# Prediction of West Nile Positive Mosquito Pools with Pollution Incorporation

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**Abstract**

West Nile Virus is a significant issue in much of the world and this disease is primarily transmitted through Culex Mosquitoes. Many people are uninformed on how pollution affects mosquito density and outbreak likelihood in a region. Our group sought to study how air pollution and air temperature affect mosquito density and inform the public of mosquito prediction based on these two variables. Our proposed method is to construct a prediction model that relies on pollution data to predict the density of West Nile Vectors, specifically Culex Mosquitoes. We aim to understand how pollution affects mosquito density and focus on how we can inform the public on vector density based on pollution data. Our goals are to accurately predict the density of West Nile Vectors based on temperature and air quality levels and temperature. We will focus our research on Dallas County, Texas and utilize Air Quality Index Data from the Environmental Protection Agency (EPA) and Arbovirus Weekly Activity Reports From Texas Department of State Health Services.

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## Introduction and Background

Pollutants produced by human activity have both significantly altered the ecosystems and environmental conditions that mosquitoes live, develop, and reproduce in. These changing environmental factors due to pollution (especially increasing temperature and air pollution) not only pose a serious threat to humans, but they can potentially have profound effects on the transmission of disease via mosquitos.

In our project, we aim to evaluate the correlation between mosquito density and various environmental factors that are changing due to pollution. Specifically, we investigate the effect of air pollution and air temperature on mosquito vector density and how this can impact the health of the general public. Furthermore, we also consider how these various environmental factors would change over time, particularly due to climate change, and develop a predictive model to forecast these changes in mosquito populations based on our research.

## Changing Environmental Conditions

When deciding on which environmental factors to evaluate in relation to mosquito populations, we selected air quality, air temperature, and water quality as our factors of interest. There were two key considerations as we selected these particular factors to evaluate in relation to mosquito populations. Firstly, these factors are of particular interest to us because they are forecasted to continue to change with human-produced pollution. Secondly, we selected these particular environmental factors based on prior research conducted on the biological effects of these factors on mosquitoes.

## Air Pollution

Air pollution, which can stem from a variety of sources, not only poses a serious threat to human livelihood, but potentially to mosquitoes' ability to transmit diseases. Air pollution can stem from natural air pollution. This includes geothermal sources, land emission, and plants. Air pollution can also stem from industrial plants and human-caused emissions. Metal pollution is a global issue that has been increasing in recent years. Traffic also contributes to metal emissions releasing Pb, Cd, and Zn. These and other industrial human activities continue to introduce harmful substances into the atmosphere. (Abdullah Aksu, 2015). All these factors contribute to air pollution and are measured using the U.S Air Quality Index (AQI). This is an index used by the environmental protection agency (EPA) that ranges from 0 to 500. The larger the AQI means there is increased air pollution which causes a greater health concern. Generally, if the Air Quality Index is below 50 this represents good air quality in a region. However, if AQI is greater than 300, air quality is expected to be hazardous. AQI is divided into six different groups. If the AQI is 0-50 air quality is deemed good. An AQI of 51-100 is deemed moderate. An AQI of 101-150 is unhealthy for sensitive groups. An AQI level of 151-200 is deemed unhealthy and an AQI level of 201-300 is very unhealthy. We aim to further investigate the effect of air pollution on mosquito vector density and aim to further investigate how this can impact the public health of the general public.

## Previous Instances of the Influence of Pollutants on Mosquitoes

Human industrial activity has led to an extensive increase in various environmental pollutants that causes aquatic mosquito breeding grounds in South Africa to be contaminated by heavy metal toxins. The scientists found that the presence of toxins in breeding grounds allowed the mosquito larvae to develop an adaptation to water pollution that resulted in increased tolerance to pesticides. The research showed that this tolerance increases the range of malaria-transmitting mosquitoes to areas where they didn’t normally live, expanding their habitat scope and creating a potential public health hazard. (Shüné V. Oliver et al., 2018). Metal exposure is one of the most common pollutants mosquito larvae are exposed to in both urban and agricultural settings. When Anopheles mosquitoes are exposed to heavy metal and air pollution as larvae, they may experience increased resistance to insecticides as adults. This is dangerous for disease control and threatens South Africa’s malaria elimination agenda. Mosquitoes are increasingly becoming resistant to the insecticides used to kill them because of air pollution exposure as larvae. This study looked at regions across Africa that used insecticides in agricultural regions. This insecticide exposure as larvae contributed to the selection of resistance among mosquitoes. In fact, in Benin Anopheles gambiae mosquitoes actually lay eggs in breeding sites near agricultural settings in order for the mosquitoes to gain insecticide resistance. (Theresia Estomih Nkya et al., 2013)

**Insecticide Resistance**

Insecticide resistance is often developed through adaptation and isa result of selective pressure because of insecticides used for vector control. This can be due to mutations to the protein in mosquitoes targeted by insecticides (Hemingway et al., 2000) , less penetration, or biodegradation of insecticides. (Hemingway et al., 2004). In addition, all these resistance methods can happen simultaneously which enables mosquitoes to be resistant to more than one insecticide. Pytheriods are chemicals used in insecticides that are used to kill insects, including mosquitoes. These insecticides can be extremely helpful in reducing the spread of diseases carried by mosquito vectors, such as West Nile Virus. Target-Site mutations are one way mosquitoes can build resistance to pyrethroid insecticides and this involves non-synonymous mutations of the gene encoding the para-type voltage-gated sodium channel (VGSC) expressed in the insect central nervous system targeted by pyrethroids (Soderlund, 2008). Another restuiance method is enhanced insecticide detoxification. This metabolic resistance involves regulation of the mosquito detoxification system to counteract the chemical aggression caused by insecticides. (Nkya et al., 2008). The last method of resistance by mosquitoes is cuticular resistance and this is characterized by a modification of the insect cuticle leading to a slower penetration of the insecticide reducing the amount of insecticide molecules within the insect. (Ahmad et al., 2006; Gunning et al., 1995). Due to the extensive resistance methods mosquitoes developed due to air pollution exposure as larvae we want to explore the relationship between air pollution levels in a region and the effect air pollution has on mosquito density.

