Influence of Tree Density Upon the Spatial Distribution of Mosquito Populations

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Abstract

Mosquitoes are vectors for pathogens such as the West Nile Virus, Dengue (DV), Zika (ZIKV), and Malaria. Determining the abiotic factors that contribute to the spread of these diseases and the conditions under which mosquito habitats thrive is essential to mitigating mosquito populations and mosquitos as a public health threat. This study aims to assess the effect of tree density and land cover on mosquito populations and the correlation between tree density and mosquito species composition. Using photos collected from NASA GLOBE Observer, we investigated three different three-by-three-kilometer areas of interest (AOI) representing various ecological settings within the surrounding Houston, Texas area. These photos were then analyzed using a GitHub machine-learning model that assessed both tree density and land cover percentages within each region. This data was then compared to an ArcGIS database representative of the mosquito population dataset of Houston, Texas. From this data, we found no clear correlation between either tree density or concentration with mosquito populations, but previously published works from other authors support the idea of a positive relationship between mosquito populations and urbanized areas with fewer trees.

Keywords: mosquitoes, tree density, land cover, Houston, Texas

Research Question

Can we find a correlation between tree density and the spatial distribution of mosquitoes using open-source databases such as ArcGIS, GLOBE, GLOBE Mosquito Habitat Mapper, iNaturalist, and a GitHub program?

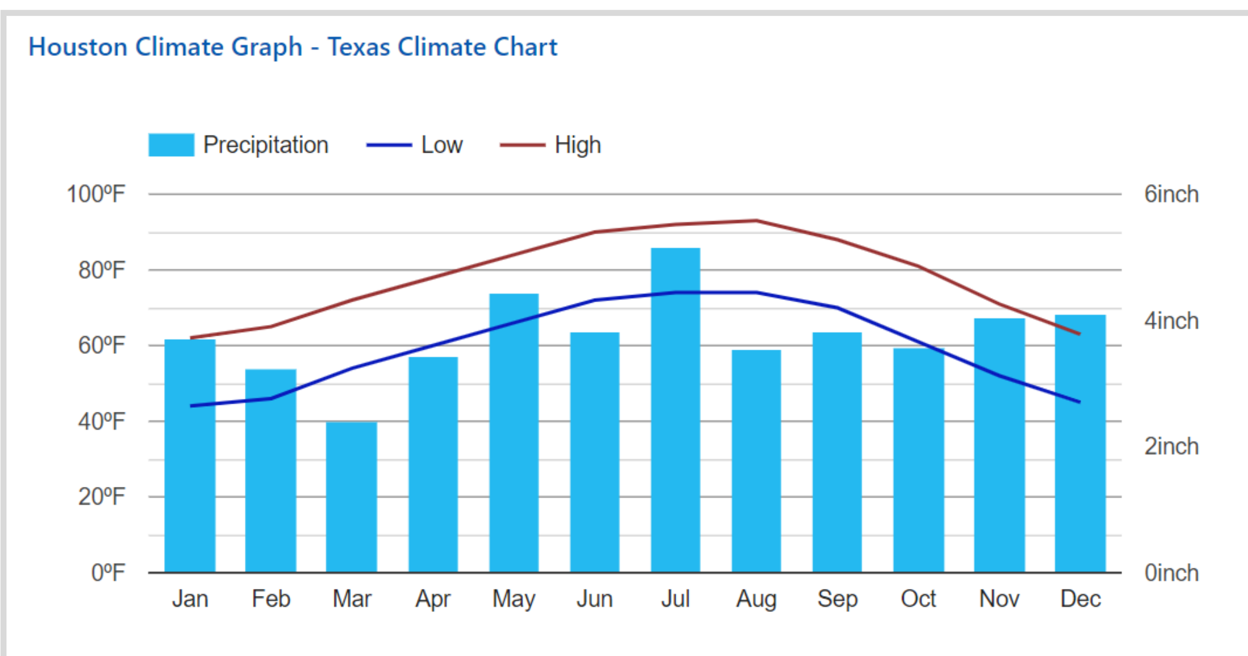
Introduction and Review of Literature

Houston, Texas is ranked as the No. 4 city in the USA with the highest mosquito population (Luna, 2019). This city is known for its high temperatures due to its proximity to the Gulf of Mexico. In addition to its heat, Houston, Texas also contains many mosquitoes. In 2012, there was a West Nile Virus (WNV) outbreak in Texas, with over 1,500 recorded cases (Murray et al., 2013). Research on mosquitoes is very important because they carry very infectious mosquito-borne diseases such as Dengue, Zika, Malaria, and West Nile Virus. Though most people do not feel the symptoms of the diseases, a small percentage could experience symptoms such as stiff neck, nausea, fevers, and lack of energy. The magnitude of each symptom depends on the type of disease caught (State of Connecticut Mosquito Management Program, n.d.).

