Senegal And Florida: A Comparison Of Regions To Understand The Likelihood Of Mosquito Habitats

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NASA SEES INTERN 2020

Mosquito Mappers

July 28th, 2020

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1. Abstract

This research focuses on comparing two specific regions to understand how mosquito habitats can thrive in different climates. Florida's subtropic climate is ideal for mosquito habitats with the rainy summers and large amounts of water bodies scattered throughout the state. Rapid urbanization in Senegal gives way to pollution, an increase in the human population in a concentrated area, irrigation, impoundments, sand pools, and large amounts of artificial containers. The entrapment of water sources even during hot seasons is what allows mosquitos to thrive and transmit viruses such as malaria and dengue. In this research, three sources are used to obtain data: Climate Engine and AppEEARS applications for remote sensing and satellite data, and GLOBE Mosquito Habitat Mapper observations collected from the Advanced Data Access Tool (ADAT). Data was collected from both regions using the same parameters and date range to provide more precise results. The main questions being observed deal with climate, environmental factors, and human activity and their effect on the mosquito population. Based on the collected data, it can be hypothesized that mosquitos adapt within their region and find means for survival, whether it means puddles and still water sources in Florida or artificial containers in Senegal. The methods used in this research were a mix of fieldwork and data collection from available applications: GLOBE observer, Climate Engine, and AppEEARS. The data provides insight on environmental differences as well as the percentage of water source type obtained from the observations which explain mosquito habitat survival. It also shows that human activity and urbanization rapidly increase the mosquito population and the increase in virus transmission. A recommendation for a way to continue this research would be to increase the sample size of observations on mosquito habitats and enforcing prevention methods based on viable data trends.

Key Words: Mosquito Habitat, Environmental factors, Urbanization, Human activity, Climate

2. Research Questions

1. **How do mosquito habitats differ between different regions and how is their likelihood of success dependent on environmental factors such as land cover and human activity?**
2. **How does Florida's sub-tropical climate attract many mosquitos similar to Senegals warm semi-arid climate?**

The importance of these questions will allow for a deeper understanding of how mosquitos are able to thrive in any region and their ability to adapt and grow. Mosquitos' transmit viruses that can be harmful to humans if infected, therefore finding optimal ways to eliminate habitats will produce a safer and healthier community and world. Habitats tend to thrive depending on environmental factors such as climate and land cover as well as human activity such as urbanization and land use. This research will persist of GLOBE Mosquito Habitat Mapper observation data and remote sensing satellite data including Land cover, Normalized Difference Vegetation Indices (NDVI), and Land surface temperature using AppEEARS and Climate Engine.

3. Introduction

Environmental factors play a key role in determining the frequency of potential mosquito habitats in a certain region. The usual desirable climates consist of warm and humid weather alongside many potential bodies of water for mosquito larvae. The main concern is how different regions produce large mosquito populations and risks of epidemics. Understanding how environmental factors, urbanization, and human activity affect the likelihood of thriving habitats will allow us to determine the best way to reduce or effectively eliminate habitats that lead to a risk in contracting viruses.

The in-depth focus on Florida and Senegal is crucial to learn about regional differences and human activity that allow viruses to thrive. Florida is a sub-tropical (tropical near the South) climate and contains a large amount of permanent standing water which makes it attractive to *Aedes albopictus* and *Aedes aegypti* to name a few. Florida has 80 species of mosquitos with viruses such as West Nile (WNV), Eastern Equine Encephalitis virus (EEEV) as well as dengue fever. Senegal has a mixed climate between a warm desert climate up north, a warm semi-arid climate in the middle, and a tropical savanna climate in the South. The country is facing a current threat from the transmission of malaria. Africa is at the world stage for many mosquito-borne viruses, it's crucial to understand what makes the region so attractive to mosquitos. A closer look at these two regions will allow us to understand the patters that mosquitos tend to follow and their ability to adapt.

