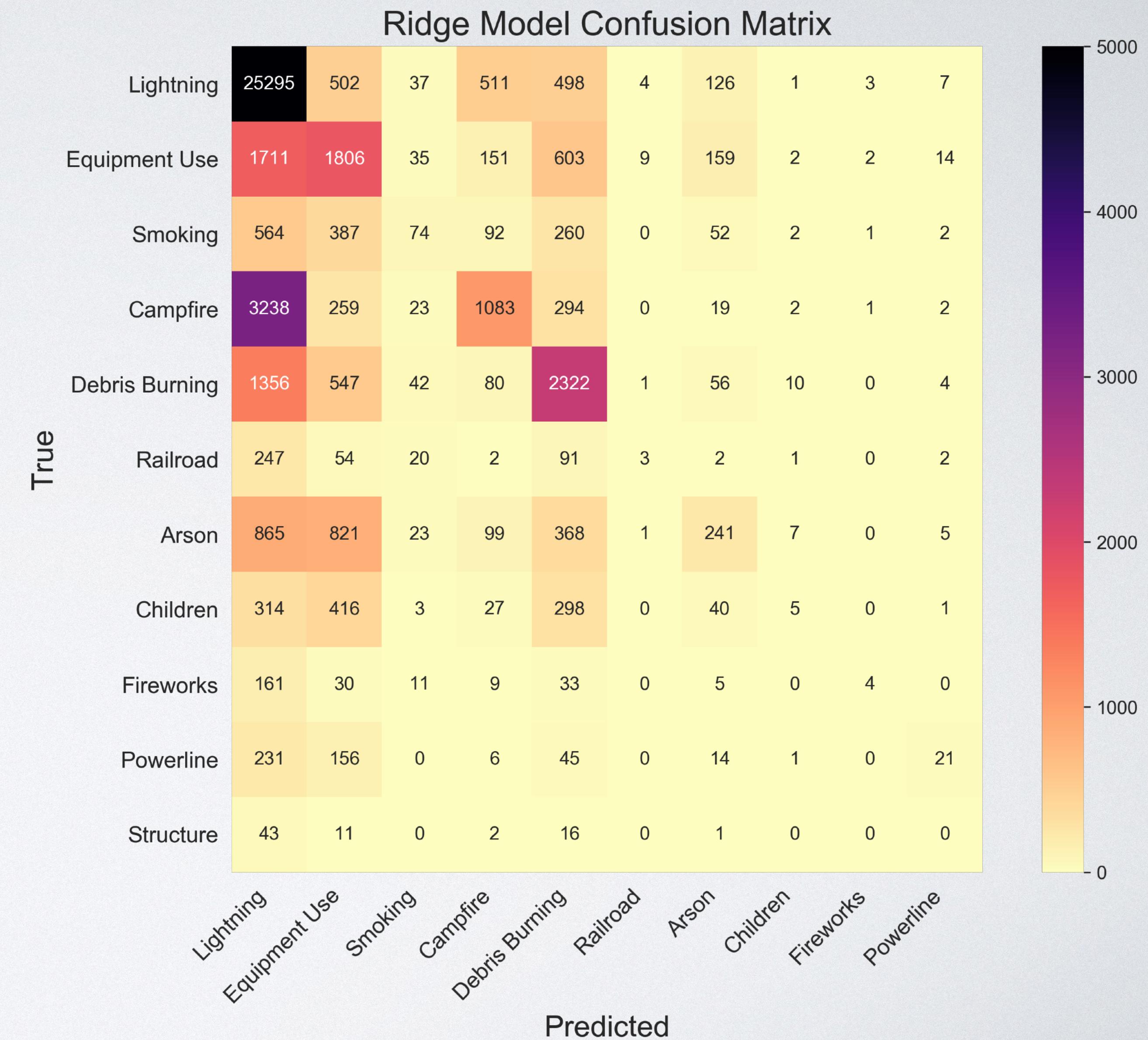
Confusion Matrix Example

| True Result | | | |
|------------------|----|----|----|
| A | B | C | |
| A | 80 | 18 | 2 |
| B | 10 | 20 | 10 |
| C | 8 | 3 | 4 |
| Predicted Result | | | |