Many studies show a rise in mosquitoes in areas with wetlands. A was conducted where it was discovered that there was a higher percentage of mosquitoes in underdeveloped areas compared to more developed areas. The study suggested that underdeveloped areas that are underdeveloped contained large numbers of waste such as bottles, cans, tires, etc. These objects would trap in rainwater and create ideal breeding grounds for mosquitoes. There were suggestive trends showing that arbovirus activities in humans or animals were higher in lower socioeconomic classes (Rio et al., 2006).

Texas is a state well known for its high temperatures, and Houston is evidence of this. With an average high temperature above 90 degrees Fahrenheit in the months of July and August and an average low of just 60 degrees Fahrenheit, it is a city known for its heat. On top of being warm in Houston, it also rains a lot. On average, there are 106 days of precipitation per year with an annual average of 45.28 inches of rain (Climate-Houston Texas, n.d.). Alongside July being one of the hottest months in Houston, it also creates on average the highest precipitation (Climate-Houston Texas, n.d, Figure 1). The mix of humidity, precipitation, and heat creates perfect breeding grounds for mosquitoes. Research conducted by Barrera et al., (2011) suggested that there were higher mosquito breeding patterns during wetter seasons, because of the rainwater creating puddles, filling up containers, tires, cups, etc. These areas abundant in rainwater created an inviting environment for mosquitoes to breed.

Figure 1: A graph representation of the average precipitation, high temperature, and high temperature in Houston, Texas. Climate Houston - Texas, by U.S. Climate Data, n.d.(https://www.usclimatedata.com/climate/houston/texas/united-states/ustx0617). In the public domain.



Throughout the world, mosquitos pose an ongoing threat to public health, and with the spread of often deadly vector-borne diseases that these insects carry, such as the Zika virus and the West Nile Virus (WNV) (Omodior et al., 2018), it is important to determine the conditions in which mosquitos thrive. As mosquitos need sources of moisture to lay eggs and often search for areas with lots of water and shade. One major aim of this project was to identify the effects of tree density on mosquito populations. Due to Houston's subtropical climate, characterized by warm and humid summers, as well as the city's large populations of disease-carrying mosquitoes such as Aedes Aegyptii and Asian Tiger Mosquitos, Houston presents itself to be an ideal environment for mosquito breeding and the spread of vector-borne illnesses. Using Houston, Texas as our model, we can identify the relationship between tree density and land cover with mosquito populations and help inform citizens of their relative risk to vector-borne diseases due to high mosquito populations. We hypothesize that an increase in tree density will lead to an increase in mosquito populations.