Review of literature suggests many different causations of high mosquito populations in regions such as human settlement, land cover type, and land-use, as well as the availability of water bodies or artificial containers. Norris (2004) explains that human modifications to the environment create potential new habitats for mosquitos to thrive and reproduce. Urbanization in a developing world allows for new habitats to form with irrigation systems, pollution, and impoundments sprawled across the cities. Junglen et al. (2009) describe that disrupted habitats saw a large and rapid increase of endemic viruses, especially with human settlements. This is important as it shows the impact of human activity and urbanization on the frequency of larval habitats. Excessive Land use and land-cover changes play a huge role in the increase in mosquito habitats. According to Mereta et al. (2013), monumental changes in land use and human activity will lead to changes in climate which have a huge potential of increasing development in mosquitos and intensify transmission of vectors such as malaria. Habitats in Africa most likely occur in sand and rain pools as well as pollution and artificial containers. According to a study done in Florida by Rey et al. (2006), *Aedes aegypti* habitats had a positive association with urbanization-related variables that include building coverage and were less likely associated with rural settings. Combining this understanding with data from GLOBE and remote sensing data from AppEEARS will give us insight into how we can reduce mosquito habitats.

4. Research Methods

The regions illustrated in **Fig. 1** were the areas of interest for this research. Florida is on the left, with a sub-tropical climate for most of the region and a tropical climate for the southern region of the state. Senegal is on the right with a mixed climate of a warm desert climate up north, a warm semi-arid climate towards the middle and a tropical savanna climate in the South. **Fig 2** shows the classifications of these regions climates using the Köppen climate classification. Although most of the data collected came from GLOBE, fieldwork observations were within central Florida since that is where I am based but included the larger scope of the state and collected all mosquito habitat observations within Florida and Senegal in order to have a larger sample size as well as a larger data set for accuracy and diversity within data. Based on the AppEEARS data, a large portion

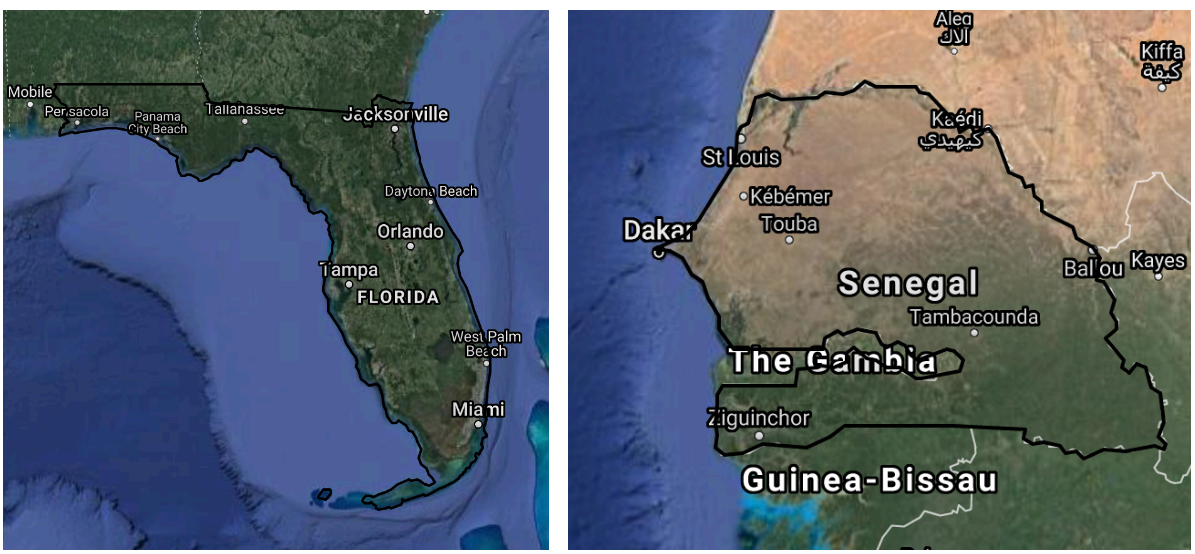

Fig. 1 Map of targeted regions: Florida, USA and Senegal

of Senegal’s land cover is Grassland (79.9%) followed up with croplands (12.8%) while

