# WEST NILE VIRUS

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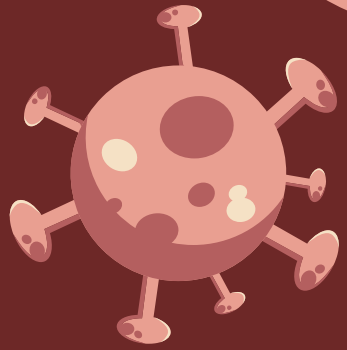
# CONTENTS

# INTRODUCTION

**Background**: Due to the recent epidemic of West Nile Virus in Chicago, the Department of Public Health has set up a surveillance and control system to collect data on mosquito population over time



# PROBLEM STATEMENT

Using the mosquito data collected over time, derive an effective plan to deploy pesticides throughout the city to control the mosquito population

**Approach**: Using ML/NN with Binary Classification, discover the important features for predicting the presence of WNV and develop a model to make predictions that the city of Chicago can use when it decides where to spray pesticides

# WHAT IS WEST NILE VIRUS?

## Transmission

WNV is transmitted to humans via the bite of infected mosquitoes.

01

02

## Effects

While most people infected with WNV do not feel sick, about 1 in 5 people develop a fever and flu-like symptoms. Age group over 60 is the most vulnerable.

03

## Incurable

Currently, there are no medication for the virus, prevention is the only way to stop the virus.

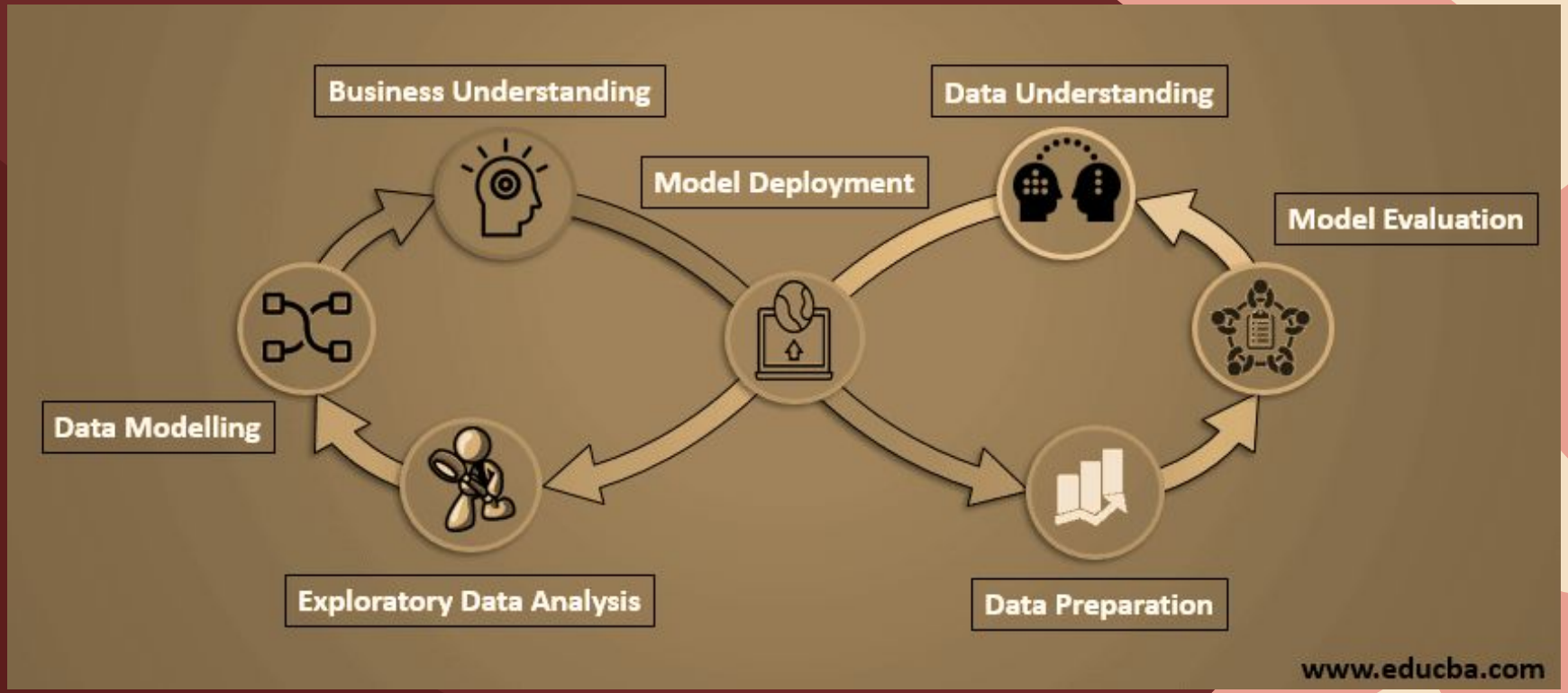
# 1,000

Cases detected in US 2019

# 60

Deaths caused

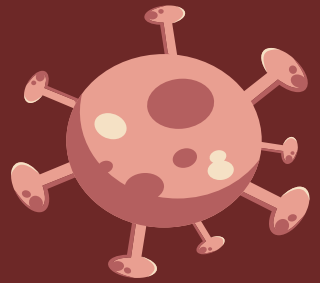
# METHODOLOGY



# WHAT IS IN THE DATA?

- Data used for the prediction model is from a Kaggle competition for West Nile Virus Prediction for the city of Chicago (link)

- Data provided:
  - Main dataset contains testing results of mosquitos found in traps placed in Chicago. WNV test data has been split into a train and a test dataset.
  - Spray dataset contains the spray dates and locations of the spray.
  - Weather dataset contains the weather conditions of each day at the two weather stations.

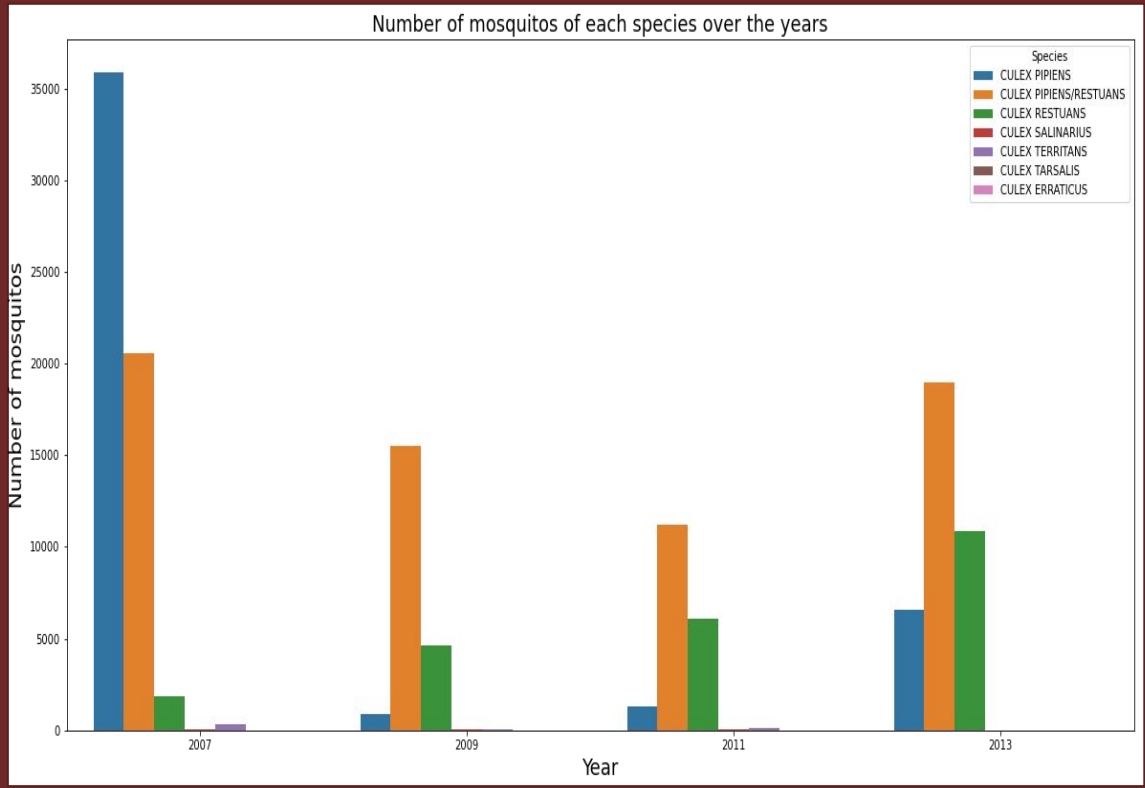


# EDA: TRAIN DATA

Total number of mosquitoes dropped over the years, especially the Culex Pipiens species. It experienced a tremendous drop from 2007 to 2009.