INITIAL MODELS

LOGISTIC REGRESSION

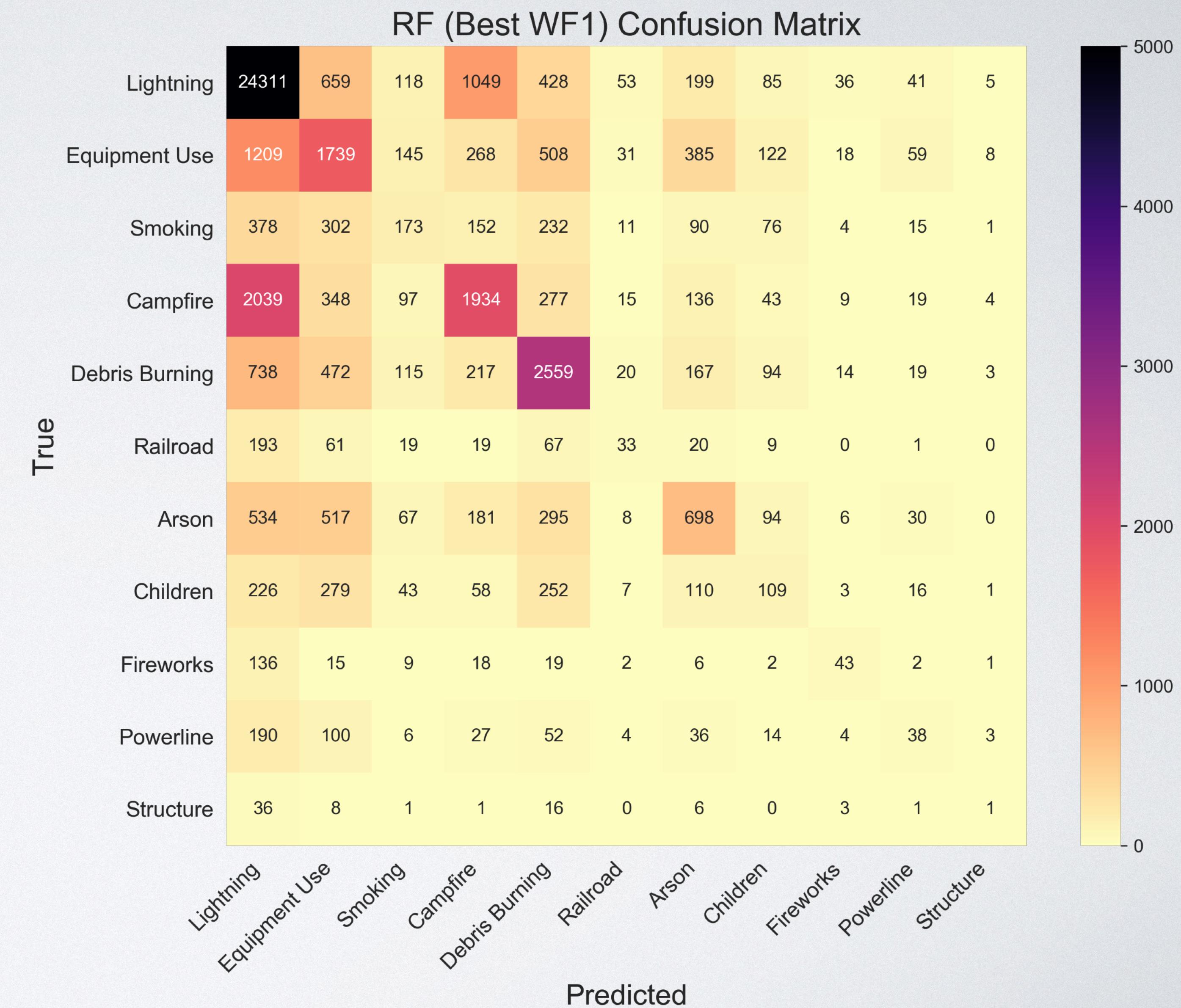
- Ridge Regression
 - Solver = lbfgs
 - C = 0.9
- Did not predict any **structure** fires
- Low precision for **lightning** class
- Low accuracy for all classes