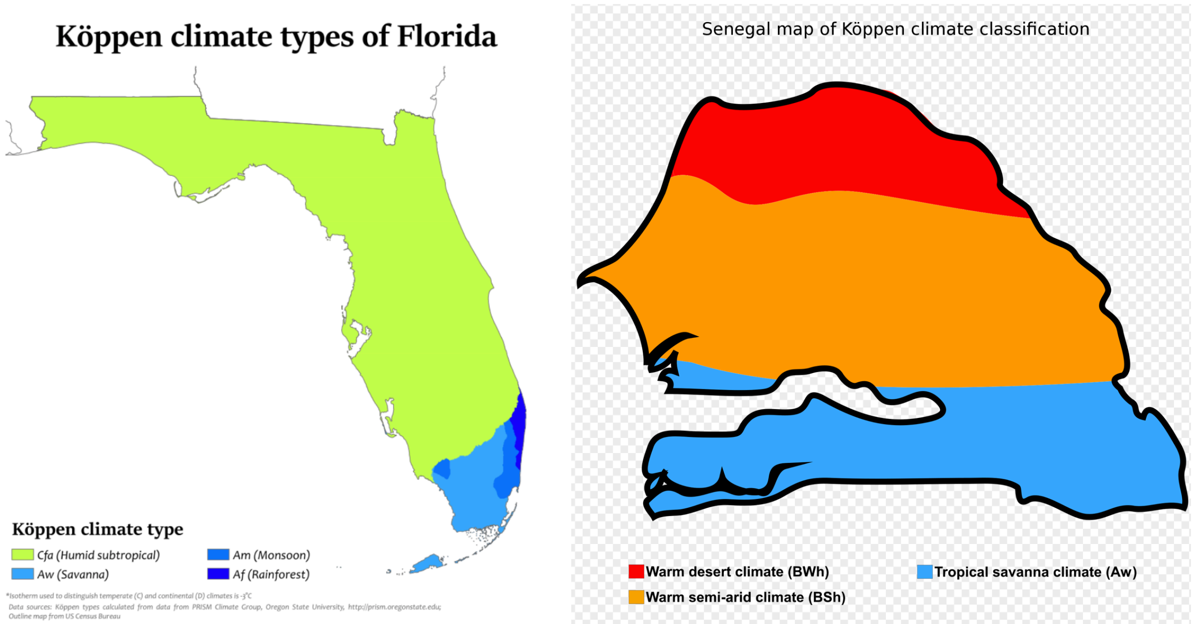

Fig. 2 Köppen climate classification of the targeted regions

on the other hand, Florida's major land cover features include savanna (31.9%) followed up with woody savannas (27.9%).

(i) Data collection

This research required data from three applications: GLOBE observer database using ADAT, AppEEARS for remote sensing, and satellite data on Land Cover and Land Surface Temperature (LST), and Climate Engine tool to calculate NDVI. Fieldwork data was restricted to Central Florida and had a total of 58 observations, 15 of those being Mosquito Habitat Mapper. This leads to many issues and restrictions to the research, first being a too-small sample size, the second being an inaccurate representation of Florida, and the third being unsuccessful larvae samples. To resolve the issue, data were expanded using GLOBE observer data that includes all observations taken in Florida. GLOBE data was accessed using ADAT. The protocols set to mosquito larvae and mosquito habitat mapper; the date set from January 1st, 2018 until July 27th, 2020. These parameters applied to both regions. The results showed a total of 527 sites with approximately 3200 observations for Senegal and a total of 133 sites with approximately 350 observations for Florida. These measurements allow for a detailed view of classifications of habitats and the number of larvae spotted, it also allowed for an understanding of the habitats found in the different regions and the most common type of habitat found in each area. AppEEARS was used for Area extraction and access to many different NASA satellites such as Aqua MODIS, Terra MODIS, and combined MODIS to explore land cover, and land surface temperature. Although Climate Engine had many restrictions on its data and what regions of the world one could access, it was successful in collecting data on NDVI between Senegal and Florida through its ‘Make a Graph’ feature. Using its access to MODIS Terra 16 data, the date ranged from Feb. 2015 to June 25, 2020, but the only data that will be used Jan. 2018 until June 25, 2020, to remain continuous and accurate with the rest of the collected data.