## Water Pollution

Prior research has suggested a relationship between water pollution, particularly heavy metal pollution, and mosquito insecticide resistance. Human industrial activity in South Africa has led to the contamination of aquatic mosquitos with heavy metal toxins. Prior research has found that the presence of toxins in breeding grounds allowed the mosquito larvae to develop an adaptation to water pollution that resulted in increased tolerance to pesticides. The research showed that this tolerance increases the range of malaria-transmitting mosquitoes to areas where they didn’t normally live, expanding their habitat scope and creating a potential public health hazard. (Shüné V. Oliver et. al 2018). Metal exposure is one of the most common pollutants mosquito larvae are exposed to in both urban and agricultural settings. When Anopheles mosquitoes are exposed to heavy metal pollution as larvae, they may experience increased resistance to insecticides as adults. This allows for the expanded range of mosquitos

## Changing Climate and Global Warming

The air quality index is not the only measure of human-induced pollution. Global warming is the long term heating of earth due to human industrial activities such as fossil fuel burning. Climate change is a long term change in average weather patterns in regional climates. This is also primarily driven by human industrial activities but can also be influenced by natural processes like ocean patterns, sun energy output, and volcanic activity. (Nasa.gov). In many regions warming has increased 1.5 degrees Celsius above pre-industrial levels. About 20% of the world lives in a region that has seen this drastic increase in one season. Most land regions will see more hot days, especially in the tropics.At Earth's mid-latitudes, the hottest days will be up to 3 degrees Celsius (5.4 degrees Fahrenheit) hotter at 1.5 degrees Celsius warming and up to 4 degrees Celsius (7.2 degrees Fahrenheit) warmer at 2 degrees Celsius warming. (Buis, 2019). Coldest nights are also predicted to be 4.5 degrees Celsius warmer. Climate change is most commonly measured using the average surface temperature of the planet but temperature and climate changes can be seen at different degrees across the world. We will use temperature change over time as an additional measure of human-induced pollution.

## The Effect of Temperature on Mosquitoes

Temperature is a significant factor affecting insect vectors and their transmitted pathogens. In the past 30 years mosquito transmitted diseases and viruses have significantly expanded. Their distribution range has increased alongside frequent and lengthy epidemics.  (Gubler, 1996, 2002b; Mayer et al., 2017). Mosquito borne viruses account for millions of human cases and a significant number of human deaths. Mosquito borne viruses are arboviruses which are usually transmitted from hosts that are vertebrae, such as birds, to vectors, such as mosquitoes. In their vertebrate host, arboviruses replicate at temperatures ranging from 37°C up to 44°C (Kinney et al., 2006). Temperature can influence molecular changes that impact protein structures and other functions within the mosquito. (Pain, 1987). The temperature of a region is often a determining factor in the range of different organisms. The ability of a virus to spread increases as temperature increases (Kramer et al., 2015). Lower temperature is less beneficial for mosquito-borne viruses. Temperature can influence viron properties and their interactions with other cellular components during replication of the virus. Temperature also has a significant effect on the hatching time and viability of mosquito eggs-this phenomenon varies across mosquito species. Mosquito-borne diseases are generally very prevalent in tropical regions but in recent years there has been an influx of mosquito-borne diseases in temperate regions due to increases in the average surface temperature of the earth. (Bellone et al., 2020). The effect of temperature on Anopheles mosquitoes was studied and they are sensitive to temperature changes. Each mosquito life stage as well as the blood meal egg laying cycle (gonotrophic cycle) is dependent on temperature but dependencies are not consistent throughout stages in these cycles. Their model predicts that mosquito populations (defined as a population size larger than one) will persist from temperatures ranging from 17 to 33 degrees celsius. Adult mosquito abundance is significantly influenced by temperature as populations were only able to persist at the same temperatures that are suitable for juvenile mosquitoes despite predicted survival range being much larger. (Beck-Johnson et al., 2013). The world climate is currently in a warming phase. Models of the potential impact of increased greenhouse gasses in the earth's atmosphere predict that global warming will have the most impact near the poles and this in turn would change weather patterns such as wind and humidity which can influence biological systems and organism functions. In tropics higher temperatures are predicted to raise the maximum altitude for malaria transmission and cause a resurgence of the disease in major cities. (Reiter, 2001). Climate factors also impact the survival and transmission rate of mosquito borne viruses and pathogens. Specifically, temperature affects the rate of multiplication of pathogens within the mosquito. We will use temperature as a measurement of pollution due to increased emission because of recent human industrialization. Temperature not only has an effect on mosquito density and abundance but regional temperatures can also affect virus transmission rate and effectiveness. Temperature change over time due to global warming can also influence other environmental factors such as humidity which impact the abundance of mosquitoes.

## West Nile Virus History

We want to focus our correlation models on air quality index and temperatures effect on mosquito density on West Nile Mosquito Vectors. West Nile virus is a mosquito-borne flavivirus. This virus is indigenous to Africa, Europe, Asia, and Australia. Birds are the natural host of West Nile Virus and the virus is present in nature in a mosquito-bird-mosquito transmission cycle. The primary vector of this virus is the Culex mosquito. Despite not being native to North America, it was introduced to that region in 1999 first recorded in New York City. (DrGrant LCampbell 2002). In 2002, West Nile Virus caused the largest arboviral meningoencephalitis outbreak ever recorded in North America. (Lyle R. Petersen, 2003). Currently, there is no specific treatment or vaccine available for West Nile Virus. Since the virus was detected in the United States in 1999, 16,706 cases have been reported to the Centers for Disease Control and Prevention (CDC) and the virus has since spread to the rest of the country. West Nile Virus is seasonal in the temperate regions of North America, Europe, and the Mediterranean Basin. Peak Season in temperate climates is from July through October. In the United States, all ages are susceptible to West Nile Virus but rates of mortality due to the disease seem to increase with age. (Edward B. Hayes, 2005). Mosquito Vectors of West Nile Virus are most abundant during dusk to dawn. Currently, the main method of reducing West Nile Virus in humans is to prevent human contact with mosquitoes. West Nile Virus is likely to continue to be a public health concern in the foreseeable future and working to inform the public on the health risks is one of our goals.