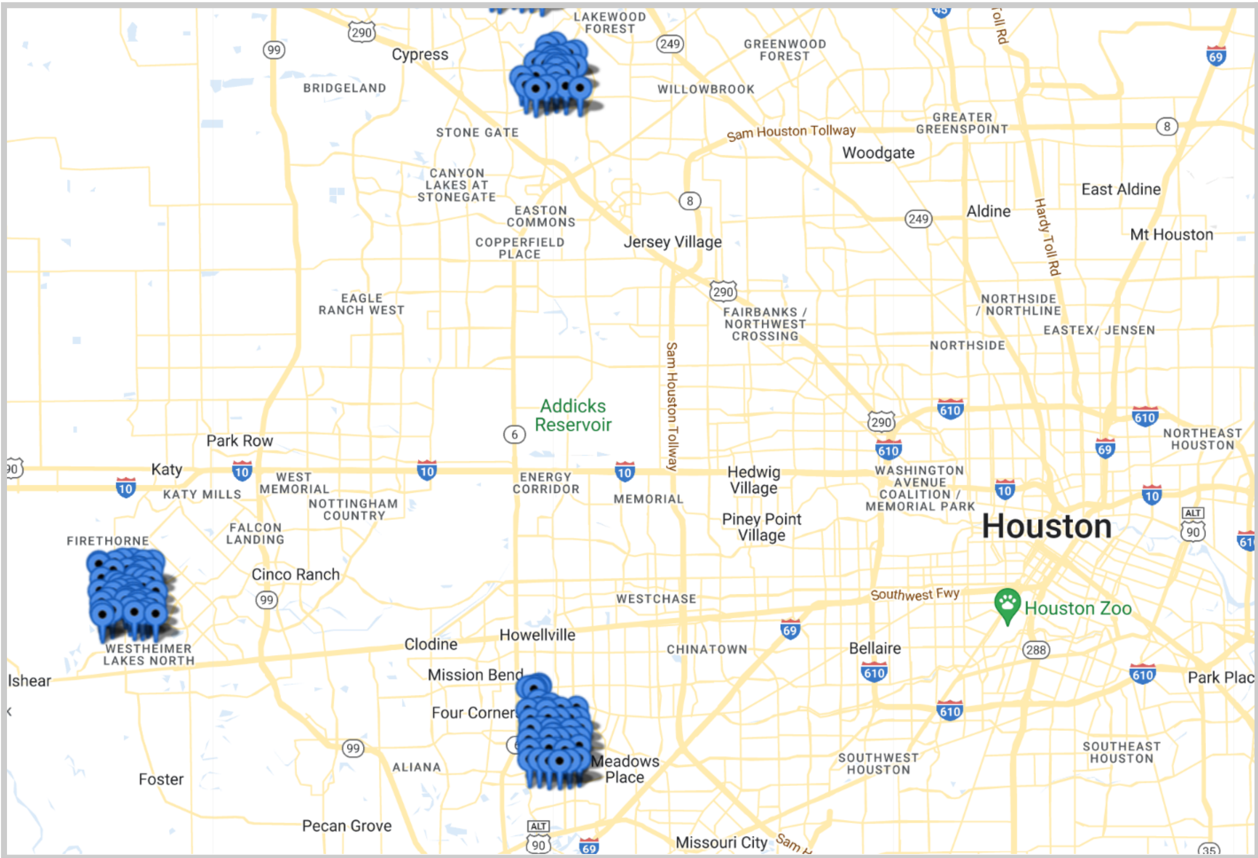
Open Source data is very valuable to upcoming scientists and researchers. Throughout our quest to find a suitable topic to conduct an experiment on, we faced many difficulties. One major difficulty was finding free data for everyone to use. It seemed that almost all journal articles we were interested in were hidden behind a paywall we weren't able to access. This is one of the major reasons why Global Learning and Observations to Benefit the Environment (GLOBE) and other sources such as ArcGIS were used to conduct our research.

Methodology

Data Collection

Houston, Texas was not only chosen due to its known population of high mosquitoes but also due to its abundant resources in open source data. Compared to other cities in Texas, Houston was by far the easiest to find open-source data. We obtained most of our data from five main sources: GitHub, GLOBE, ArcGIS, GLOBE Mosquito Habitat Mapper, and iNaturalist. Most of our tree density and land cover data was collected from a GLOBE database that ranged from January 1, 2019- July 15, 2023. Our mosquito data was collected using ArcGIS software that allowed us to merge all the GLOBE Mosquito Habitat Mapper points and iNaturalist points in the Houston, Texas area. The very first step we took was to use the GLOBE database to our advantage. There we figured we could attain all our important land cover and tree density data (GLOBE 2022). The research was continued by gathering 500 preliminary images of land cover data around three areas of interest (AOI) in Houston, Texas, which included the following neighborhoods: Cypress, Fulshear, and Meadows Place (Figure 2). These images were then used to create land cover data and tree density data around Houston. We used ArcGIS to find a template layer of Houston, Texas (Esri, 2011) and layered onto it all mosquito data from both GLOBE Mosquito Habitat Mapper (PSSupport_Esri, 2022) and iNaturalist (U98487415_usflibrary, 2022), there were over three hundred total mosquito data points recorded. From this, we could see all recorded mosquito data in the Houston, Texas area. ArcGIS also allowed us to view the percentage of forest within 50 yards of each mosquito point recorded from both GLOBE Mosquito Habitat Mapper and iNaturalist. The average and standard deviation of the percent forest from each database was recorded in a table.