Observed only two species that carry the Wnv virus, namely the Culex Pipiens and Culex Restuans.

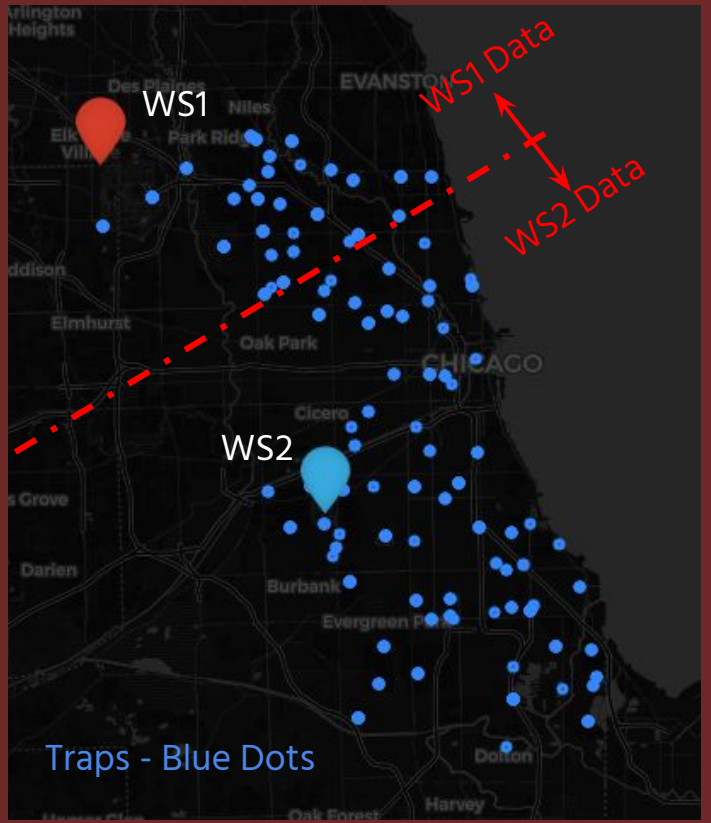
| WNV Mosquitoes Species | |
|---|---|
| CULEX PIPIENS/RESTUANS | 262 |
| CULEX PIPIENS | 240 |
| CULEX RESTUANS | 49 |



# EDA: WEATHER STATIONS & TRAPS

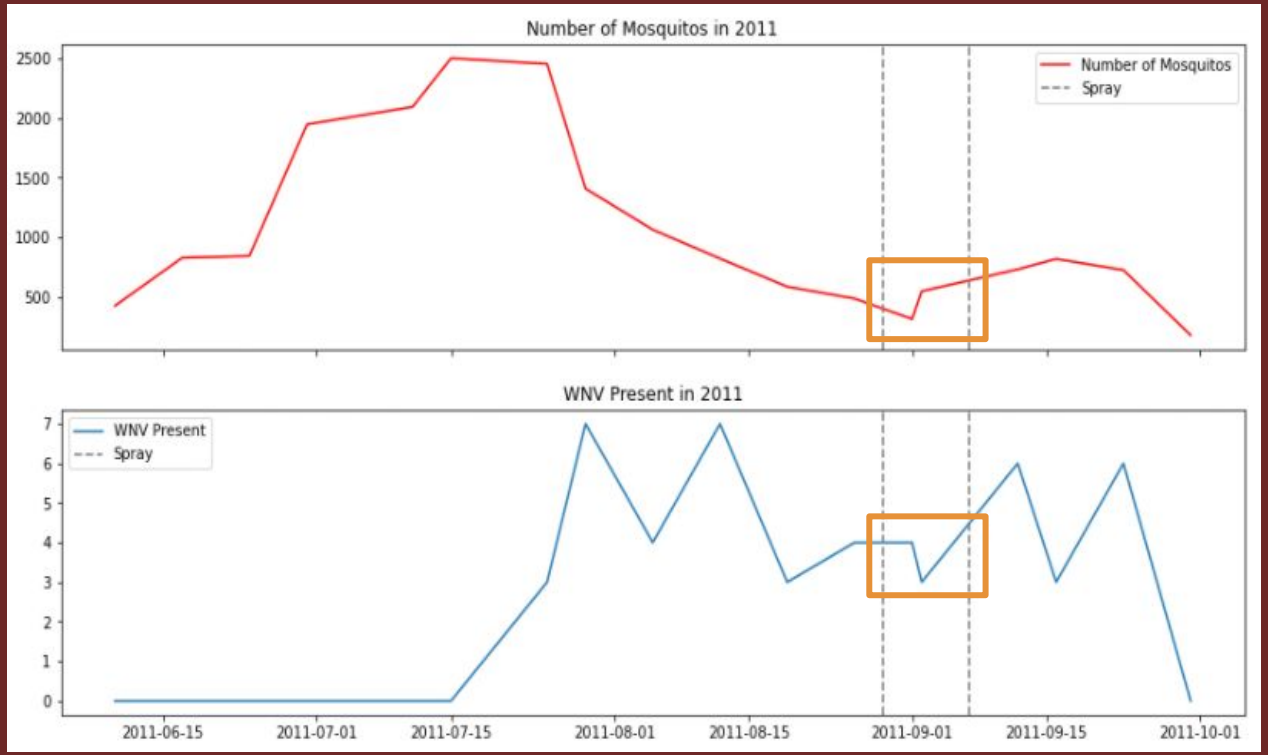
The map (on the right) shows the location of the traps and weather stations.

- Appended the weather data to the traps data.
- Based on the traps' proximity to the weather station.



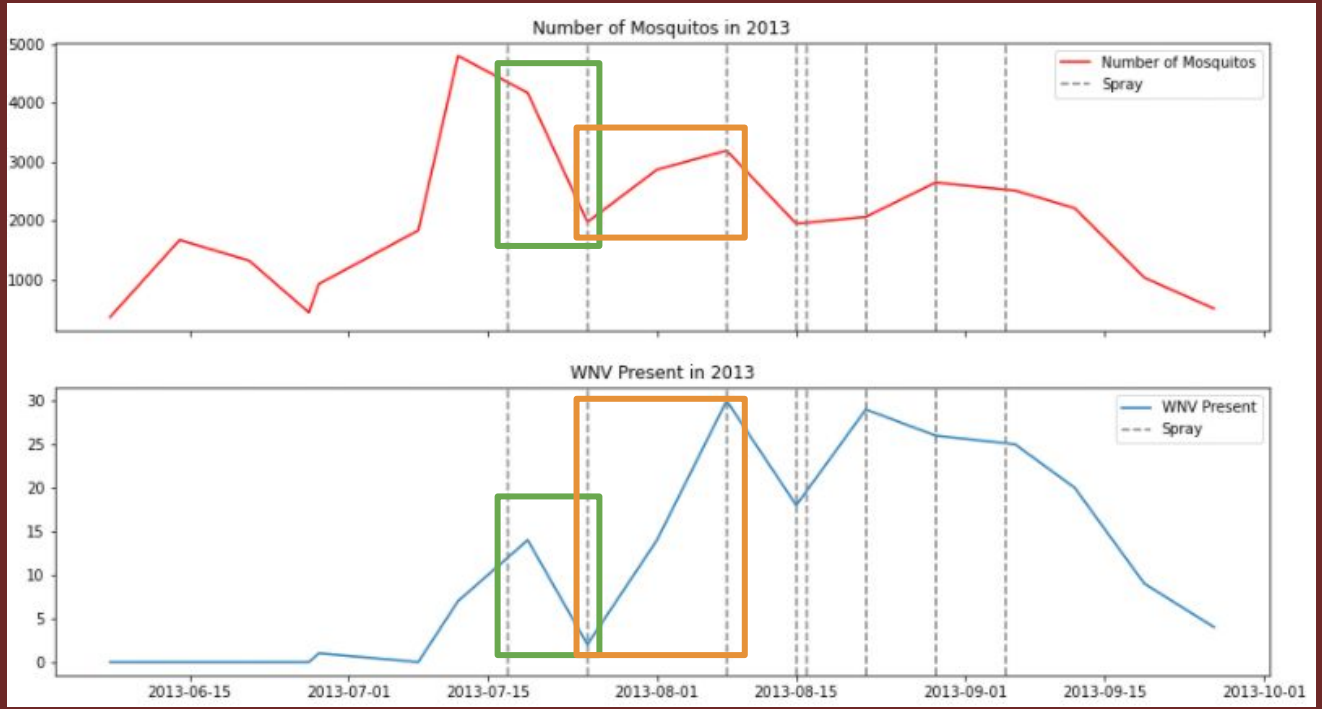
# EDA: MOSQUITOES NUMBERS & WNV IN 2011

- Two sprays were done in 2011, with little observable effect on the mosquito population and WNV presence



