WEST NILE VIRUS: RELATION TO POPULATION DENSITY, PRECIPITATION, AND ELEVATION

AUTHORS

Diya Deepak, Ananya Gummadi, Asher Jiang, and Harry Wu

FUNDING SPONSORS

ABSTRACT

This research project is centered around determining the correlation between the rate of infection by mosquito-transmitted vector-borne diseases and environmental factors such as population density, precipitation, and elevation. This research project puts mosquitoes at the center of the project due to the complex way that "mosquitoes contract and transmit illnesses... [in] five steps" (Mosquito-Authority, n.d.). These steps- starting from "a female mosquito taking a blood meal" to ending with another blood meal highlight the simplicity of the process of infection by mosquitoes and provides a clue as to why diseases are spread so quickly when mosquitoes act as vectors (Mosquito-Authority, n.d.). The data obtained will be used to determine the prevalence of West Nile Virus, a type of vector-borne disease, in each county in the state of Texas. By narrowing the data collection to only one state, and only one disease, it is possible to obtain more accurate models and in the future, develop a system to expand the results found today. Past efforts to map a correlation between population density and rate of disease spread have mostly reported inconsistent results. Socioeconomic class and type of human settlements must be taken into account in order to confidently establish a correlation, particularly in areas that contain urban settlements. Despite the inconsistent results reported in the past, determining a correlation between environmental factors and the rate of spread of vector-borne diseases is crucial for the safety of humans living in many regions around the world. Finding a relationship between population density, type of settlements, and other environmental factors, such as precipitation and elevation, and the rate of disease spread is especially crucial for countries that are rapidly industrializing, since many areas may experience rapid population density increases without a proportional improvement in medical treatment and prevention facilities. This research project will use statistical analysis programs and data from a variety of sources including the CDC and the GLOBE Observer program to determine correlations between environmental factors and West Nile virus infection rates. Then, if possible, the next steps for the project will be with regard to the methodology for other regions and vector-borne diseases.

RESEARCH QUESTION

The relevance of mosquitos has been recognized largely due to their abilities to act as vectors for the transmission of diseases such as West Nile Virus- which "is spread to people through the bite of an infected mosquito" (CDC, 2020). In the case of West Nile Virus disease, the importance of staying diligent in regards to mosquito bite prevention is especially critical as "there is no vaccine to prevent WNV infection" (CDC, 2020). The research question hopes to identify a connection between attributes like population density, precipitation, and elevation with the spread of disease. How can we predict the number of cases of West Nile Virus in different Texas counties based on environmental factors?

METHODOLOGY

This research project used data from the CDC on the amount of West Nile Virus infections in each county in Texas from 2004 to 2018 (https://www.cdc.gov/ncezid/dvbd/vital-signs/index.html), as well as GLOBE data. Other online sources provided the environmental data that the project needed on a variety of factors, such as the amount of precipitation or altitude of each county. Using HeuristicLab's symbolic regression function, the number of WNV infections was plotted against each of the factors to determine any correlations between them.

RESULTS/ FINDINGS

HeuristicLab returned the following expression for projected cases of WNV after the environmental data was plugged in. In the equation, *P* has been substituted for precipitation, *D* for population density, and *E* for elevation.

$$((0.2874 * P * 0.9618 * P + (0.7011 * D + 0.7011 * D)) * (0.2874 * P * 0.6780 * D + 1.9156 * E) * 3.6660 * 10^{-7} - 0.1103)$$

Sources

Authority, M. (n.d.). *How do mosquitoes transmit disease?* Mosquito Authority - Mosquito Service. Retrieved July 28, 2022, from https://www.mosquito-authority.com/blog/how-do-mosquitoes-transmit-disease/

Centers for Disease Control and Prevention. (2021, December 17). Final cumulative maps and data. Centers for Disease Control and Prevention. Retrieved July 22, 2022, from https://www.cdc.gov/westnile/statsmaps/cumMapsData.html

Centers for Disease Control and Prevention. (2020, December 7). Prevention. Centers for Disease Control and Prevention. Retrieved July 22, 2022, from https://www.cdc.gov/westnile/prevention/index.html