Figure 2: An enlarged map of the Houston, Texas region containing our three major areas of interest (AOI) collected from GLOBE. The three major clusters of points represent our AOIs. Global Learning and Observations to Benefit the Environment (GLOBE) Program, (2022), https://www.globe.gov/web/sees2023



One problem we faced when searching for data was how to turn our 500 land cover images into tree density and land cover data. That is when one of our members had the idea to use a machine learning model to calculate not only tree density in trees/acre but also to find data on land cover and percentage development in different areas of Houston.   The machine learning model program was run using an already functioning GitHub code (Li, 2023). Another problem we faced was the fact that GLOBE Mosquito Habitat Mapper on ArcGIS did not provide us with the genus of each mosquito recorded, while iNaturalist did. To solve this problem, we simply created a pie chart using only iNaturalist data, showing the average percent forest within 50 yards of the mosquitoes, categorized by genus. With this, we were able to properly compare land cover, tree density, and mosquito populations in the Houston, Texas area.

Data Analysis and Results

Using all of our collected data, we were able to create three identical maps of Houston, Texas, each containing different features such as tree density, mosquito population, and land cover percentages. Tree density and land cover were chosen as research factors because we believed that they held a greater impact on the breeding patterns of mosquitoes. The machine learning model used to create the data on trees did two major things, it first analyzed all 500 images and then created representative graphs of both tree density and land cover (Figure 3, and Figure 4). With the tree density and land cover data collected and properly organized for analysis, we were now able to work on the mosquito data, which was slightly more difficult. To find proper mosquito data, we went to ArcGIS Online and discovered GLOBE Mosquito Habitat Mapper data and iNaturalist data (Figure 5). The problem was that the mosquito data points were for the entire globe, and we had to isolate the points for just Houston, Texas. To do this, we found a base layer of Houston, Texas (Texas Department of Transportation, 2016), and layered all the GLOBE Mosquito Habitat Mapper (PSSupport_Esri, 2022), and iNaturalist mosquito points (U98487415_usflibrary, 2022). When this was all done, we were also able to create a data table using ArcGIS that included the percentage of forest within 50 yards. We found the mean and standard deviation percentage of forest for GLOBE Habitat Mapper and iNaturalist. All this data was collected and placed into a chart (Table 1).

Figure 3: The figure below shows the spatial distribution of trees in Houston, Texas (trees/acre). Each color and point on the map represents different levels of trees in the area, as represented by the key on the right-hand side.