(ii) Data Analysis

Globe Observations were stored in Google Sheets and transferred into a graph. The values were then counted for each category to be illustrated by percentages. The data obtained from AppEEARS was also stored in Google Sheets. For Land Cover, Combined MODIS was applied with five layers: Type 1-5. The data were pooled and duplicates were removed to create a combined final chart that summarizes all land cover types found in the targeted regions. The value corresponds to the land cover type that is associated with the Collection 6 MODIS Land Cover (MCD12Q1 and MCD12C1) Product in AppEEARS. AppEEARS was also used to collect Land Surface Temperature using the MOD11A2 v006 MODIS/Terra Land Surface Temperature/Emissivity 8-Day L3 Global product, this provided a table full of statistical data of the temperatures (in Kelvin). The layers used were Land Surface temperature (LST) day and LST night as there is usually a slight difference in temperature between areas within regions such as urban areas containing warmer weather at night. This was stored into google excel and using the equation given in excel the averages were determined for median, mean, and standard deviation for both layers. Remote sensing was used from Climate Engine to NDVI (Vegetation index), the data was transformed into a graph comparing the two targeted regions.

5. Results

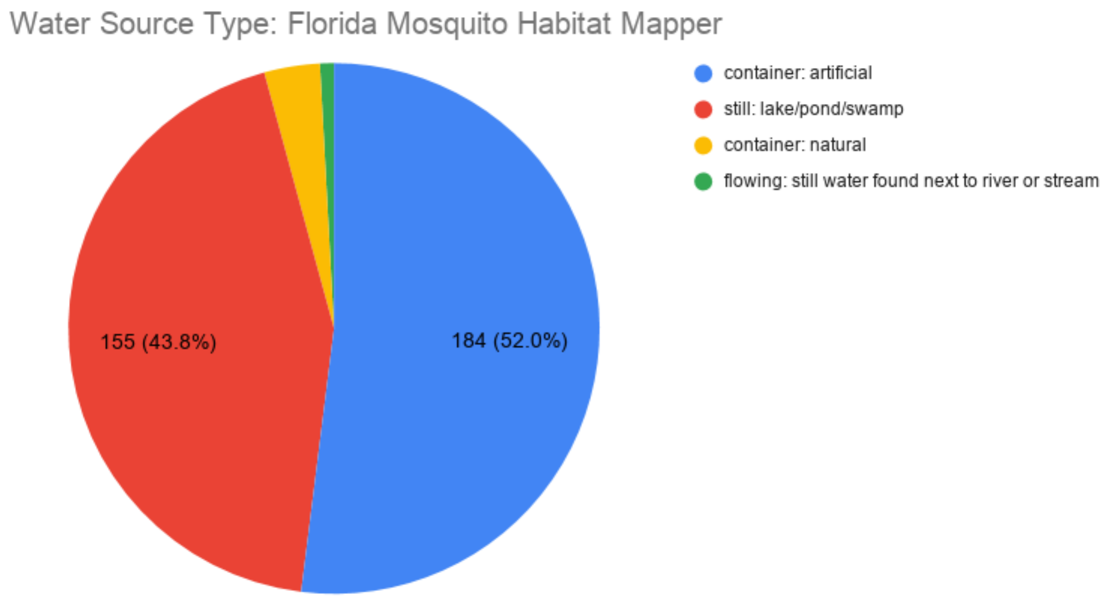

Fig. 3.1 Water Source Type: FL Mosquito Habitat Mapper. Total of ~350 obtained measurable data and 133 sites. Retrieved from GLOBE observer data (Includes personal observations collected in Central Florida)