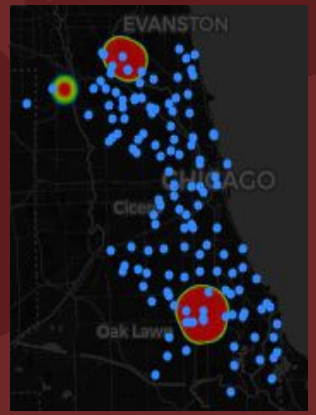
# EDA: MOSQUITOES NUMBERS & WNV IN 2013

- 1st spray in 2013 had helped to reduce the number of mosquitos and WNV presence
- 2nd spray did not have the same effect, perhaps location of spray was not ideal

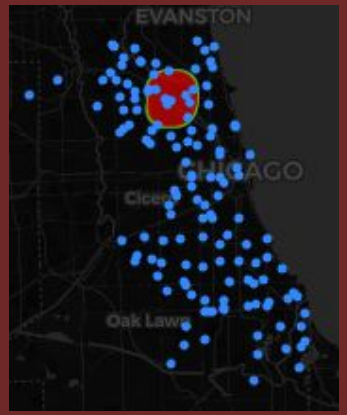


# EDA: SPRAY & SPREAD OF WNV

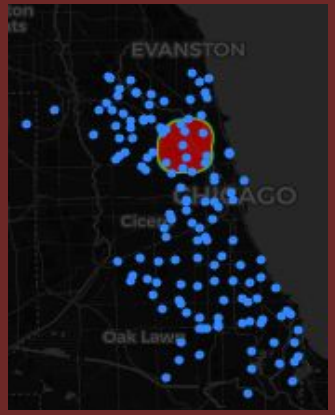
Spray Timeline




2013-07-17



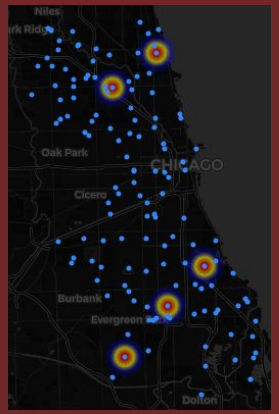

2013-07-25




2013-08-08

Mosquito Spread Timeline

2013-07-12

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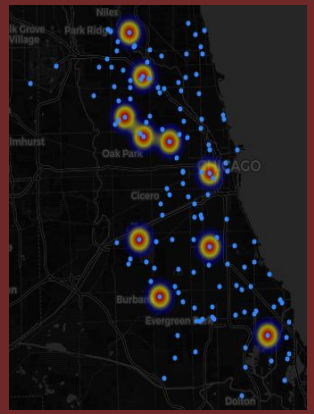


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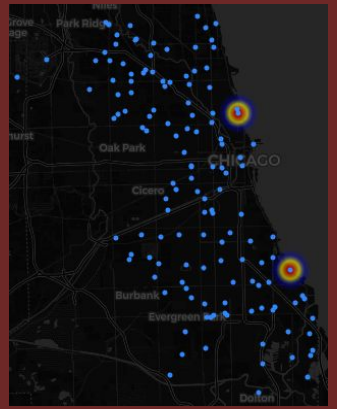
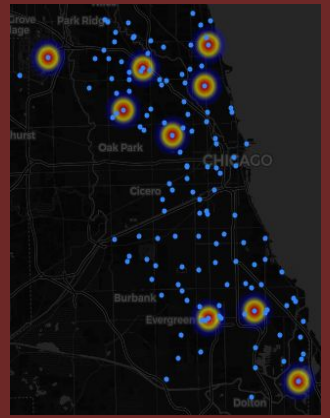



2013-08-01

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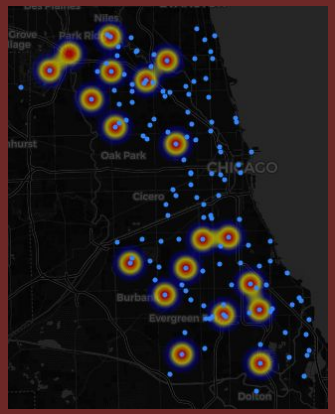
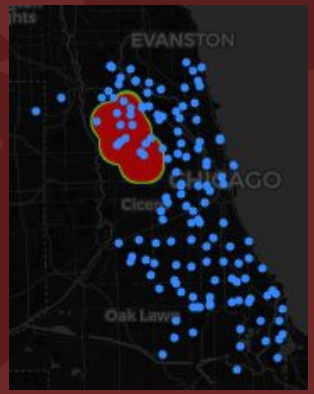
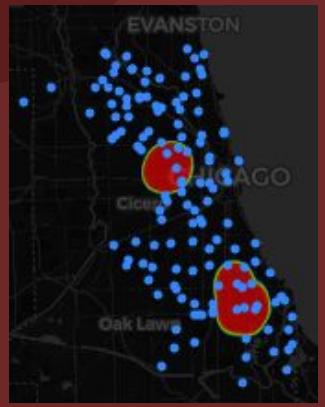
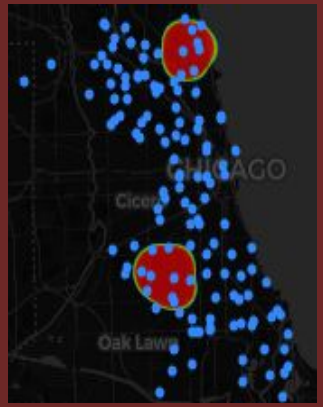


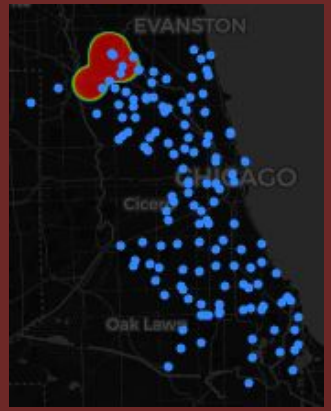
# EDA: SPRAY & SPREAD OF WNV

Spray Timeline



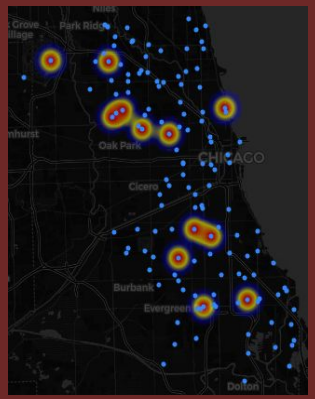



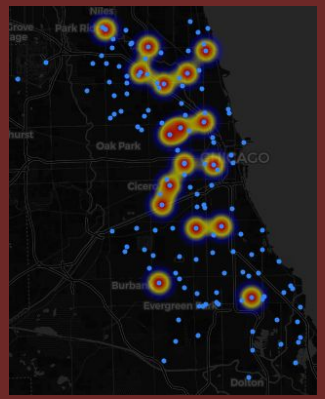



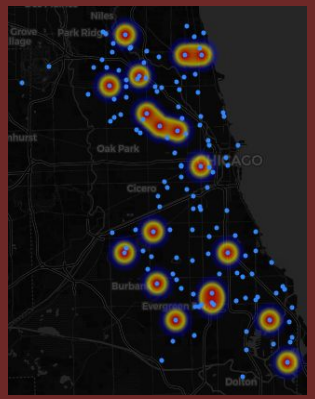

2013-08-15 2013-08-22 2013-08-29 2013-09-05

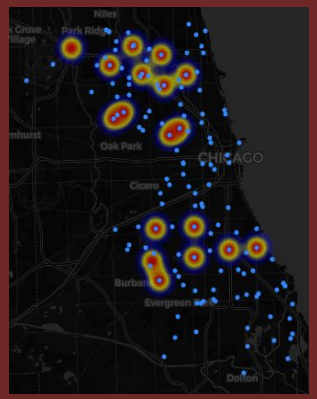
2013-08-15 2013-08-22 2013-08-29 2013-09-06 2013-09-12