## Culex Mosquitoes as Vectors of West Nile Virus

Culex mosquitoes are the primary vectors of West Nile Virus. This group of over 1000 mosquito species, distributed across the world, is the main vector for the West Nile Virus. Culex larvae are identifiable due to their distinctive egg-laying pattern. The female Culex mosquito's eggs form a floating raft of 100 to 300, floating on the surface of the water. West Nile Virus is now a common occurrence in temperate and tropical climates of the United States and Culex pipiens are implicated as the primary vectors for the disease within the U.S. Culex mosquitoes are also responsible for transmission of West Nile Virus amond bird hosts. (Marra et al. 2004). Culex pipiens mosquitoes are thought to serve as enzootic and epidemic vectors. (Apperson et al. 2004). Culex genus mosquitoes are thought to be responsible for over 80% of human cases involving West Nile Virus in the northeastern United States. (Kilpatrick et al. 2005).

## West Nile Virus in Texas

West Nile Virus is now a common occurrence in temperate and tropical climates of the United States and Culex genus mosquitos are implicated as the primary vectors for the disease. In our study, we focus our research in the county of Dallas, Texas. West Nile Virus emerged in Texas in 2002 and since then has been detected yearly in the state. The largest case of West Nile Virus outbreak occurred in Texas in 2012 and this disease remains a significant public health concern for the region (Diana Martinez et al. 2017).

## Methodology and Materials

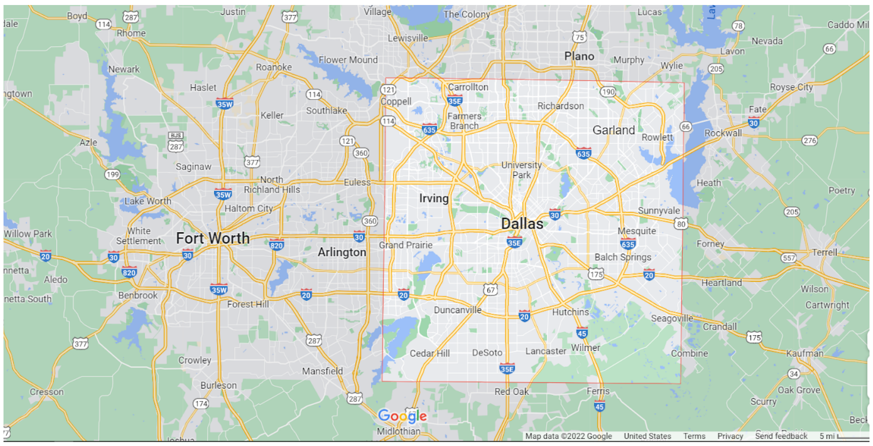
We aim to understand the relationship between environmental factors (specifically air quality, air temperature) and abundance of West Nile Vectors in Dallas County, Texas. We will use data on mosquitoes in Dallas, Texas that test positive for West Nile Virus. We will use data from Texas's Department of State Health Services Arbovirus Weekly Reports. We will compare the number of mosquitoes per year that carry West Nile Virus to levels of air pollution that year. We will use Air Quality Index Data from Dallas County, Texas using the United States Environmental Protection Agency's (EPA) Air Quality Index Report. We will then compare the number of mosquitoes per year using the same Arbovirus Weekly reports to average yearly temperature reports from the National Weather Service.

Using our collected data we aim to use linear and exponential regression to fit our data and create a predictive equation to estimate the amount of West Nile Positive Mosquito Pools in Dallas County, Texas using average monthly temperature and Air Quality Index monthly data.

## Study Site

We will be focusing our study on Dallas County, Texas in the United States. Dallas county is located in North Central Texas, approximately 250 miles North of the Gulf of Mexico. Dallas

County's climate is humid and subtropical with hot summers and mild winters. There is a wide range of temperatures annually. There is also a wide range in annual precipitation ranging from around 20 inches to over 50 inches. The "warm season" in Dallas (Characterized by a freeze-free period) lasts about 249 days on average. In Dallas County there are 558 total gauges of water recorded.



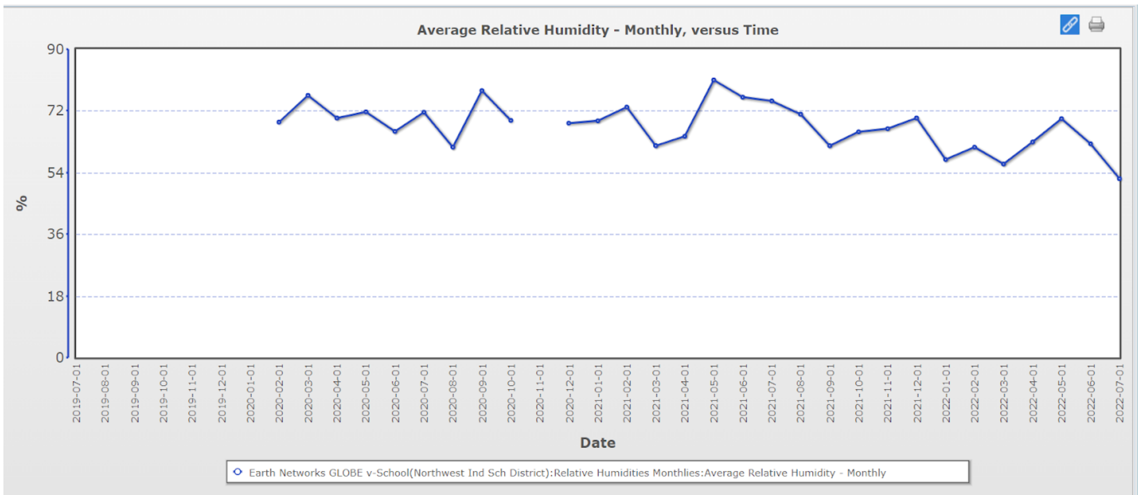

Source: Google Maps

## GLOBE Data Incorporation

Using GLOBE data from the Northwest Independent School District in Dallas County we were able to look at other climate factors in our area of interest. Although for our prediction model we only focused on temperature and air quality, this GLOBE data was extremely helpful for understanding the precipitation, humidity, and other environmental factors in the Dallas area.

## Average Relative Humidity

Relative humidity measures water vapor relative to the temperature of the air. Average humidity in Dallas County was collected at the Northwest Independent School District Study Site once a month starting February 1st of 2020 and the last data collection was July 1st in 2022.