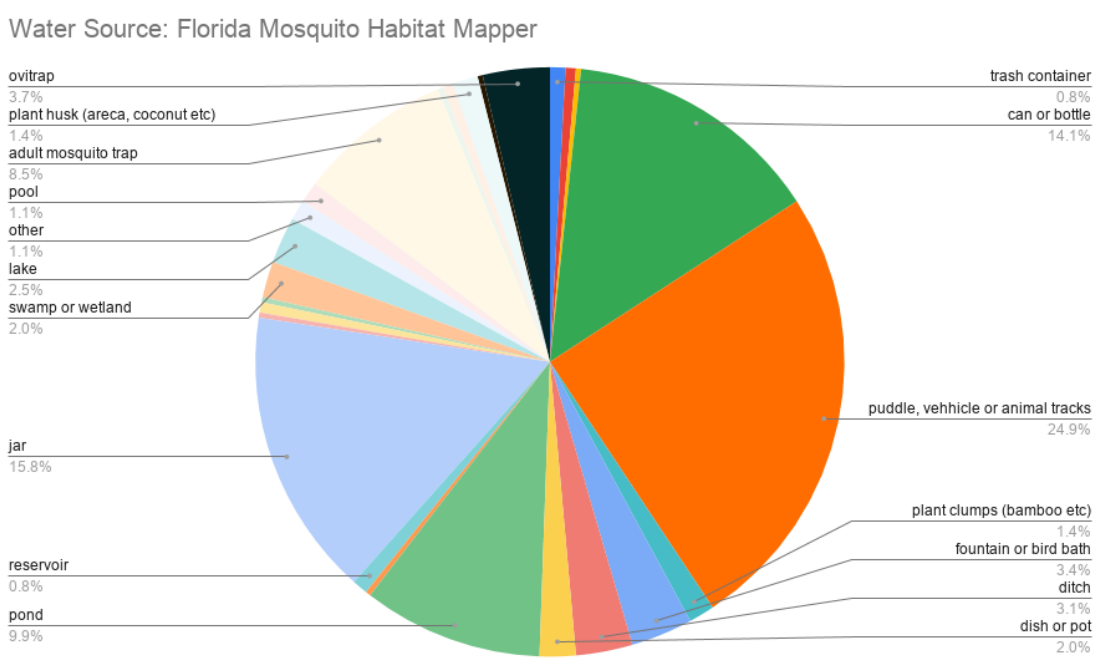

Fig. 3.2 Water Source: FL Mosquito Habitat Mapper. Total of ~350 obtained measurable data and 133 sites. Retrieved from GLOBE observer data

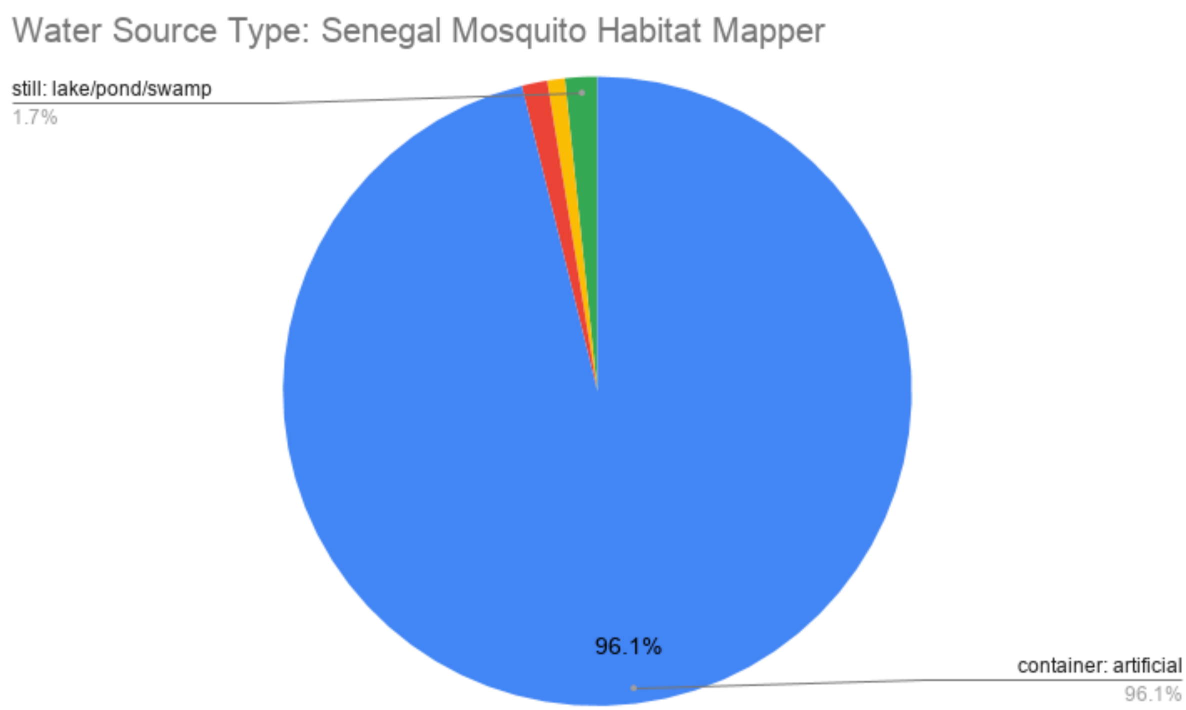

Fig 4.1 Water Source Type: Senegal Mosquito Habitat Mapper. Total of ~3200 obtained measurable data and 572 sites. Retrieved from GLOBE observer data