RANDOM FOREST

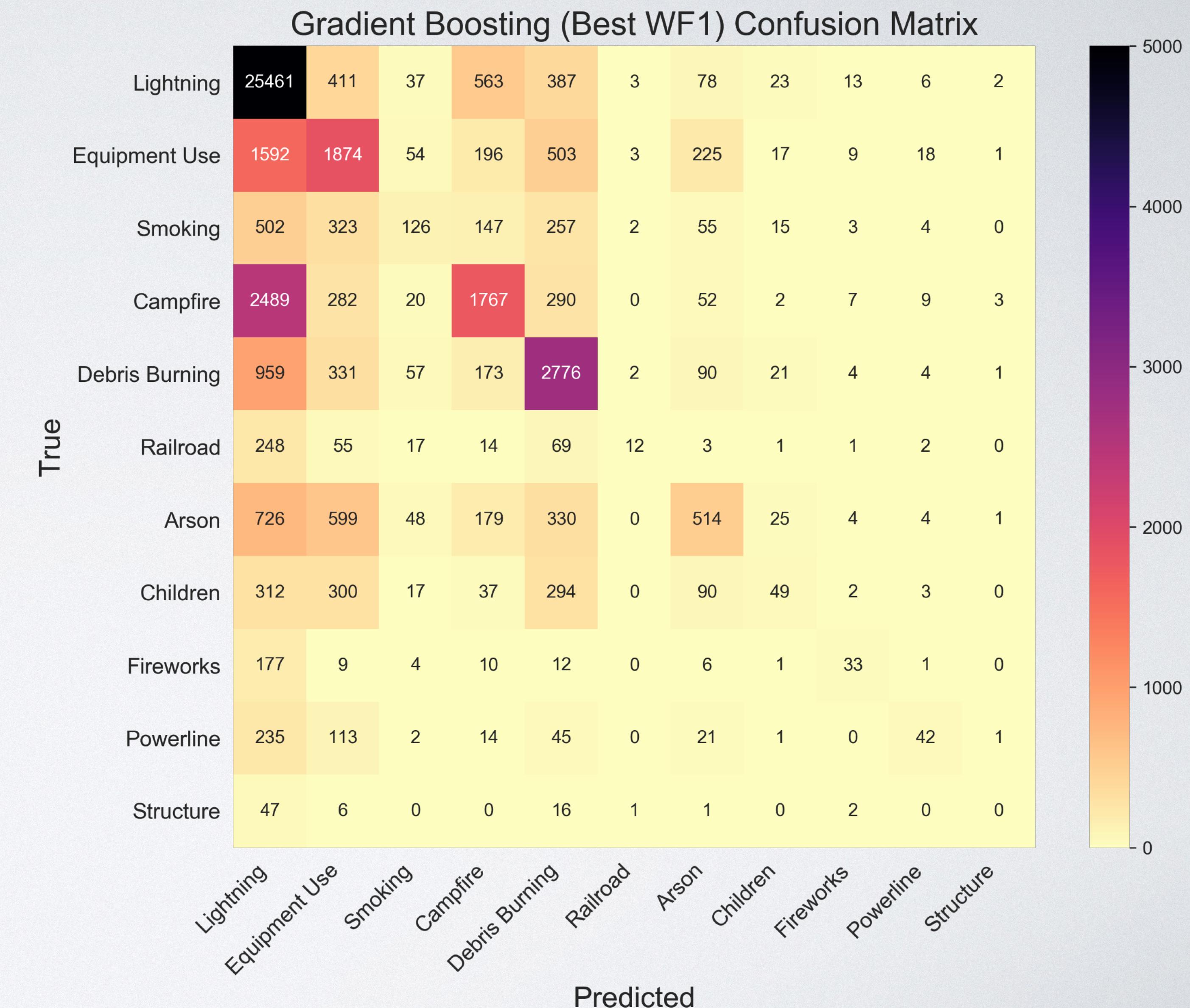
- Hyperparameters:
 - N_estimators = 500
 - Max_depth = 20
- Predicted all classes
- Better accuracy for all classes except **lightning** compared to Ridge

Weighted F1 **0.660**



GRADIENT BOOSTING

- Hyperparameters:
 - N_estimators = 250
 - Max_depth = 5
 - Learning_rate = 0.1
- Lower recall for small minority classes than RF
- Higher **lightning** accuracy than RF