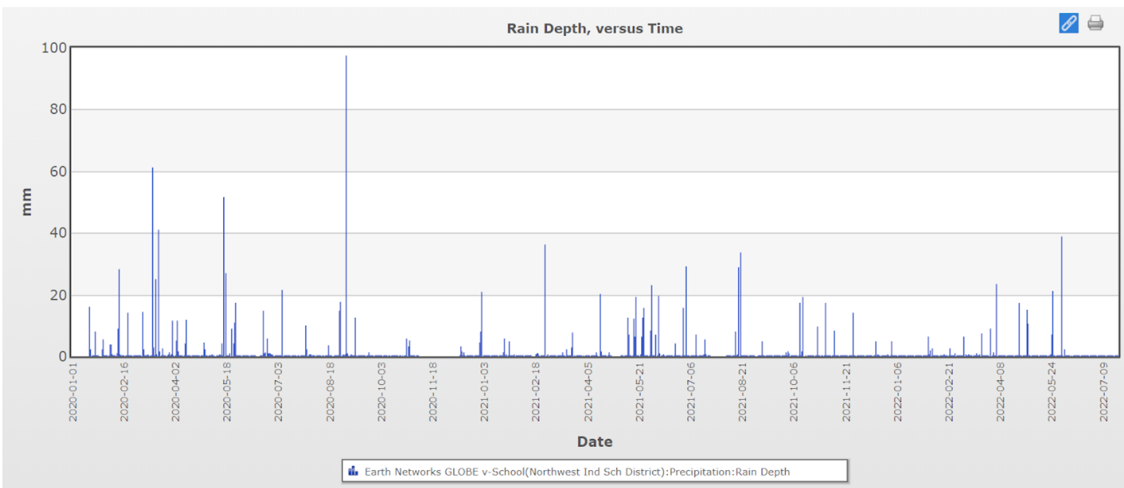



Source: GLOBE Visualization Page depicting average relative humidity over time

The Average relative humidity of this study site has been above 52.2% over the past two years reaching a peak in May of 2021 with a monthly average humidity of 81%. Statistical analysis shows a significant moderate positive relationship between monthly relative humidity and number of sampled *Cx. pipiens* and *Ae*, *detritus.* (Katerina Drakou et al. 2020). We want to acknowledge the correlation between Culex pipiens abundance and humidity and recognize that humidity levels could possibly influence the amount of sampled West Nile Virus positive mosquito pools. However, we are looking at the effect of pollution on positive mosquito pools so we feel that our prediction models would be more accurate regarding the effect of pollution without the incorporation of humidity data.

## Precipitation Occurrence and Rain Depth

Collecting data from the Northwest Independent School District Study Site, we also wanted to look at recipiation in Dallas County over time and the possible effects on West Nile positive mosquito pools. Data collection for occurrence of precipitation at this study site started in January of 2020 with 13 measurements recorded and the most recent data was collected in July of 2022 with 22 measurements recorded. Over the last two years the number of monthly measurements range from 5 in November of 2020 to 31 in January of 2021.




Source: GLOBE Visualization page depicting Rain Depth over time

The highest instance of rain depth was in September of 2020 with a recorded measurement of 97.3 mm. There have been many months over the past 2 years with a rain depth measurement of 0 mm. Throughout the graph we see a trend of slight decline in rain depth from 2020 to 2022.

In Northeastern Illinois precipitation was found to have a significant impact on the timing and location of increased mosquito infection. In fact, lower precipitation was the most important variable predicting stronger mosquito infection. ( Marilyn O Ruiz et al. 2010). We acknowledge that precipitation is another factor that may have an effect on the amount of positive West Nile mosquito pools in Dallas County. However, once again, we feel precipitation over 2 years does not do an effective job and shows the effect of pollution over time and because of this we feel the need to exclude precipitation from our prediction model.

## Temperature: Results and Analysis

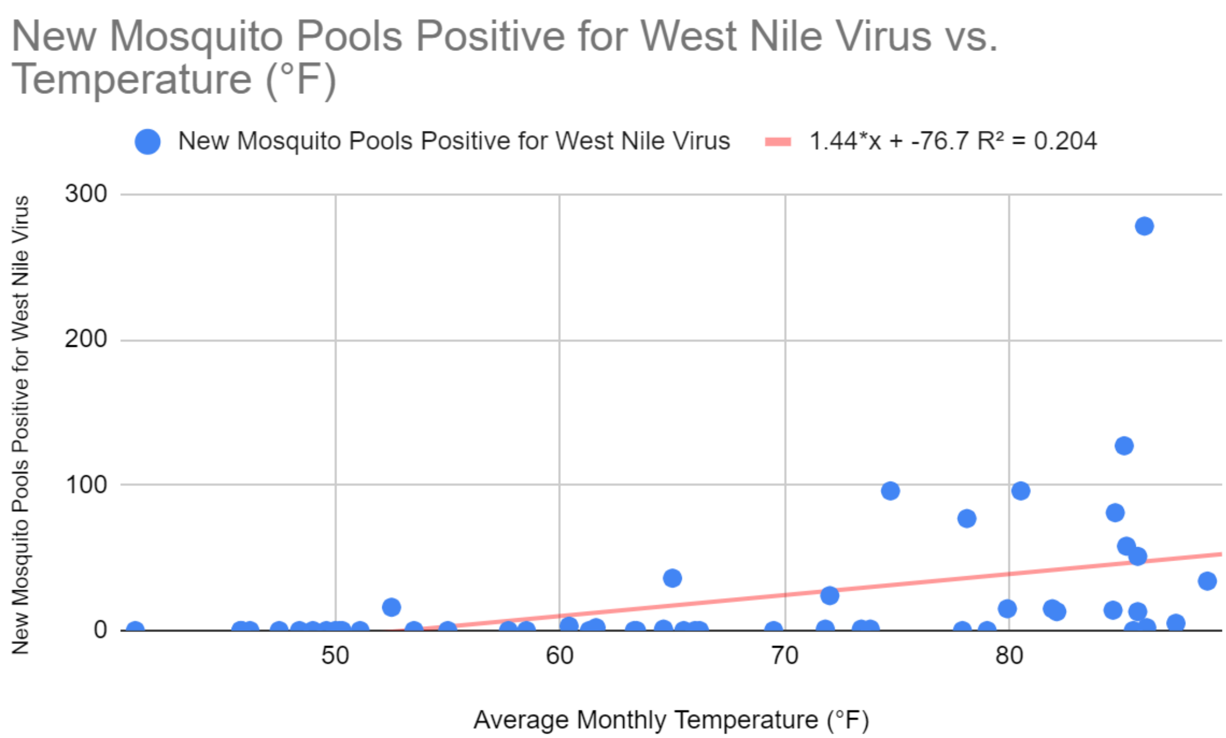
The following table displays temperature and the number of new mosquito pools that tested positive for West Nile Virus in Dallas County over time.