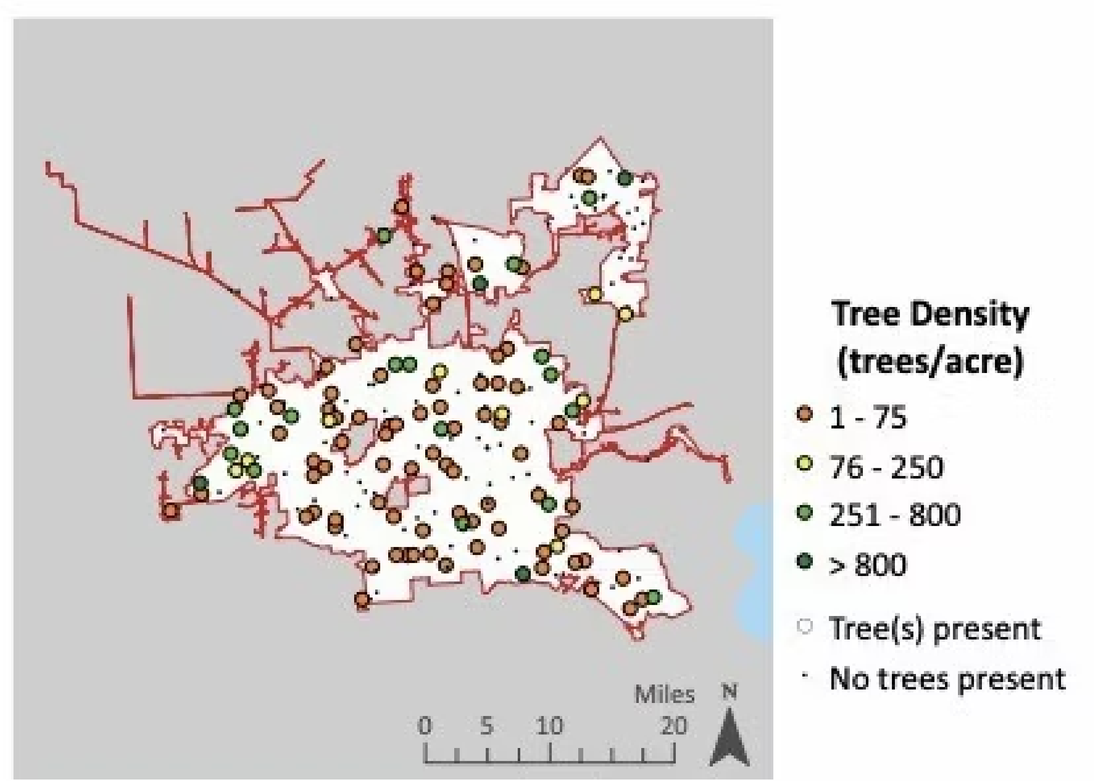


Figure 4: The image below represents the land cover distribution of Houston, Texas. The image depicts the level of development in different areas of the city in percentages as well as areas with forests, water, and grass.

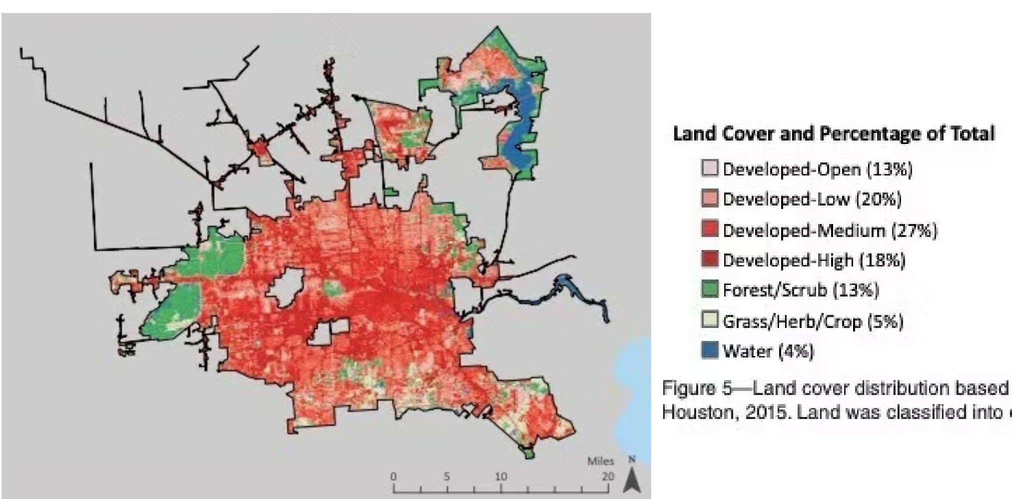


Figure 5—Land cover distribution based on National Land Cover Database (Homer and others 2015), Houston, 2015. Land was classified into one of seven land cover classes.

Figure 5: The image below shows the mosquito distribution in Houston, Texas. There are a total of over three hundred mosquito points. The red points represent points from GLOBE Mosquito Habitat Mapper While the yellow points represent mosquito data from iNaturalist.