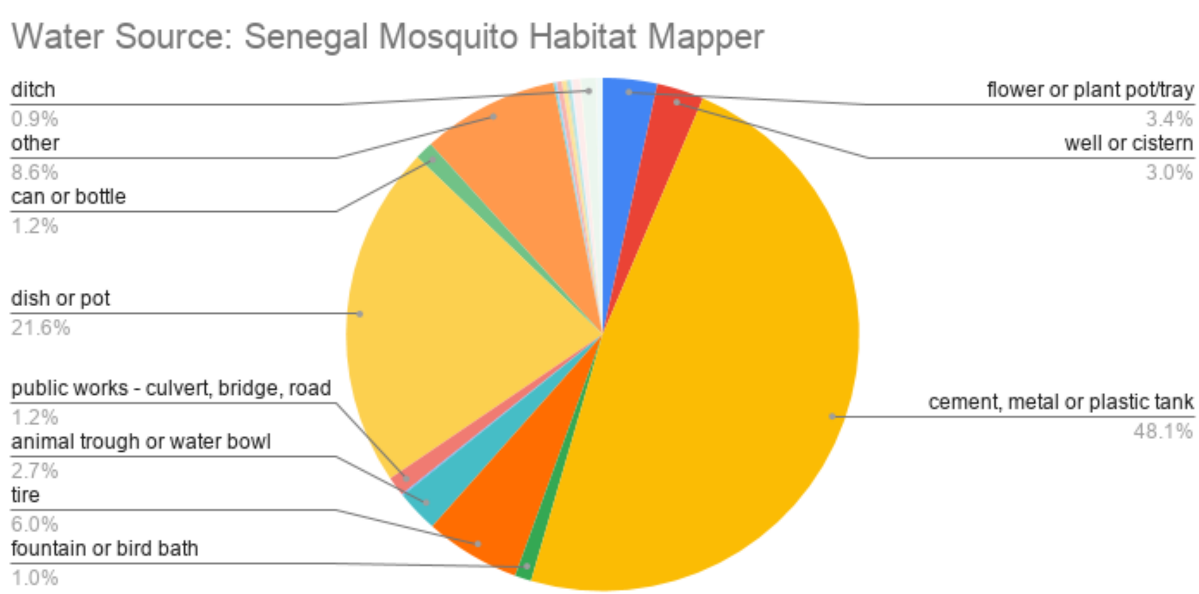

Fig. 4.2 Water Source: Senegal Mosquito Habitat Mapper. Total of ~3200 obtained measurable data and 572 sites. Retrieved from GLOBE observer data