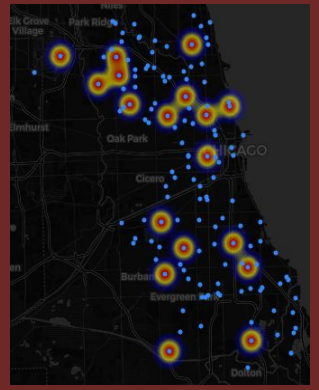
Mosquito Spread Timeline



# EDA: SUNSET & SUNRISE

This dataset contains the weather conditions data for Station 1 and 2. However, there are some missing data for some of the features.

Two of the features affected are Sunset and Sunrise timings. The missing data were from Station Two.

Using the Sun, Timezone, Latitude and Longitude, we managed to fill in the missing data for Station Two.

Another feature affected is Temperature Average. For that, we took the Max and Min Temperature's Mean to fill in the missing data.

```
# Extract sunrise/sunset values for Station 2
# This is the location of Station 2
latitude = 41.786
longitude = -87.752

sun = Sun(latitude, longitude)

central = timezone('US/Central')

sunrise_list = []
sunset_list = []
for value in weather['Date']:
    abd = value
    abd_sr = sun.get_local_sunrise_time(value, local_time_zone=central)
    abd_sr = abd_sr - abd_sr.dst()
    abd_ss = sun.get_local_sunset_time(value, local_time_zone=central)
    abd_ss = abd_ss - abd_ss.dst()
    sunrise_list.append(abd_sr.strftime('%H%M'))
    sunset_list.append(abd_ss.strftime('%H%M'))
```

Above code is for getting the Sunset and Sunrise timing for Station Two.

# FEATURE ENGINEERING: WEATHER

01

## Code Sums

This feature contains the different weather conditions code. As not all weather conditions are present, we grouped the remaining conditions to ‘Dry’ or ‘Wet’

02

## Humidity Feature

High Humidity conditions favor mosquito activity, while low humidity suppresses activity and may even cause mortality

03

## Sun Hours

Mosquitos are most active from dusk to dawn. The number of hours with sunlight might help in the modelling

04

## Time-Lag Features

As the mosquitoes’ breeding cycle might vary from 1 to 8 weeks, time-lagged weather features were created

# WEATHER FEATURES

**Weather Condition Features**

1) Average Temperature
2) Wet Bulb Temperature
3) Precipitation
4) Station Pressure
5) Sea Level
6) Resultant Wind Speed
7) Resultant Wind Direction
8) Average Wind Speed

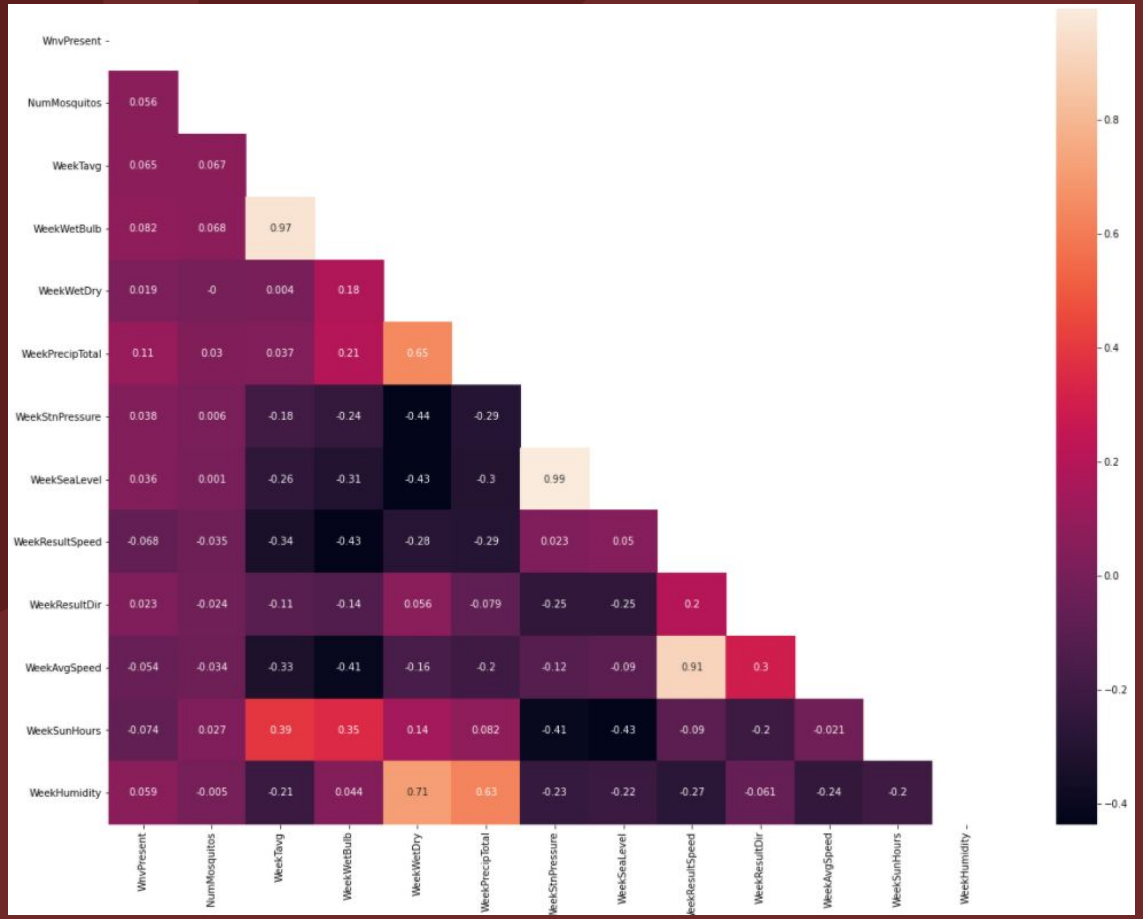
**Engineered Weather Features**

9) Sun Hours
10) Wet/Dry Day
11) Humidity

**Time-Lag Features**

As mosquitoes require one to eight weeks duration to be incubated and grow, we created 4 weekly time-lag average variable for each of the weather features.