GLOBE, Globe Data User Guide. (n.d.). Retrieved July 23, 2022, from https://www.globe.gov/documents/10157/2592674/GLOBE+Data+User+Guide_v1_final.pdf

Texas Department of State Health Services. (n.d.). *DSHS Arbovirus Weekly Activity reports*. Texas Department of State Health Services. Retrieved July 28, 2022, from https://www.dshs.texas.gov/idcu/disease/arboviral/westNile/reports/weekly.aspx

Texas State Library and Archives Commission. (n.d.). *Texas Counties: 2010 Population Density*. Texas Counties. Retrieved July 28, 2022, from http://www.texascounties.net/statistics/popdensity2010.htm

Texas State Library and Archives Commission. (n.d.). *Texas Counties: Elevation.* Texas Counties. Retrieved July 28, 2022, from http://www.texascounties.net/statistics/elevation.htm

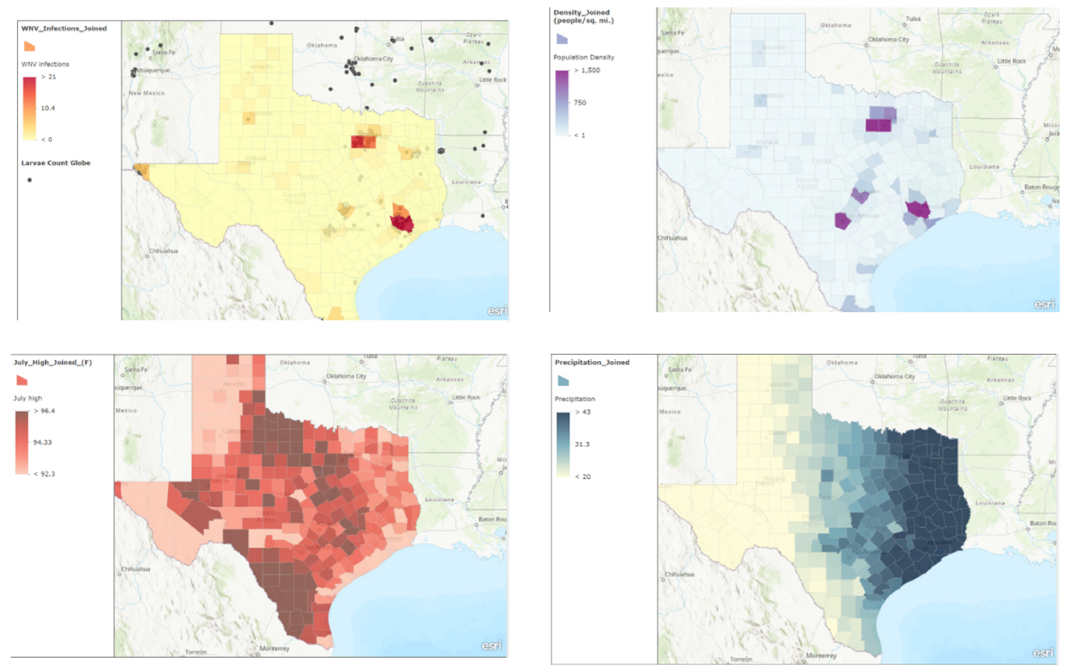
Texas State Library and Archives Commission. (n.d.). *Texas Counties: Mean July High Temperature*. Texas Counties. Retrieved July 28, 2022, from http://www.texascounties.net/statistics/temperature-julyhigh.htm