INITIAL MODEL RESULTS

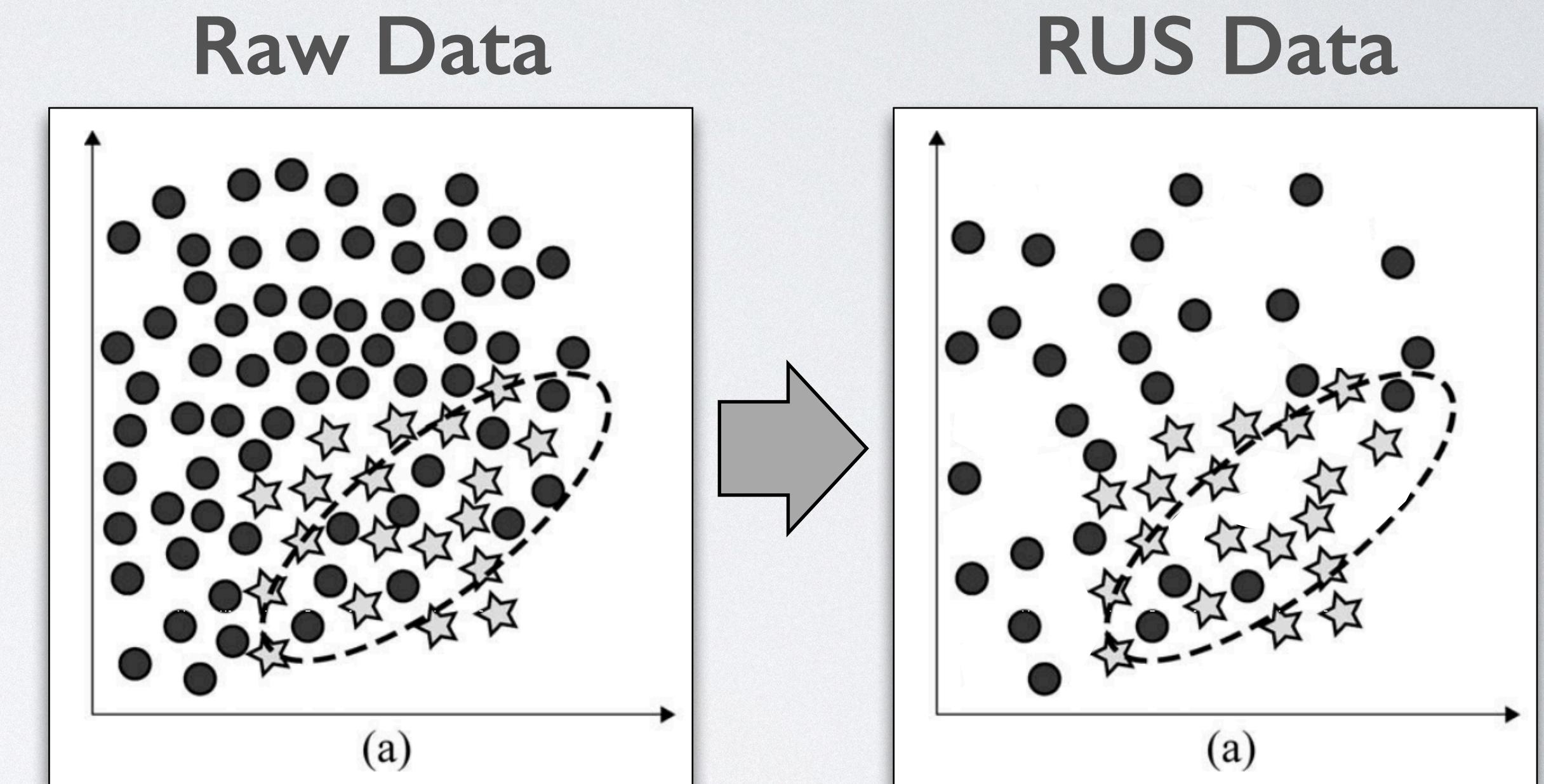
- Logistic regression
 - Comparable score to tree-based models, but failed to predict a class
- Random forest
 - Best models for minority class prediction
- Gradient boosting
 - Near identical scores to RF, but poorer minority class prediction
 - Computationally inefficient for large, multi-class problems

DATA AUGMENTATION

UNDER SAMPLING

- **Random Under Sampling**

- Under sample the majority class(es) by randomly picking samples to drop



RANDOM UNDER SAMPLED RANDOM FOREST

- Lightning RUS to 60,950
- Hyperparameters:
 - N_estimators = 250
 - Max_depth = 20
- Very similar performance to baseline RF
- Slightly better accuracy for the top half classes and slightly worse for the bottom half classes