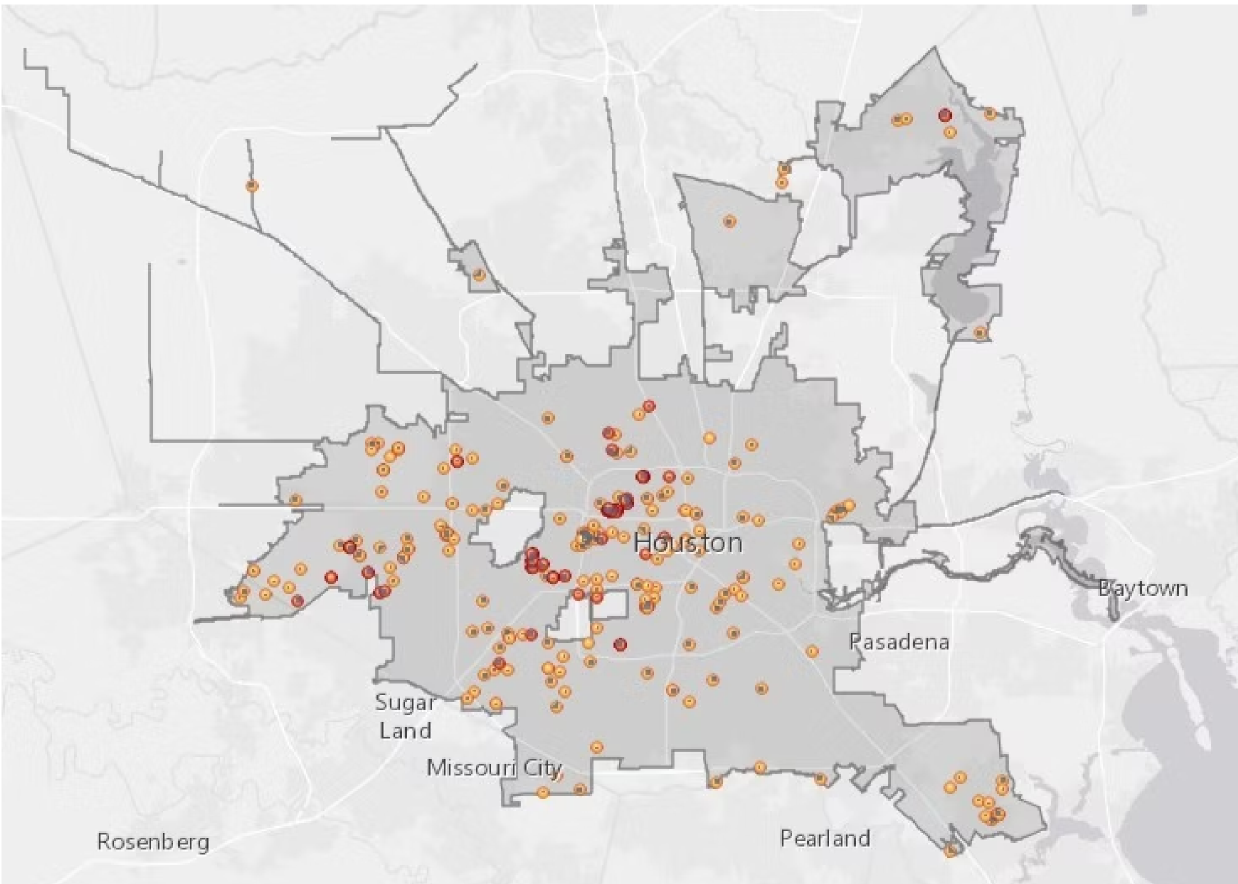
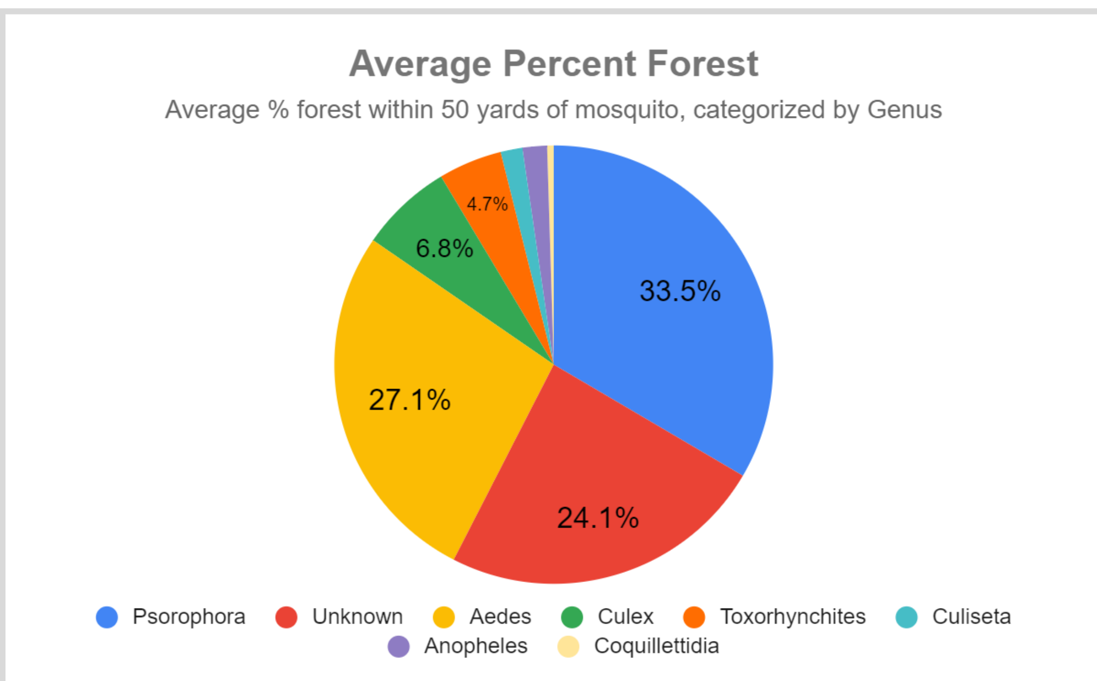