The GLOBE Program. (n.d.). Retrieved July 22, 2022, from https://www.globe.gov/

INTRODUCTION

Although seen as small and insignificant, mosquitos are largely considered one of the most dangerous animals on the planet and it is largely advised that individuals take precautions against mosquitoes with "the use of insect repellant, ...long-sleeved shirts and pants, and [controlling] mosquitoes outdoors and indoors" (CDC, 2020). Of the over 3,000 species of mosquitoes and although "many have the potential for carrying and spreading various diseases", 3 species stand out: *Aedes*, *Anopheles*, and *Culex* (Mosquito-Authority, n.d.). Aedes mosquitos are common vectors of large-scale diseases like Yellow Fever, Dengue, and Zika and are characterized by their black and white striped legs and biting during the day. Anopheles mosquitos are recognized as being "responsible for the spread of probably the most well-known mosquito-borne illness in the world" called malaria and typically bite late at night (Mosquito-Authority, n.d.). Last but not least, Culex mosquitos are the species at the center of this research project research due to their transmission of the West Nile Virus. The purpose of this research is to identify a possible link between population density and the transmission of this disease which may or may not be anthropogenically influenced by different types of environmental factors. With more than 55% of the world's population living in urban areas, the possibility of a relation existing between population density and the transmission of mosquito-transmitted vector-borne disease cannot be overlooked due to the future implications that a possible, existing correlation could have. Due to predictions of a larger disparity between the world's population that lives in urban or rural areas, identifying existing influences on the transmission of the disease is critical to mitigating mosquito oviposition that could lead to the large-scale spread of illnesses. This research project aims to act as a preemptive form of disease control by identifying the conditions that support mosquito-transmitted disease and preventing conditions from being like so. In that way, "the best way to prevent West Nile is [not] to protect yourself from mosquito bites" but to use similar modeling tools to prevent the spread of the disease before outbreaks can occur (CDC, 2020). Precipitation and elevation are variables that this research project placed great focus on as by collecting information on both of these factors and the species of mosquitoes found there, certain regions can be recognized as being more or less susceptible to certain diseases for housing certain types of mosquitos. In addition, this research project places a focus on population density as the number of people living in a certain area in close proximity results in a different rate in the spread of disease than those who live in rural areas. By identifying any correlation between mosquito-transmitted vector-borne diseases and said environmental factors, the effects of fluctuations in population density and possible implications of disease outbreaks can be recognized and prepared for in areas of varying population size.

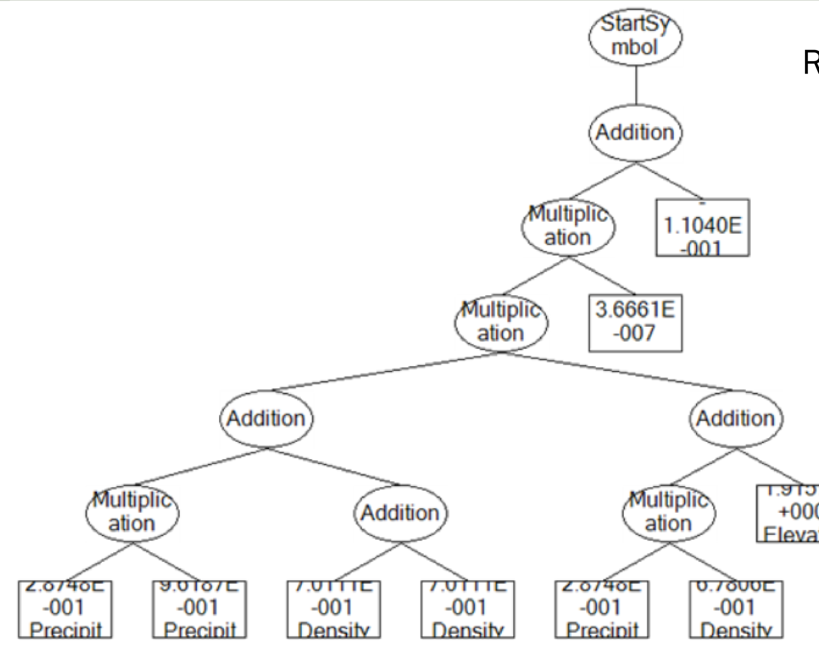
ANALYSIS



Using data largely compiled from CDC's data on West Nile Virus from 2004-2018 as well as GLOBE Observer in the form of an ArcGIS map, the four variables were determined:

- Population Density (D) in people/mi^2
- High temperature in July (T) in Fahrenheit
- Annual Precipitation (P) in inches
- Elevation (E) in feet

HeuristicLab's symbolic regression function (a modeling program) was then used to determine correlations between each environmental factor and WNV cases. Using population density and other climate variables as inputs, Heuristic Labs generated an equation that would allow for inputs of measurements of elevation, precipitation, and population density to produce predictions of West Nile Virus cases based on the specific conditions.