Weighted F1 **0.663**



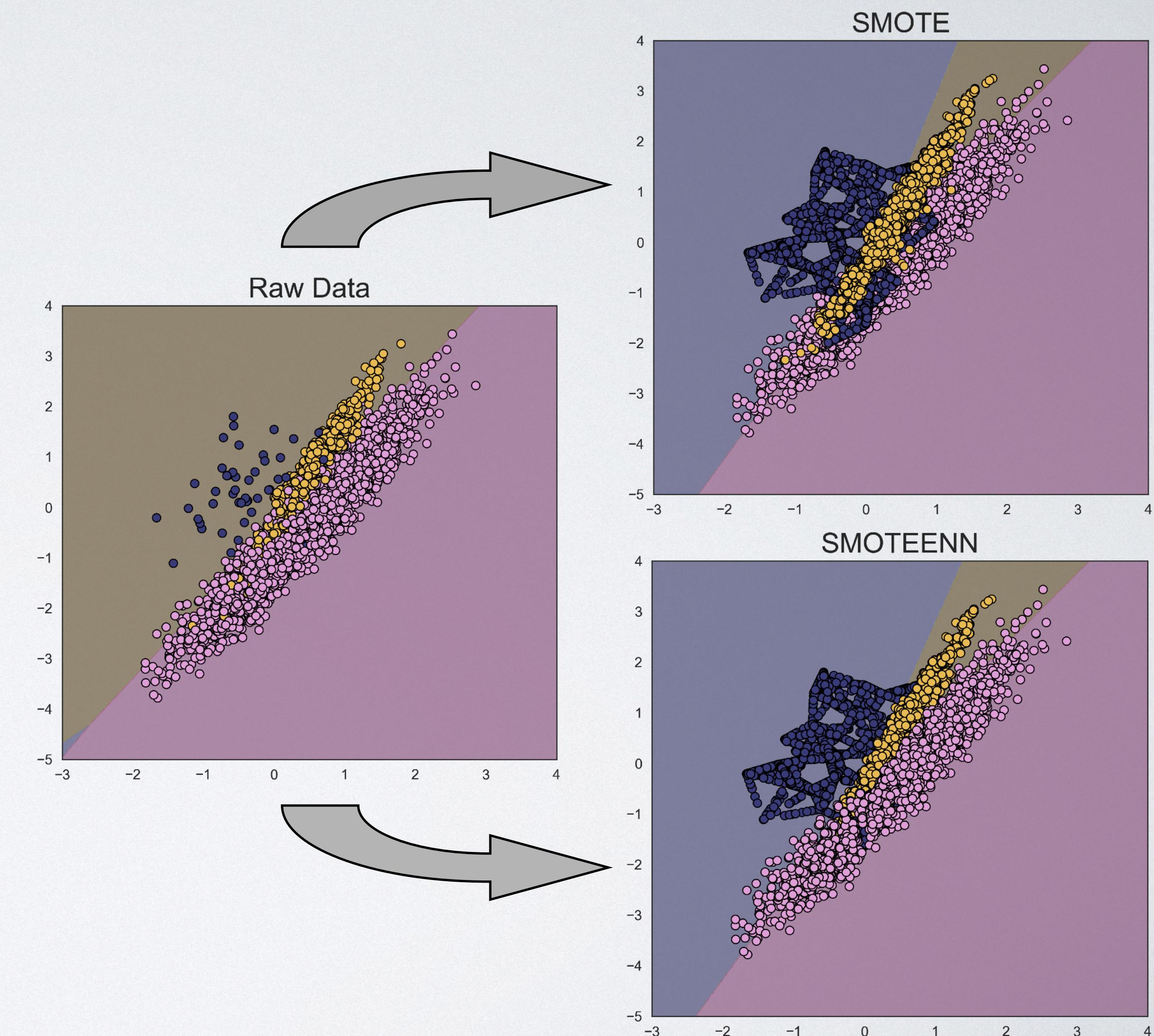
OVERSAMPLING (*Then Undersampling*)