# EDA: WNV MOSQUITOES & WEATHER CONDITIONS

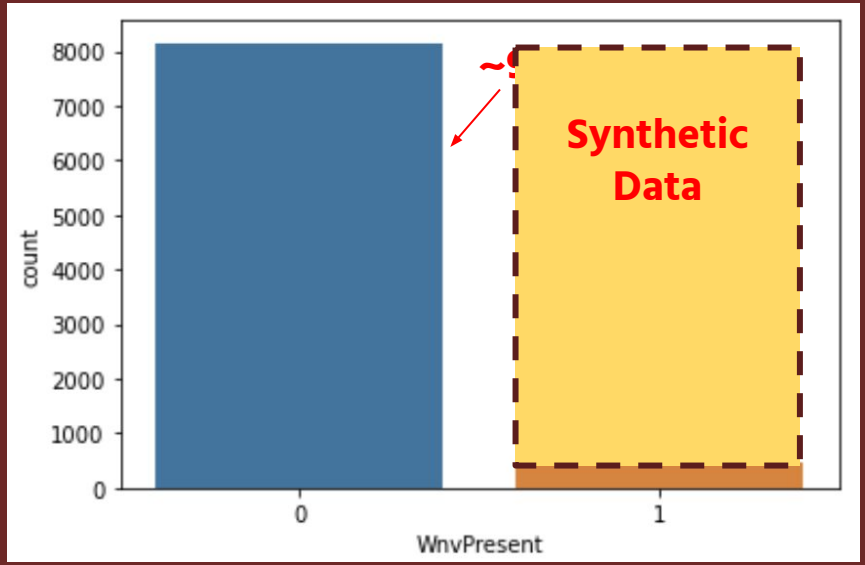



**Weather Conditions**

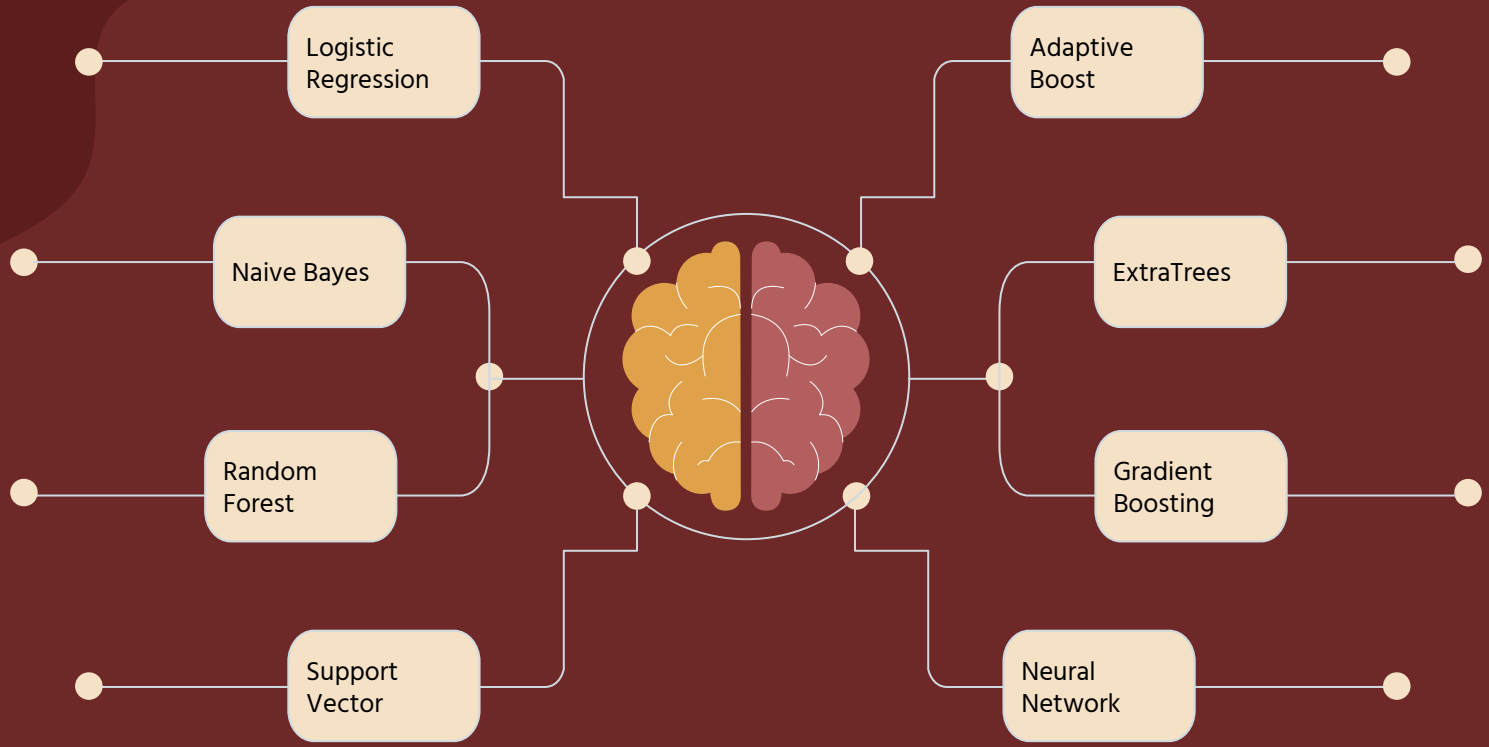
- As we study the different weather conditions, we will look specifically on five weather conditions which will affect the growth of mosquitoes.
- The five conditions are:
  - Wind
  - Temperature
  - Precipitation
  - Humidity
  - Sunlight Duration

# PREPROCESSING

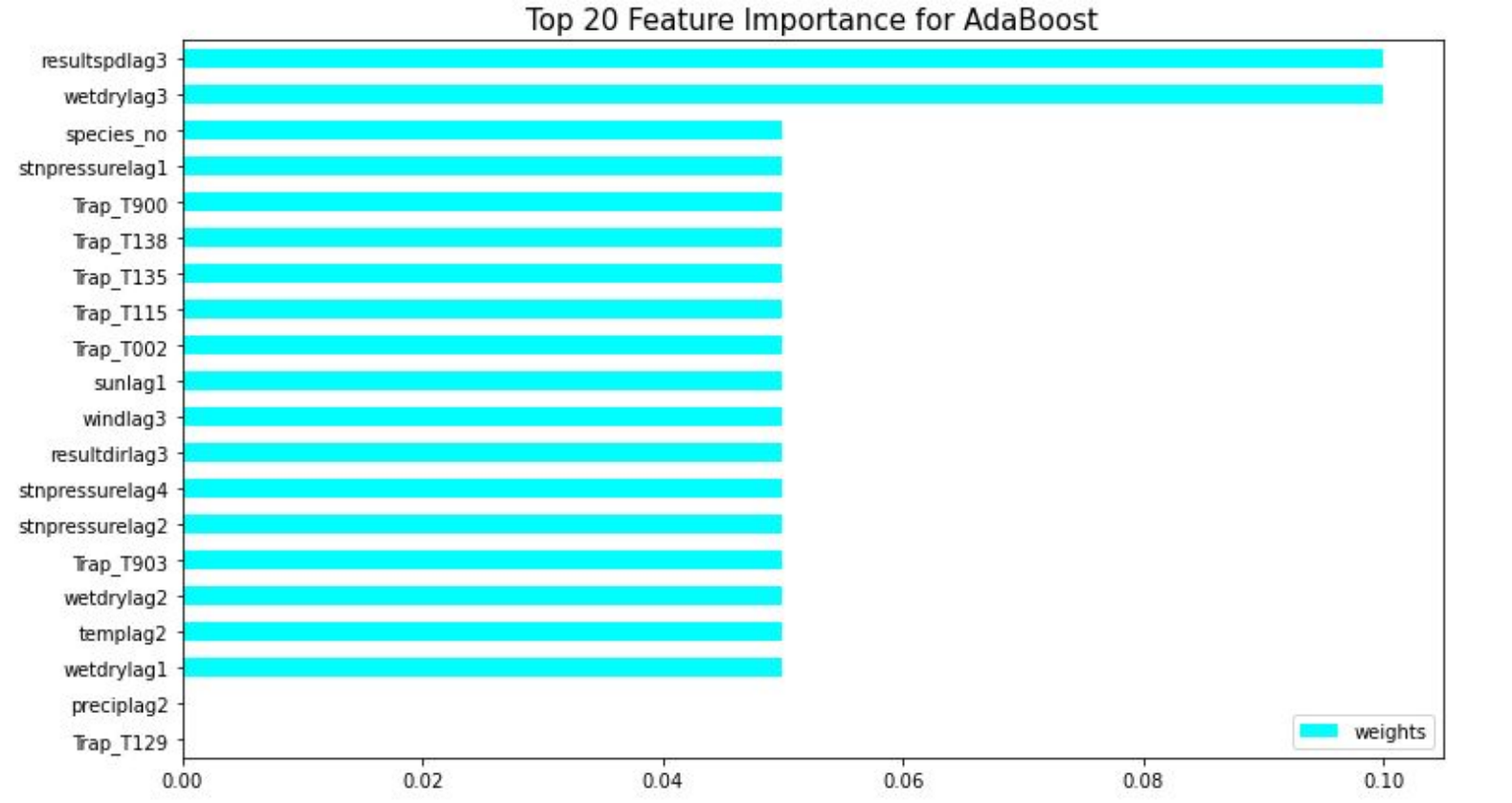
- Heavily imbalanced data in training set.
- Baseline prediction: 95% Wnv Not Present.
- Optimize AUC score instead of accuracy.
- Adopt over-sampling technique such as SMOTE.