Table 1: The table below represents the average percentage of forest within 50 yards of the mosquito points from iNaturalist and GLOBE Mosquito Habitat Mapper. The chart also includes the standard deviation and mosquito count from both databases.

	iNaturalist	GLOBE Mosquito Habitat Mapper
Avg. % Forest within 50 yards	4.091	4.343
Standard Deviation	5.416	8.740
Mosquito Count	258	120

On top of creating charts and tables for the Mosquito distribution and tree distribution, we also wanted to see what Genus presented itself to the nearest forests. For this, we created a pie chart that contained the average percentage of forest within 50 yards of each mosquito based on its genus (Figure 6). The data contained in the pie chart was only from iNaturalist because it was the only database that contained sufficient data on the genus of the mosquitoes.

Figure 6: The pie chart represents the average percent forest near each mosquito, categorized by mosquito Genus. The average percentage of forest is only within 50 yards of each mosquito.



Discussion

From this data, it can be assumed that there is both a positive relationship between urbanization, areas with high human populations, and mosquitoes and a negative relationship between tree density and mosquitoes. The idea of a positive relationship between mosquitoes and highly developed areas has been supported by the previous works of researchers such as Francisco et al., (2021), who conducted research using machine learning and remote sensing and discovered that there were higher dengue vector mosquito occurrences in areas with higher population density. Other research such as the one by Gantare (2018) explains that areas that experience a lot of deforestation also seem to have high mosquito populations due to a greater magnitude of solar radiation hitting the mosquito breeding grounds. Previous research has also supported the idea of an inverse relationship between tree density and mosquito populations (Robbins, 2016), the research suggested that Rapid Deforestation leads to increases in vector-borne diseases caused by mosquitoes such as malaria and dengue fever. The research also stated that an estimated 60 percent of diseases that affect humans live most of their lives in wild and domestic animals. Other works do not support our hypothesis that tree density and mosquito populations are positively related, but our data do not support our hypothesis either. Our data also support the ideas of previous authors.

Conclusion

We predicted that mosquitoes will have a positive correlation to tree densities, but our hypothesis was not supported by our data. Our data support previously accepted ideas that areas with less tree density and high human populations will contain more mosquitoes. This is because a higher human population creates more waste such as empty containers that collect rainwater and waste that creates ideal breeding grounds for mosquitoes. Our data gave us visually appealing, easily understandable pieces of information that debunked our hypothesis.

Though our prediction was proven false, our data is still perfectly usable. Our data can be used to determine which locations are at a higher risk for mosquito-borne illnesses. More developed areas are more likely to host more significant mosquito populations, and thus the citizens of these areas are at higher risk of vector-borne diseases.

In the future, this experiment can be expanded by choosing more areas of interest (AOIs) so we can maximize our data for that particular location and reduce the probability of an outlier. By choosing a greater area of interest, we could have more data to look at. We could then cross-reference this newly discovered data to our current data to see if it is similar and to see if any outliers greatly skewed our current data.