- **SMOTE**

- Synthetic samples on a line connecting a sample with its KNN of the same class

- **SMOTEENN**

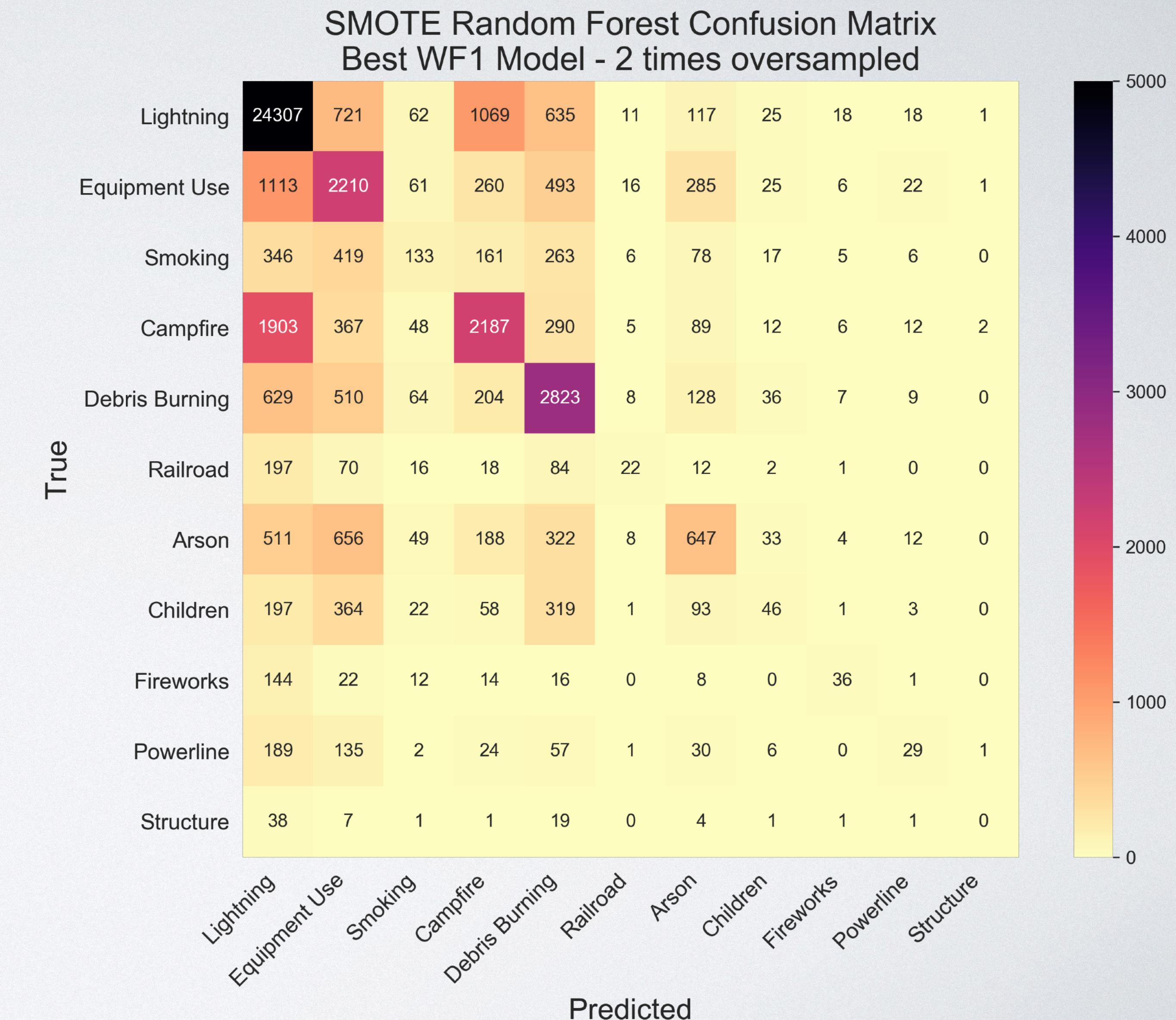
- SMOTE but removes all points where a majority of its KNNs are from a different class