| Date (Month, Year) | Average Monthly Temperature (°F) | New Mosquito Pools Positive for West Nile Virus | Date (Month, Year) | Average Monthly Temperature (°F) | New Mosquito Pools Positive for West Nile Virus |
|---|---|---|---|---|---|
| January, 2018 | 45.8 | 0 | April, 2020 | 64.6 | 1 |
| February, 2018 | 51.1 | 0 | May, 2020 | 73.8 | 1 |
| March, 2018 | 63.3 | 0 | June, 2020 | 81.9 | 15 |
| April, 2018 | 61.6 | 2 | July, 2020 | 85.7 | 51 |
| May, 2018 | 79 | 0 | August, 2020 | 86 | 278 |
| June, 2018 | 85.7 | 13 | September, 2020 | 74.7 | 96 |
| July, 2018 | 88.8 | 34 | October ,2020 | 65 | 36 |
| August, 2018 | 85.2 | 58 | November, 2020 | 60.4 | 3 |
| September, 2018 | 78.1 | 77 | December, 2020 | 49 | 0 |
| October ,2018 | 66.2 | 0 | January, 2021 | 47.5 | 0 |
| November, 2018 | 52.5 | 16 | February, 2021 | 41.1 | 0 |
| December, 2018 | 48.4 | 0 | March, 2021 | 61.4 | 0 |
| January, 2019 | 45.8 | 0 | April, 2021 | 64.6 | 0 |
| February, 2019 | 50.2 | 0 | May, 2021 | 71.8 | 1 |
| March, 2019 | 55 | 0 | June, 2021 | 82.1 | 13 |
| April, 2019 | 66 | 0 | July, 2021 | 84.7 | 81 |
| May, 2019 | 73.4 | 1 | August, 2021 | 85.1 | 127 |
| June, 2019 | 79.9 | 15 | September, 2021 | 80.5 | 96 |
| July, 2019 | 84.6 | 14 | October ,2021 | 72 | 24 |
| August, 2019 | 87.4 | 5 | November, 2021 | 57.7 | 0 |
| September, 2019 | 85.5 | 0 | December, 2021 | 61.3 | 0 |
| October ,2019 | 65.5 | 0 | January, 2022 | 45.8 | 0 |
| November, 2019 | 53.5 | 0 | February, 2022 | 46.2 | 0 |
| December, 2019 | 50 | 0 | March, 2022 | 58.5 | 0 |
| January, 2020 | 50.3 | 0 | April, 2022 | 69.5 | 0 |

| | | | | | |
|---|---|---|---|---|---|
| February, 2020 | 49.6 | 0 | May, 2022 | 77.9 | 0 |
| March, 2020 | 63.4 | 0 | June, 2022 | 86.1 | 2 |

We propose two possible methods of fitting the data for prediction. We can fit using linear regression which mainly takes into account the large amount of data points with a low number of positive mosquito pools.

**Linear Regression Model**




Source: Google Sheets

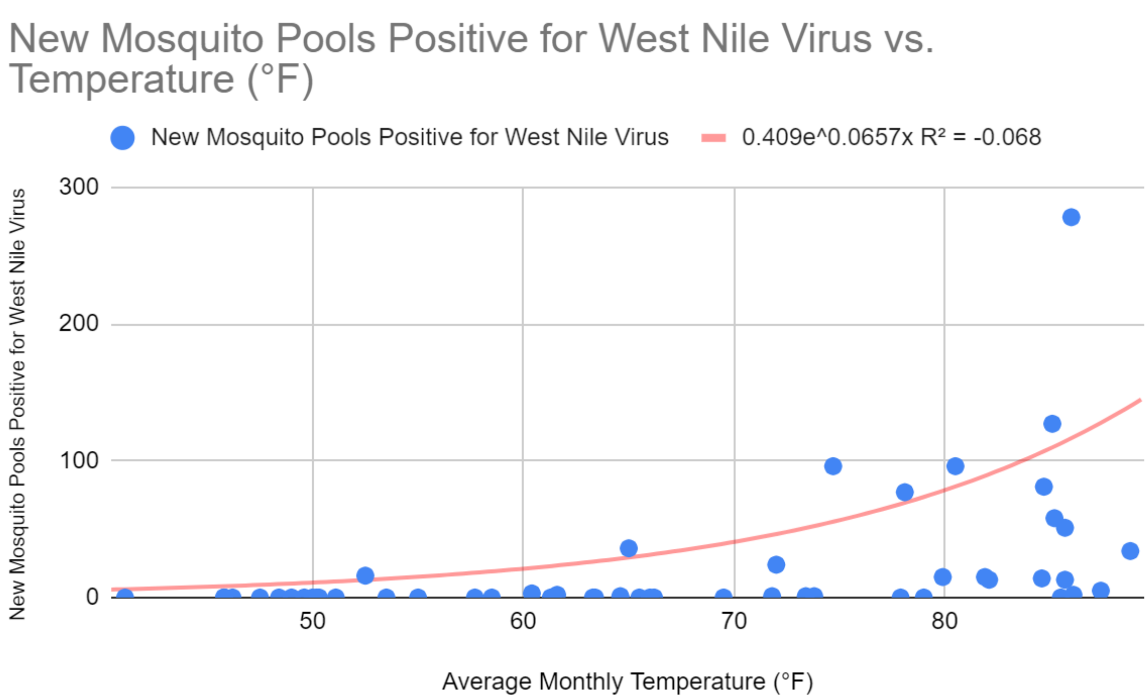
We calculated our correlation coefficient (R) to be about .451664. This indicates a moderate positive correlation between the average monthly temperature in Dallas County, Texas and the number of new mosquito pools that tested positive for West Nile Virus in Dallas County.