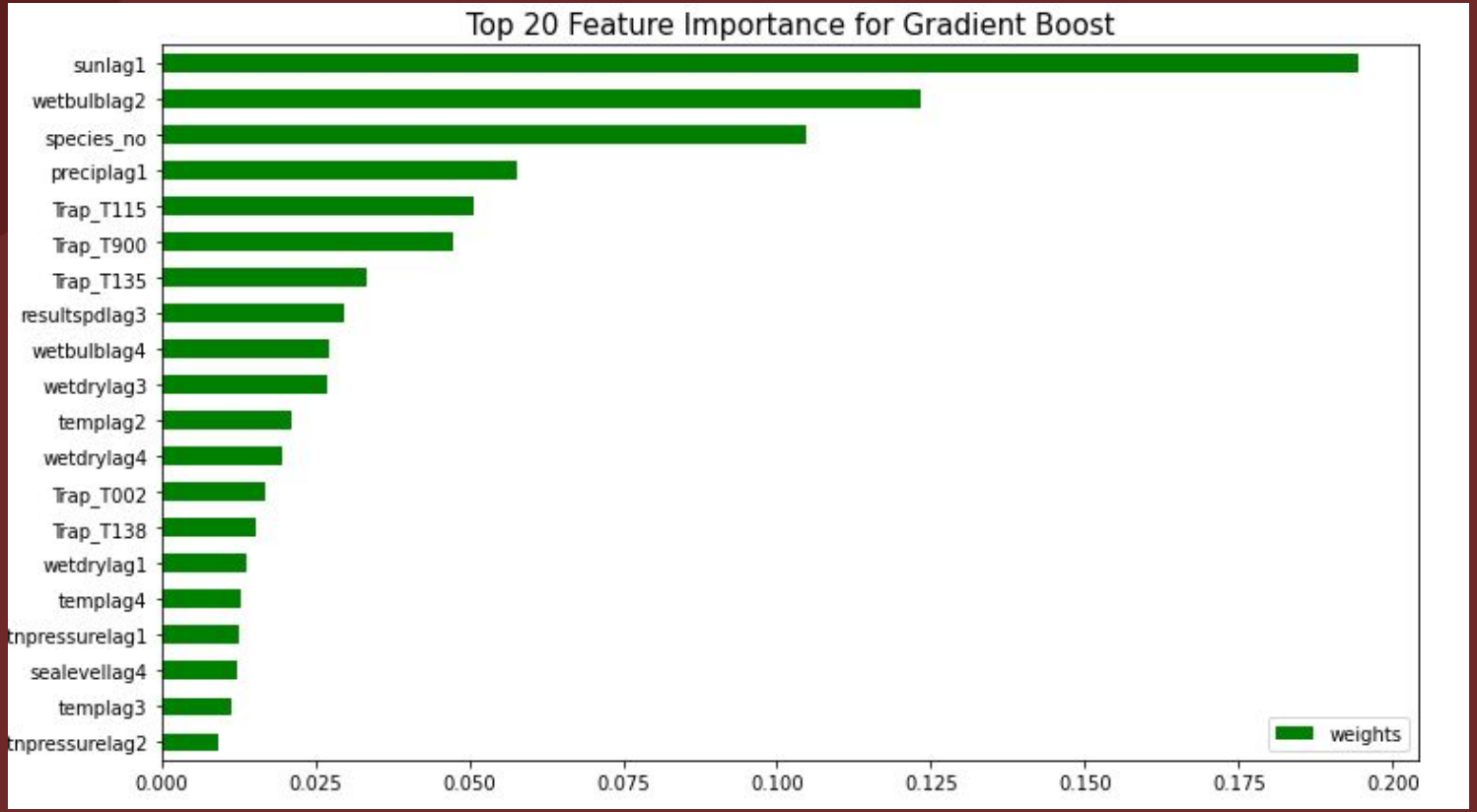
# MODELLING


Logistic Regression
Naive Bayes
Random Forest
Support Vector
Adaptive Boost
ExtraTrees
Gradient Boosting
Neural Network