SMOTE RANDOM FOREST

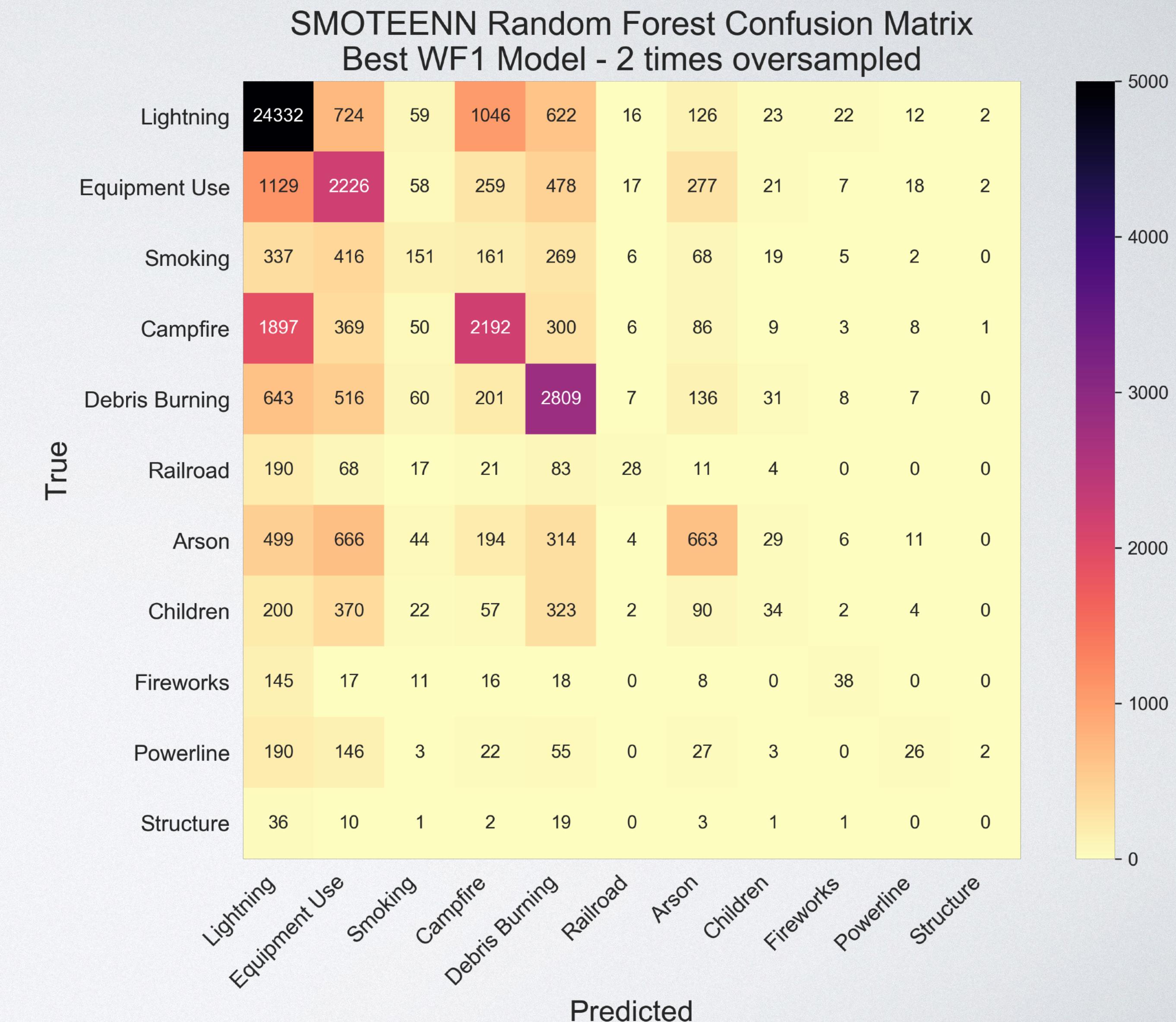
- Minority classes over-sampled by a factor of two
- Hyperparameters:
 - N_estimators = 500
 - Max_depth = 20
- Best weighted F1 score
- Very similar to baseline RF
- Slightly better with middle class prediction

Weighted F1 **0.666**



SMOTEENN RANDOM FOREST

- Minority classes oversampled by a factor of two
- Hyperparameters:
 - N_estimators = 250
 - Max_depth = 20
- Essentially identical to SMOTE model