Using our data inputs we are able to predict the number of new positive mosquito pools with West Nile Virus using average monthly temperature. The following equation represents our linear regression model and can be used for prediction of the amount of positive West Nile Virus mosquito pools in Dallas County.

| | |
|---|---|
| Predicted West Nile Virus Positive Mosquito Pools in Dallas County | = -76.7 + (1.44) * (Average Monthly Temperature in Dallas County) |

**Exponential Fitting Model**

We also propose an exponential fitting method for the data that takes into account the pattern of the data.

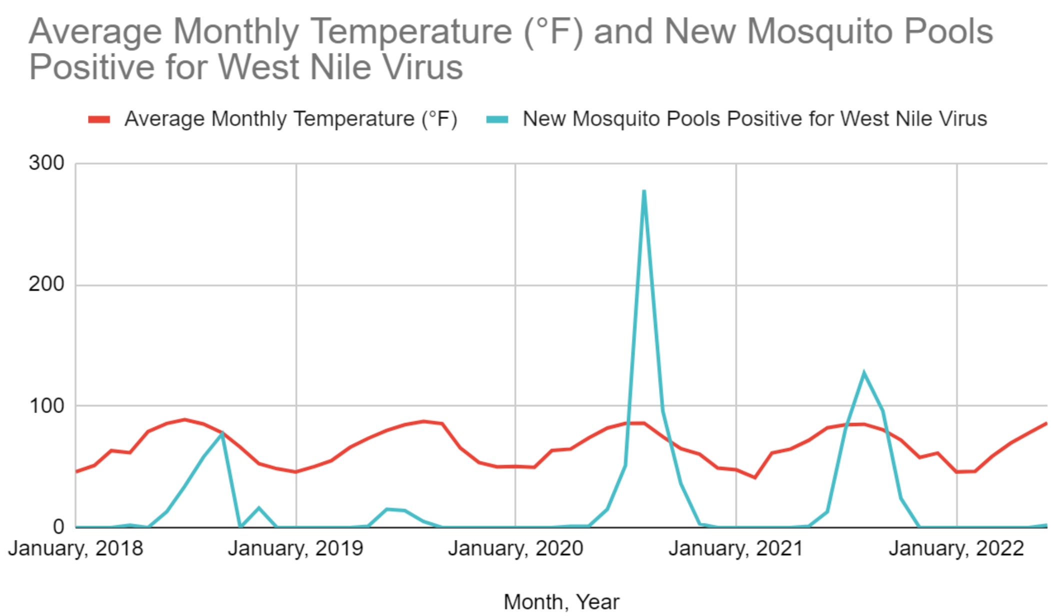



Source: Google Sheets

Using the data in the table and chart we formed an exponential fitting model to predict the number of West Nile Virus Positive Mosquito Pools in Dallas County using Average Monthly Temperature.

Predicted West Nile Virus Positive Mosquito Pools in Dallas County $= 0.409*10^{0.657}$ (Average Monthly Temperature in Dallas County)

**Temperature and Mosquito Patterns Over Time**




Source: Google Sheets

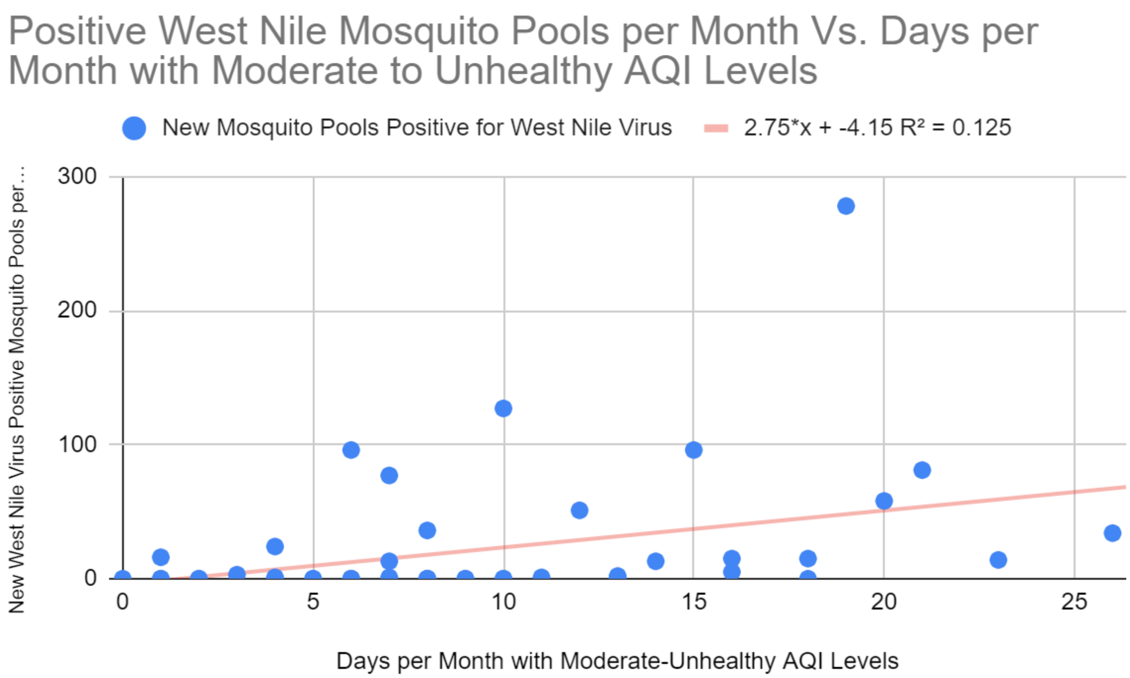
We plotted Average Monthly Temperature and West Nile Virus Positive Mosquito pools in Dallas County over time and were able to clearly see peak mosquito season in Dallas County, Texas and how temperature cycles correlate with positive West Nile Virus mosquito pools.