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References

Barrera, R., Amador, M., & MacKay, A. J. (2011). Population Dynamics of Aedes aegypti and Dengue as Influenced by Weather and human behavior in San Juan, Puerto Rico. PLoS Neglected Tropical Diseases, 5(12). https://doi.org/10.1371/journal.pntd.0001378

Climate Houston - Texas [Graph] (n.d.). Retrieved August 3, 2023, from https://www.usclimatedata.com/climate/houston/texas/united-states/ustx0617

Esri. (September 26, 2011). "World Light Gray Base" [Basemap]. Scale Not Given. Retrieved July 21, 2023, from https://www.arcgis.com/home/item.html?id=ed712cb1db3e4bae9e85329040fb9a49.

Francisco, M. E., Carvajal, T. M., Ryo, M., Nukazawa, K., Amalin, D. M., & amp; Watanabe, K. (2021). Dengue disease dynamics are modulated by the combined influences of precipitation and landscape: A machine learning approach. Science of The Total Environment, 792, 148406. https://doi.org/10.1016/j.scitotenv.2021.148406

Gantare, N. (2018, December 31). Mosquitoes Densities are Positively Correlated with Tree Densities. HSC Projects. Retrieved August 1, 2023, from, https://hscprojects.com/mosquitoes-densities-are-positively-correlated-with-tree-densities/#:~:text=Mosquitoes%20Densities%20Are%20Positively%20Correlated%20With%20Tree%20Densities

Global Learning and Observations to Benefit the Environment (GLOBE) Program, (2022), SEES2023. Retrieved July 21, 2023, from https://www.globe.gov/web/sees2023

Li, S. 2023, TreeCountSegHeight. Retrieved July 21, 2023, from https://github.com/sizhuoli/TreeCountSegHeight.

Luna, M. de. (2019, February 14). So you think Houston has the country's worst mosquito problem? close, but not quite. Retrieved August 3, 2023, from https://www.chron.com/news/houston-texas/houston/article/houston-no-4-for-mosquitoes-terminix-pests-insects-13617247.php

Murray, K. O., Ruktanonchai, D., Hesalroad, D., Fonken, E., & Nolan, M. S. (2013). West Nile Virus, Texas, USA, 2012. Emerging Infectious Diseases, 19(11), 1836-1838. https://doi.org/10.3201/eid1911.130768.

Omodior, O., Luetke, M. C., & Nelson, E. J. (2018). Mosquito-borne infectious disease, risk-perceptions, and personal protective behavior among U.S. International Travelers. Preventive Medicine Reports, 12, 336–342. https://doi.org/10.1016/j.pmedr.2018.10.018

PSSupport_Esri. (October 26, 2022). "GLOBE Mosquito Habitat Mapper USF" [Layer]. Scale Not Given. Retrieved July 21, 2023, from https://igestrategies.maps.arcgis.com/home/item.html?id=5dc2f7e9cbfc4291bcd85622b1523b97#.

Rios, J., Hacker, C. S., Hailey, C. A., & Parsons, R. E. (2006). DEMOGRAPHIC AND SPATIAL ANALYSIS OF WEST NILE VIRUS AND ST. LOUIS ENCEPHALITIS IN HOUSTON, TEXAS. Journal of the American Mosquito Control Association, 22(2), 254–263. https://doi.org/https://doi.org/10.2987/8756-971X(2006)22[254:DASAOW]2.0.CO;2

Robbins, J. (2016, February 23). How forest loss is leading to a rise in human disease. Yale Environment360. Retrieved August 3, 2023, from https://e360.yale.edu/features/how_forest_loss_is_leading_to_a_rise_in_human_disease_malaria_zika_climate_change

State of Connecticut Mosquito Management Program. (n.d.). Mosquito Transmitted Diseases. Connecticut's Official State Website. Retrieved August 2, 2023, from https://portal.ct.gov/Mosquito/Diseases/Mosquito-Transmitted-Diseases

Texas Department of Transportation. (August 12, 2016). "TxDOT City Boundaries" [Layer]. Scale Not Given. "Polygon layer of Texas city boundaries.". Retrieved July 21, 2023, from https://igestrategies.maps.arcgis.com/home/item.html?id=09cd5b6811c54857bd3856b5549e34f0.

U98487415_usflibrary. (October 28, 2022). "iNaturalist USF" [Layer]. Scale Not Given. "iNaturalist USF". Retrieved July 21, 2023, from https://igestrategies.maps.arcgis.com/home/item.html?id=06fca9c70c9c4b668964e770583fcdcd.