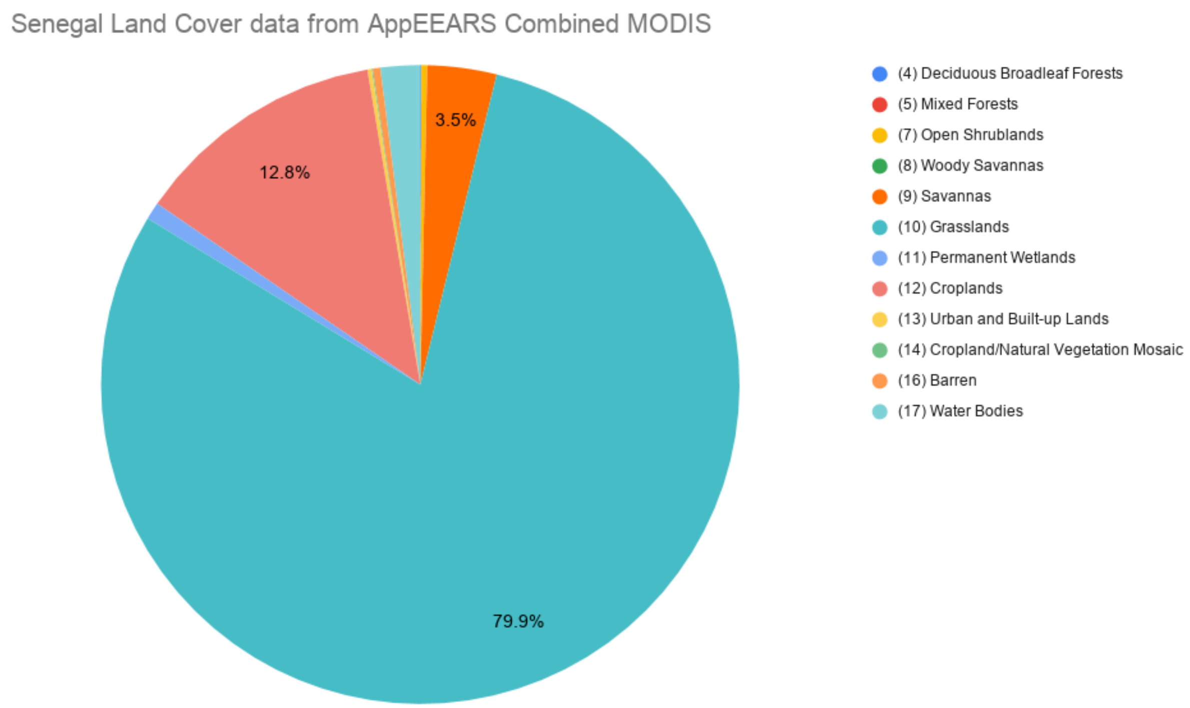

Fig. 5.1 Senegal Land Cover Data obtained from AppEEARS area extract using 5 layers that were pooled together (Type1-Type5)

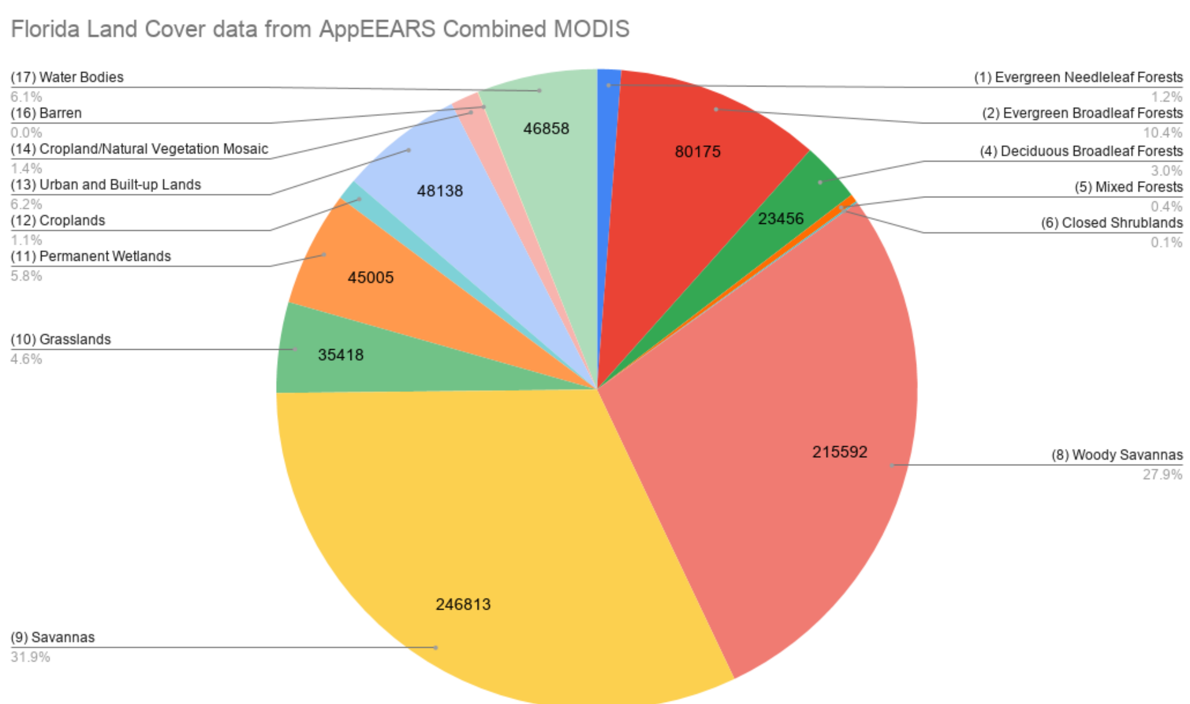

Fig. 5.2 Florida Land Cover Data obtained from AppEEARS area extract using 5 layers that were pooled together (Type1-Type5)