## Air Quality: Results and Analysis

The following table has AQI data for Dallas Texas and West Nile Positive Mosquito pools.

| Month, Year | Days per Month with AQI in Good Levels | Days Per Month with Moderate AQI | Days per Month with AQI Unhealthy for Sensitive groups | Days per Month with Unhealthy AQI | Days per Month with AQI Moderate level or Below | New Mosquito Pools Positive for West Nile Virus |
|---|---|---|---|---|---|---|
| January, 2018 | 23 | 8 | 0 | 0 | 8 | 0 |
| February, 2018 | 23 | 5 | 0 | 0 | 5 | 0 |
| March, 2018 | 23 | 8 | 0 | 0 | 8 | 0 |
| April, 2018 | 17 | 11 | 2 | 0 | 13 | 2 |
| May, 2018 | 13 | 15 | 3 | 0 | 18 | 0 |
| June, 2018 | 16 | 12 | 2 | 0 | 14 | 13 |
| July, 2018 | 5 | 17 | 6 | 3 | 26 | 34 |
| August, 2018 | 11 | 17 | 3 | 0 | 20 | 58 |
| September, 2018 | 23 | 7 | 0 | 0 | 7 | 77 |
| October ,2018 | 30 | 1 | 0 | 0 | 1 | 0 |
| November, 2018 | 29 | 1 | 0 | 0 | 1 | 16 |
| December, 2018 | 25 | 6 | 0 | 0 | 6 | 0 |
| January, 2019 | 23 | 8 | 0 | 0 | 8 | 0 |
| February, 2019 | 20 | 8 | 0 | 0 | 8 | 0 |
| March, 2019 | 18 | 13 | 0 | 0 | 13 | 0 |
| April, 2019 | 20 | 10 | 0 | 0 | 10 | 0 |
| May, 2019 | 18 | 12 | 1 | 0 | 13 | 1 |
| June, 2019 | 14 | 14 | 2 | 0 | 16 | 15 |
| July, 2019 | 8 | 23 | 0 | 0 | 23 | 14 |
| August, 2019 | 15 | 15 | 1 | 0 | 16 | 5 |
| September, 2019 | 19 | 9 | 2 | 0 | 9 | 0 |
| October ,2019 | 22 | 9 | 0 | 0 | 9 | 0 |
| November, 2019 | 23 | 7 | 0 | 0 | 7 | 0 |
| December, 2019 | 25 | 6 | 0 | 0 | 6 | 0 |
| January, 2020 | 30 | 1 | 0 | 0 | 1 | 0 |
| February, 2020 | 29 | 0 | 0 | 0 | 0 | 0 |
| March, 2020 | 26 | 5 | 0 | 0 | 5 | 0 |
| April, 2020 | 23 | 7 | 0 | 0 | 7 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| May, 2020 | 20 | 9 | 2 | 0 | 11 | 1 |
| June, 2020 | 12 | 16 | 2 | 0 | 18 | 15 |
| July, 2020 | 19 | 12 | 0 | 0 | 12 | 51 |
| August, 2020 | 12 | 17 | 2 | 0 | 19 | 278 |
| September, 2020 | 24 | 6 | 0 | 0 | 6 | 96 |
| October ,2020 | 23 | 8 | 0 | 0 | 8 | 36 |
| November, 2020 | 27 | 3 | 0 | 0 | 3 | 3 |
| December, 2020 | 27 | 4 | 0 | 0 | 4 | 0 |
| January, 2021 | 27 | 4 | 0 | 0 | 4 | 0 |
| February, 2021 | 26 | 2 | 0 | 0 | 2 | 0 |
| March, 2021 | 25 | 6 | 0 | 0 | 6 | 0 |
| April, 2021 | 20 | 10 | 0 | 0 | 10 | 0 |
| May, 2021 | 27 | 4 | 0 | 0 | 4 | 1 |
| June, 2021 | 22 | 3 | 4 | 1 | 7 | 13 |
| July, 2021 | 10 | 18 | 3 | 0 | 21 | 81 |
| August, 2021 | 21 | 10 | 0 | 0 | 10 | 127 |
| September, 2021 | 15 | 13 | 2 | 0 | 15 | 96 |
| October ,2021 | 27 | 4 | 0 | 0 | 4 | 24 |
| November, 2021 | 28 | 2 | 0 | 0 | 2 | 0 |
| December, 2021 | 18 | 13 | 0 | 0 | 13 | 0 |



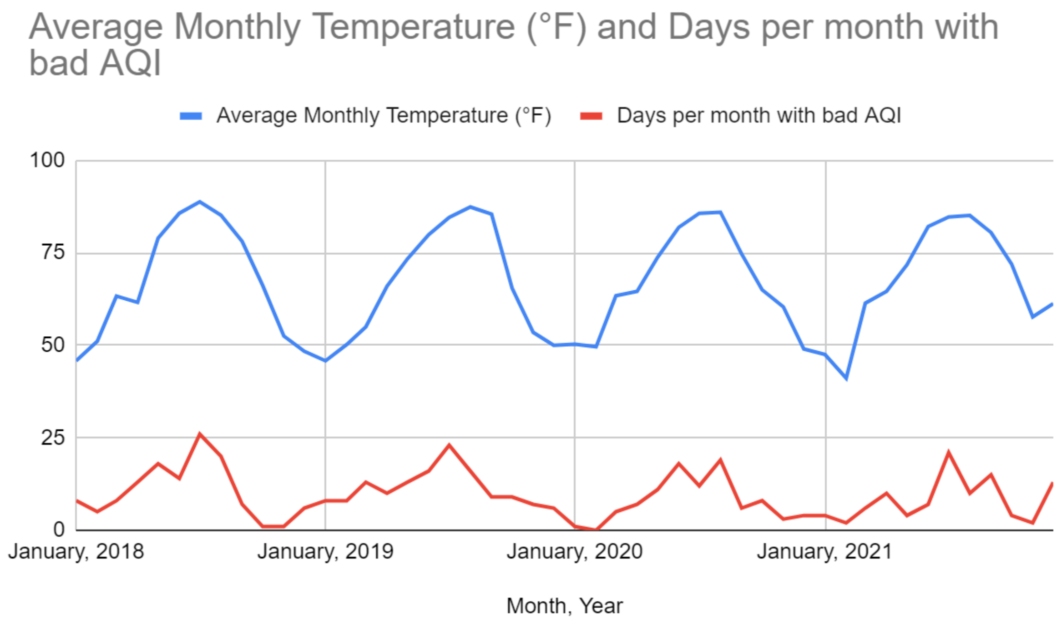

Source: Google Sheets

We fit our data for air quality using a linear regression model and calculated our correlation coefficient (r) to be .3536 indicating a moderate positive correlation between days per month with moderate or below AQI levels and the amount of West Nile Virus positive mosquito pools in Dallas County.