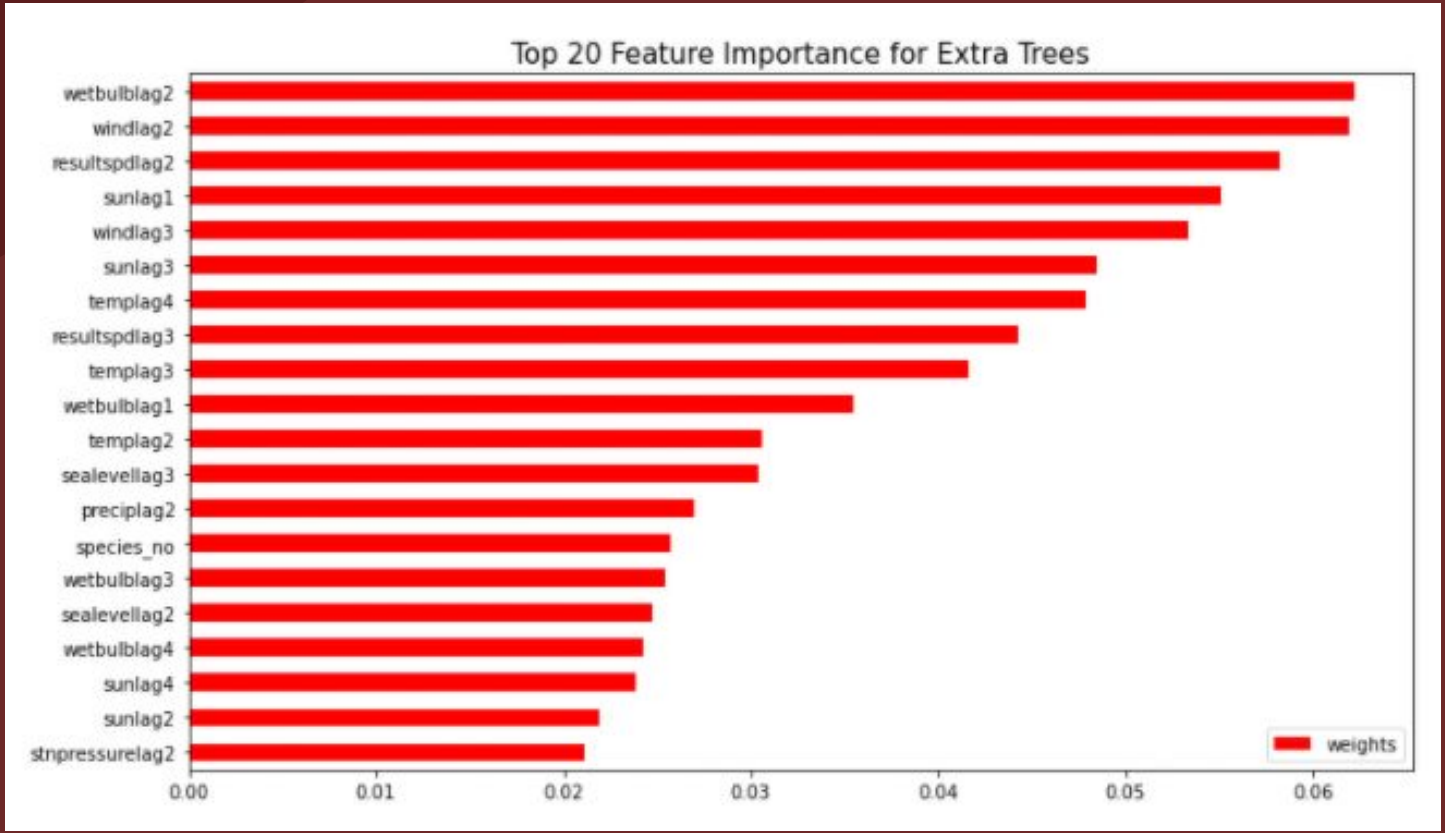
# FEATURE IMPORTANCE: ADABOOST



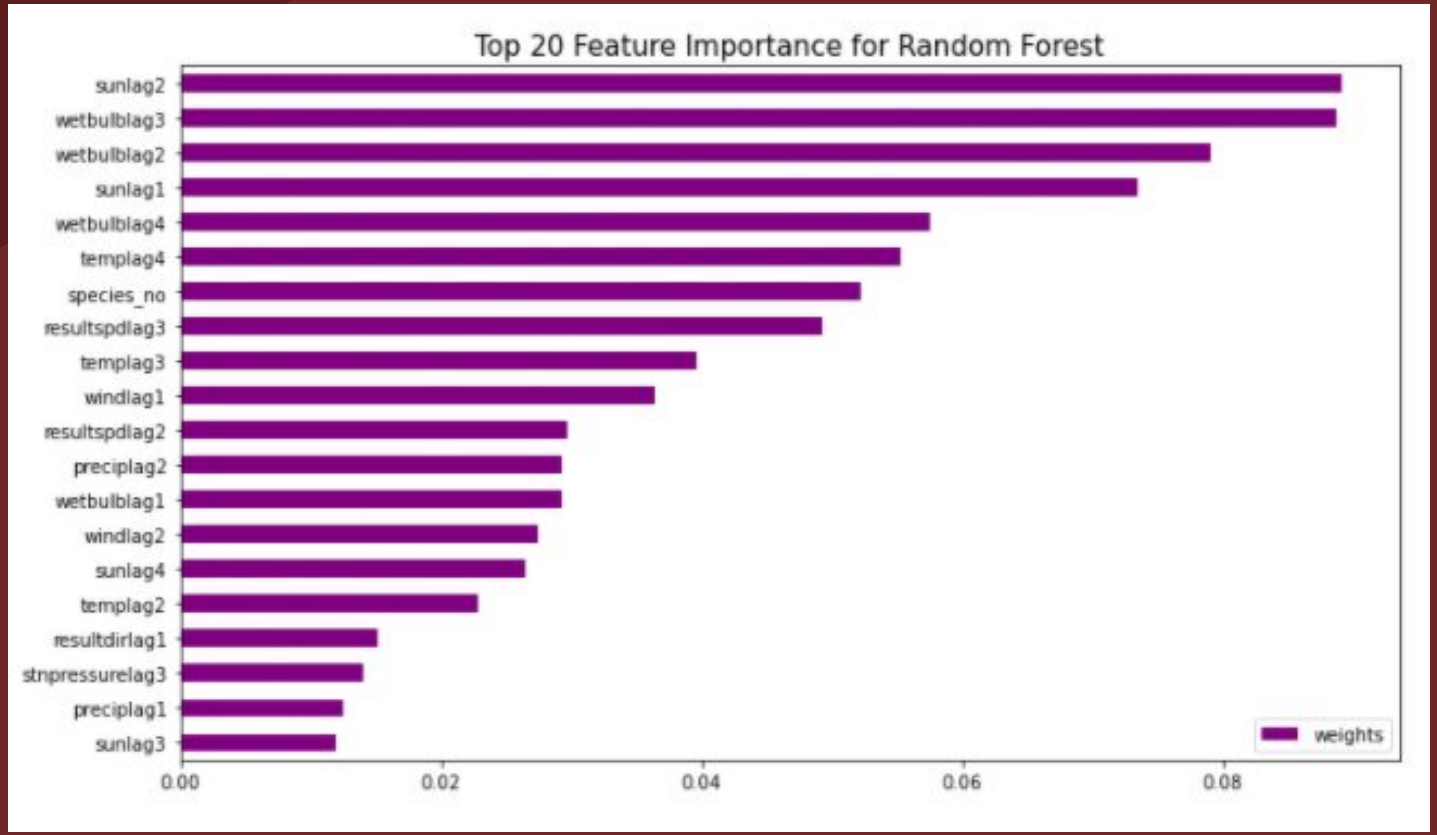
# FEATURE IMPORTANCE: GRADIENT BOOSTING



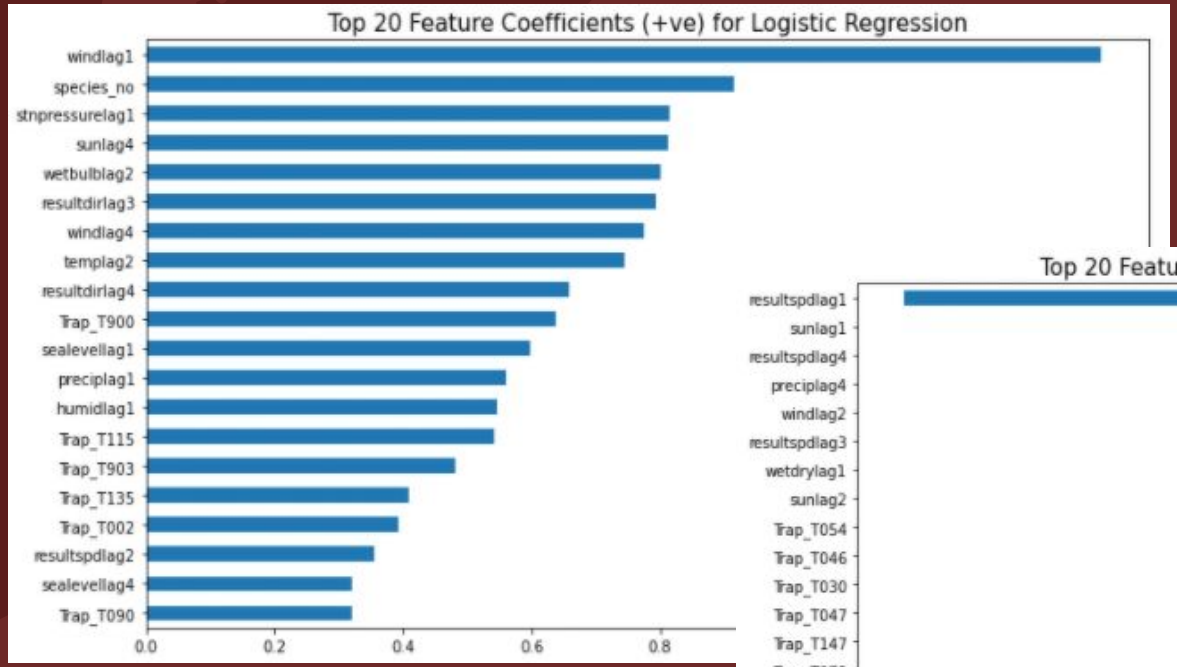
# FEATURE IMPORTANCE: EXTRA TREES

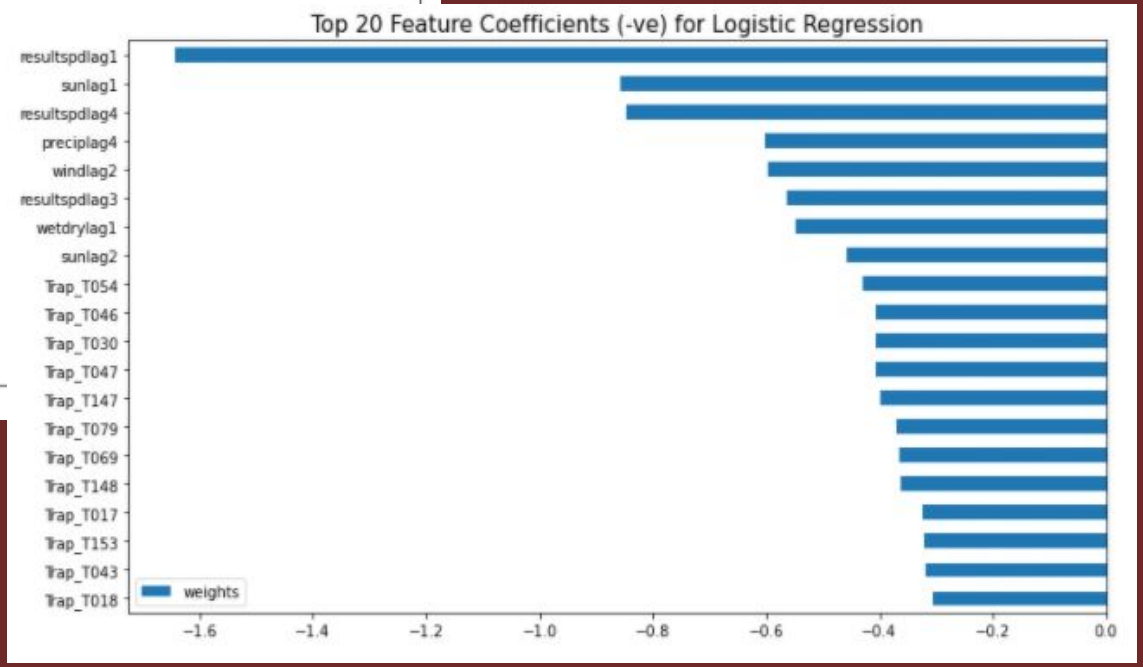


# FEATURE IMPORTANCE: RANDOM FOREST



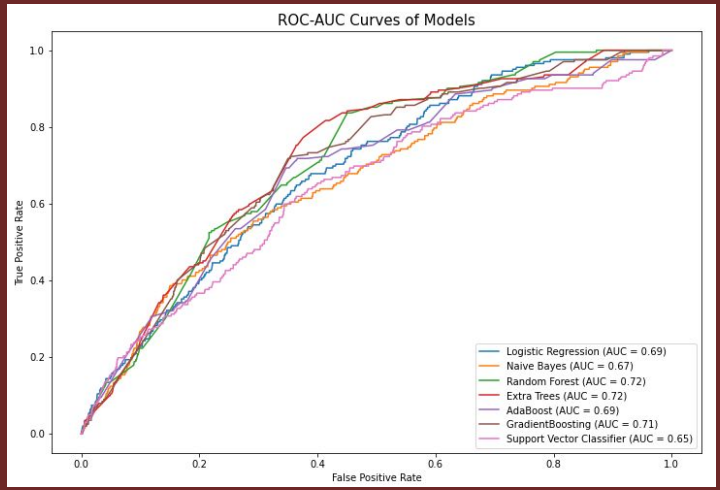
# FEATURE IMPORTANCE: LOGISTIC REGRESSION



# MODEL SELECTION

| Model Type | Train AUC | Test AUC | F1-Score | Recall | Precision |
|---|---|---|---|---|---|
| AdaBoost | 0.768642 | 0.584945 | 0.555765 | 0.584945 | 0.550529 |
| Logistic Regression | 0.832545 | 0.584520 | 0.556905 | 0.584520 | 0.551264 |
| Support Vector Classifier | 0.860891 | 0.574051 | 0.572417 | 0.574051 | 0.570921 |
| GradientBoosting | 0.676681 | 0.520733 | 0.520463 | 0.520733 | 0.582550 |
| Random Forest | 0.752317 | 0.508107 | 0.493737 | 0.508107 | 0.635600 |
| Extra Trees | 0.755211 | 0.501450 | 0.479825 | 0.501450 | 0.553212 |
| Naive Bayes | 0.749913 | 0.500000 | 0.475390 | 0.500000 | 0.453089 |




## AdaBoost Model

- Highest Test AUC score.
- Highest Recall score.
- Lowest number of False Negatives.
- Some overfitting, but acceptable.

| | Predicted Negative | Predicted Positive |
|---|---|---|
| Actual Negative | 0.76 | 0.14 |
| Actual Positive | 0.06 | 0.03 |

Normalized Confusion Matrix – Positive = Wnv Present

# ADDITIONAL MODEL: NEURAL NETWORK

Model: "sequential"

| Layer (type) | Output Shape | Param # |
|---|---|---|
| dense (Dense) | (None, 182) | 33306 |
| dropout (Dropout) | (None, 182) | 0 |
| dense_1 (Dense) | (None, 128) | 23424 |
| dropout_1 (Dropout) | (None, 128) | 0 |
| dense_2 (Dense) | (None, 64) | 8256 |
| dropout_2 (Dropout) | (None, 64) | 0 |
| dense_3 (Dense) | (None, 32) | 2080 |
| dropout_3 (Dropout) | (None, 32) | 0 |
| dense_4 (Dense) | (None, 16) | 528 |
| dense_5 (Dense) | (None, 1) | 17 |

Total params: 67,611
Trainable params: 67,611
Non-trainable params: 0

Neural Network Summary

```
Results for NN Model
------------------------
AUC: 0.5386
F1-Score: 0.1593
Recall: 0.1337
Precision: 0.1971
```

- Lower Test AUC score compared to AdaBoost.
- Low complexity neural network.
- Not easily interpretable.

# COST-BENEFIT ANALYSIS

| | City Level Spraying | Targeted Spraying |
|---|---|---|
| Direct Cost ($0.92/acre)<br>- Spray(truck/backpack) | $1,653,467.04 | $145,060.68 |