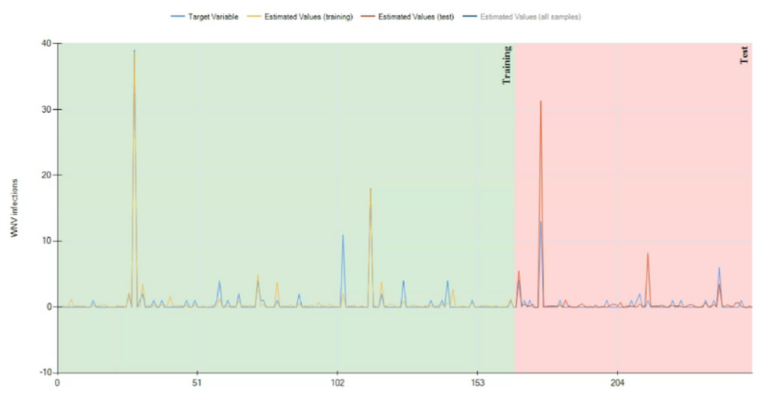


Regression

- The ratio for training test segments was 66-34
- Limited complexity to reduce overfitting
  - Depth 10 & Length 20

<-- Image of the decision tree used to produce the final equation

Density	0.92544560170148371
Precipitation	0.2496272955344746
Elevation (ft.)	0.011630938689099368
July High Temp	0



The equation that we obtained, along with the variable impacts, shows a strong correlation between population density and West Nile Virus cases. However, a weaker correlation occurs with precipitation and elevation, and no correlation at all with temperature.

CONCLUSION

Although it was necessary to work under the premise of certain assumptions and simplify the model due to limitations of time and sparse data, the equation that was obtained through the modeling program demonstrated a strong correlation between population density and West Nile Virus cases. The equation also indicated a weaker correlation of the cases with precipitation and elevation and did not identify any correlation with the temperature variable. With greater resources and more time, there is unlimited potential for this project in terms of the next steps as the equation currently only uses a limited subset of data available but with greater availability of West Nile Virus data, including factors other than environmental factors that make an individual more or less susceptible to this disease, more accurate predictions could be used to issue warnings and mitigate the effects of the transmission of this disease by mosquitoes. In addition, by modifying this equation to work with all different programs and programming languages, it can be used in a similar fashion to predict outbreaks and identify correlations between other diseases like "eastern equine encephalitis... and chikungunya virus... [that] do not have specific vaccines or treatments" and the environmental factors that are currently inputted into our equation (or even expand to include additional factors (Mosquito-Authority, n.d.).

SEES EARTH SYSTEM EXPLORER MENTORS; DR. RUSANNE LOW, MS. CASSIE SOEFFING, MR. PEDER NELSON, DR. ERIKA PODEST, ANDREW CLARK, AND PAXTON CALDER

THE MATERIAL CONTAINED IN THIS POSTER IS BASED UPON WORK SUPPORTED BY THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA) COOPERATIVE AGREEMENTS NNX16AE28A TO THE INSTITUTE FOR GLOBAL ENVIRONMENTAL STRATEGIES (IGES) FOR THE NASA EARTH SCIENCE EDUCATION COLLABORATIVE (NESEC) AND NNX16AB89A TO THE UNIVERSITY OF TEXAS AUSTIN FOR THE STEM ENHANCEMENT IN EARTH SCIENCE (SEES). ANY OPINIONS, FINDINGS, CONCLUSIONS, OR RECOMMENDATIONS EXPRESSED IN THIS MATERIAL ARE THOSE OF THE AUTHORS AND DO NOT NECESSARILY REFLECT THE VIEWS OF NASA.