Using our linear regression model we created a predictive equation. The following equation represents our linear regression model and can be used for prediction of the amount of positive West Nile Virus mosquito pools in Dallas County based on days per month with moderate or below AQI levels.

| | |
|---|---|
| Predicted West Nile Virus Positive Mosquito Pools in Dallas County | = -4.15 + (2.75) * (Days per month with Moderate or Below AQI Levels in Dallas) |

We plotted the average monthly temperature in Dallas County, Texas and the days per month with “bad” AQI. We defined bad AQI as levels of moderate or below.

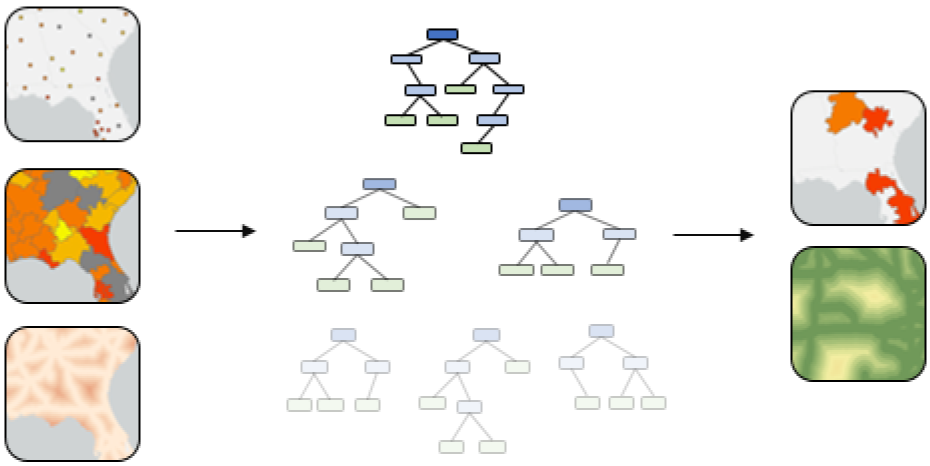



Source: Google Sheets

Average monthly temperature and days per month with “bad” AQI follow roughly the same pattern which could be a possible reason both factors have a positive correlation with the amount of West Nile positive mosquito pools in the Dallas County Region.

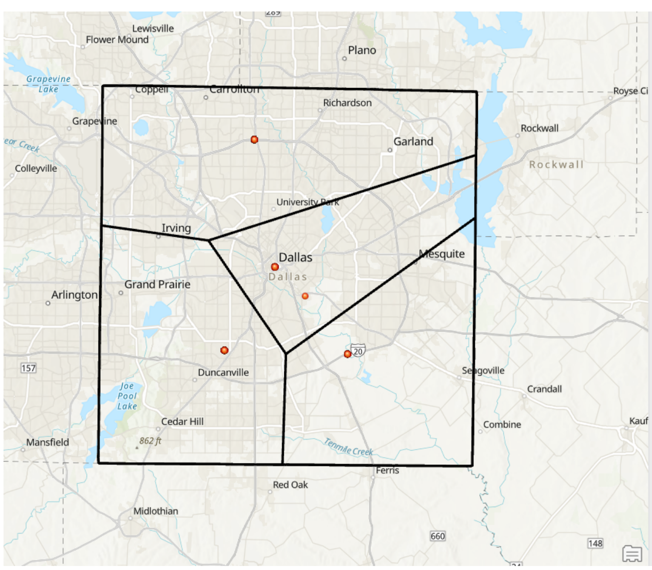
## Forest-based Classification and Regression

Using the data listed above we created a supervised machine learning model on ArcGIS Pro to predict the presence of WNV mosquito pools given climate factors. Forest-based analysis works by creating hundreds of decision trees, each given a randomly sampled portion of the input data. Each individual tree then analyses its given data, makes a prediction, and casts a vote for the result. To predict or categorize the results of an unknown sample, the forest model takes into account the votes from all decision trees.



Source: ArcGIS Pro illustration of forest-based classification and regression

The model was specifically trained on Air Quality Index Data from the Environmental Protection Agency (EPA) and monthly temperature information from the National Weather Service. We expanded the data from point form using Voronoi polygons and spatial joins to define proximal regions around the individual data points and create a single layer of data for analysis.




Source: ArcGIS Pro data visualization of our model

I. Model Training Performance

## Model Characteristics

| | |
|---|---|
| Number of Trees | 100 |
| Leaf Size | 5 |
| Tree Depth Range | 1-5 |
| Mean Tree Depth | 3 |
| % of Training Available per Tree | 100 |

## Training Data: Regression Diagnostics

| | |
|---|---|
| R-Squared | 0.591 |
| p-value | 0.001 |
| Standard Error | 0.009 |

## Validation Data: Regression Diagnostics

| | |
|---|---|
| R-Squared | 0.562 |
| p-value | 0.001 |
| Standard Error | 0.032 |

An R-Squared value of 0.591 indicates a moderate positive correlation between temperature and air pollution to WNV mosquito pools. The model estimated that temperature had a 54 percent important contribution and that air quality had a 46 percent importance contribution when examining variable importance. This model has some limitations. We only had access to restricted climate data in the Dallas region, and a more extensive data set could've created a higher-performing model.

## Conclusions

There is a significant correlation between temperature, air quality levels, and the abundance of West Nile positive mosquito pools in Dallas County, Texas. Recent outbreaks in Texas have caused West Nile Virus to be of great concern to the general public. By using our prediction model the general public can reduce their exposure to West Nile Virus positive mosquitoes based on monthly temperatures and AQI levels. We also hope to improve public health by informing the public on when to take the proper precautions against West Nile Virus exposure. Exposure is significantly increased during the late summer when AQI levels are highest (indicating large amounts of air pollution and poor air quality) and when temperatures are highest.

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