| Indirect Cost:<br>- Hospitalization cost<br>- Loss of production cost | - | $459,617.33<br>(using yr 2020 as a benchmark due to falsely predicted negative) |
| Benefits | $604,678.01<br>(If the control of mosquito is done regularly on a city level spraying, the chances of a west nile virus case is effectively 0. The amount saved from both the indirect and direct costs associated if we were to use the targeted spray can be used to fund the city level spraying) | $1,048,789.03<br>(amount saved from excessive spraying which could be used to increase catch basins and maintenance of them, leading to increase in data for better analysis to increase accuracy and decrease west nile virus cases efficiently) |
| Benefit-cost ratio | 0.37 | 1.73 |

# CONCLUSIONS & RECOMMENDATIONS

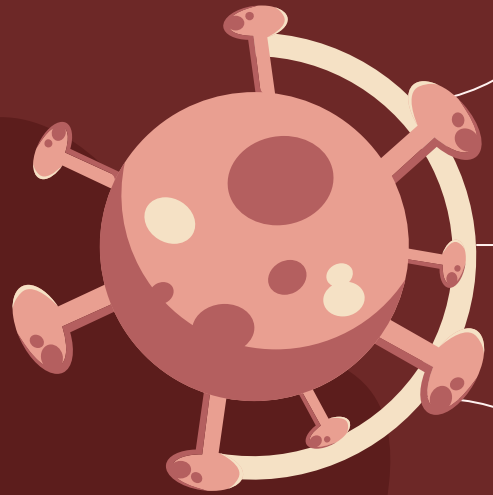
Important features:

- Mosquito species - some species are more competent vectors of Wnv
- Duration of the day - longer the Sun is out, the lower the mosquito activity
- Temperature - lower the temperature, lower the mosquito activity
- Wind - higher the wind speed, lower the mosquito activity
- Humidity - lower the humidity, lower the mosquito activity

## Do

1. Use insect repellent that contains DEET, Picaridin, IR3535 or Oil of Lemon Eucalyptus
2. Eliminate stagnant water
3. Wear long pants, long-sleeved shirts at night

# MOVING FORWARD



01

## Demographics

Human demographics within the area affects probability of Wnv.

02

## Geography

Landscapes affect the mosquitoes' livelihoods and activity.

03

## Mosquito Species

Study other species such as Culex Tarsalis / Quinquefasciatus that could possibly spread the virus.

# THANKS

Do you have any questions?

# Sources


1) Prevention Measures - [https://www.chicago.gov/city/en/depts/cdph/provdrs/health_protection_and_response/news/2020/july/cdph-conducts-a-comprehensive-mosquito-surveillance-and-control.html]
2) Life Cycle of Mosquitoes - [https://www.mosquito.org/page/lifecycle]
3) Mosquito Treatment Duration - [https://www.callnorthwest.com/2019/05/how-long-does-a-mosquito-treatment-last/]
4) Mosquito Spray Information - [https://www.montcopa.org/DocumentCenter/View/8932/FAQMosquitoSpraying?bidId=]
5) Calculation for Sunrise/Sunset for Station two - [https://stackoverflow.com/questions/38986527/sunrise-and-sunset-time-in-python/38986561)]
6) Daylight Savings For Calculations - [(https://www.timeanddate.com/time/zone/usa/chicago)]