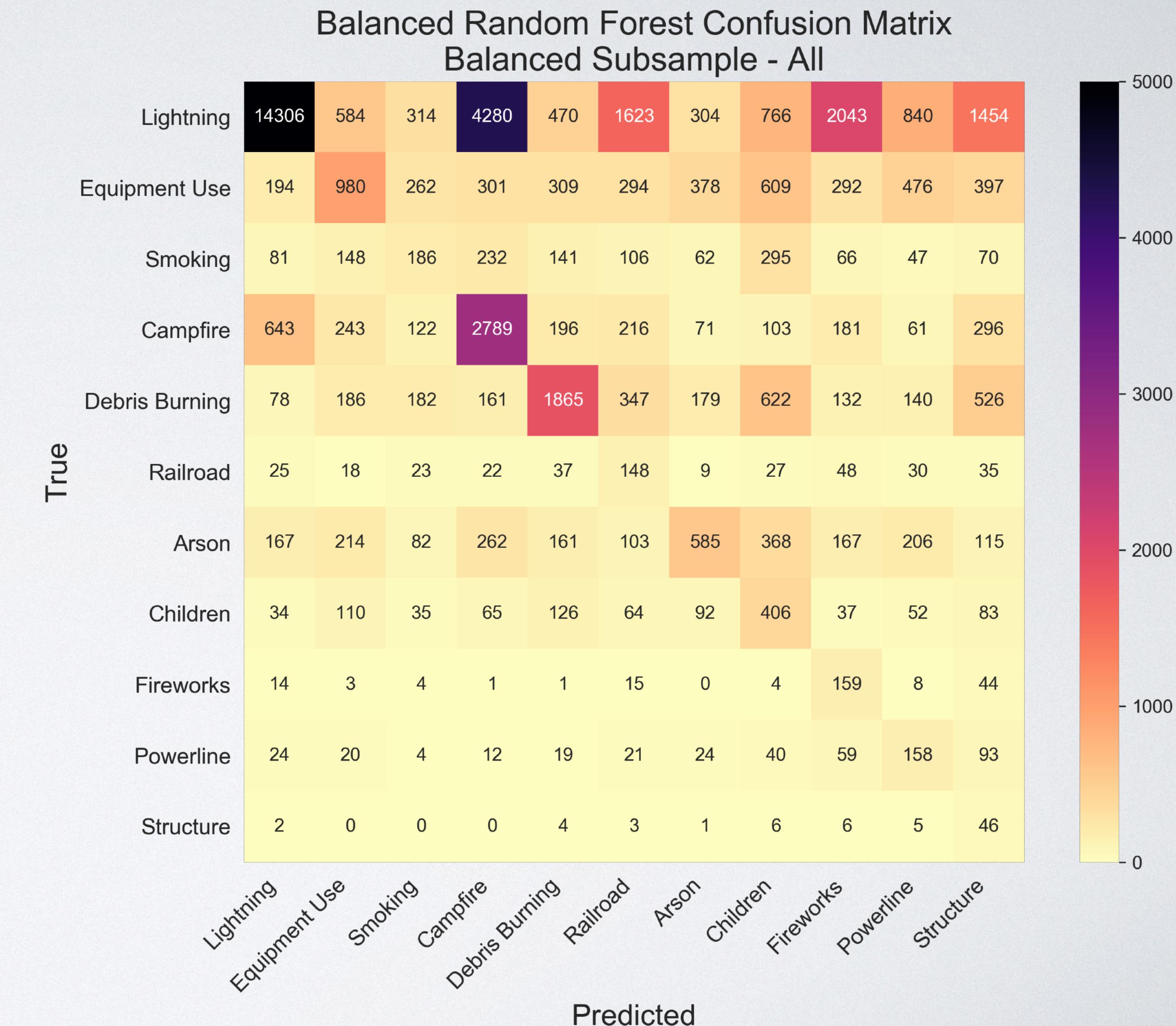


ALGORITHM MODIFICATION

BALANCED RANDOM FOREST

- RUS each tree to force a balanced sample
- Hyperparameters:
 - N_estimators = 250
 - Max_depth = 20
 - Class_weight = 'balanced_subsample'
 - Sampling_strategy = 'all'
- Much lower **lightning** recall
- Much lower precision for low minority classes

| | |
|--------------------|--------------|
| Weighted F1 | 0.529 |
|--------------------|--------------|



RESULTS

| Model | Weighted F1 | Balanced Acc |
|-------------------------|--------------|--------------|
| Ridge | 0.604 | 0.210 |
| Random Forest | 0.660 | 0.272 |
| Gradient Boosting | 0.656 | 0.267 |
| RUS RF (L=60950) | 0.663 | 0.282 |
| SMOTE RF (OvSmp * 2) | 0.666 | 0.284 |
| SMOTEENN RF (OvSmp * 2) | 0.655 | 0.270 |
| Balanced Random Forest | 0.529 | 0.402 |

FUTURE WORK

- More feature engineering
 - Elevation
 - Weather
 - Land cover type
 - Land use type
 - County-level demographic data
- Utilize different data sampling techniques
- Impute missing county FIPS codes
- GIS mapping work
- Unsupervised clustering analyses
- Time-series analyses