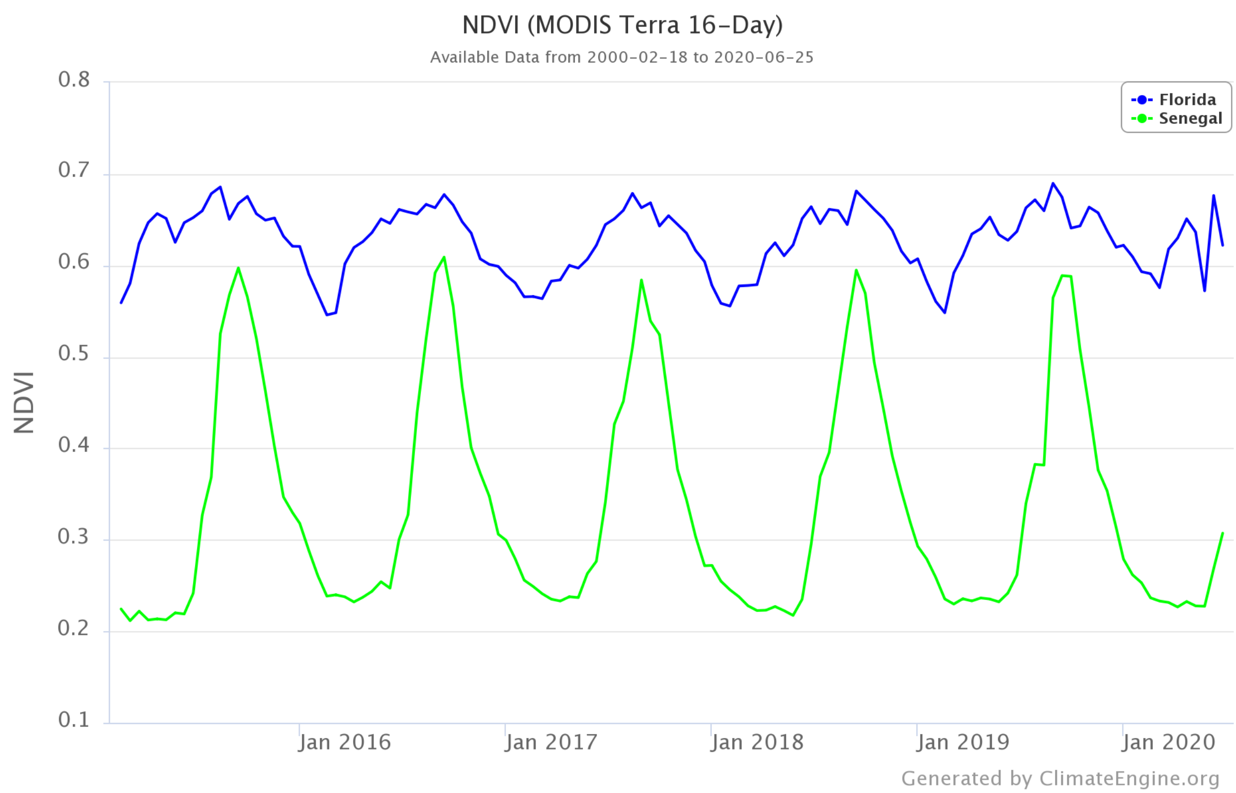

Fig. 6 NDVI (Normalized Difference Vegetation Index) data from Climate Engine. Senegal (green) vs. Florida (blue)

Table 1

	Avg. Mean	Avg. Std. Deviation	Avg. Median
LST Day (Day Land Surface Temperature)	299.3465627	3.227941525	299.22661016949
LST Night (Night Land Surface Temperature)	290.00359661017	2.5572025423729	290.0206779661

Fig. 7 FLORIDA Land Surface Temperature (In Kelvin)

Table 2

	Avg. Mean	Avg. Std. Deviation	Avg. Median
LST Day (Day Land Surface Temperature)	310.0518059322	3.5807728813559	310.36949152542
LST Night (Night Land Surface Temperature)	293.67586101695	2.4488186440678	294.03966101695

Fig. 7.2 SENEGAL Land Surface Temperature (In Kelvin)

Table 3 - Field Work Observations over the Summer of 2020

Mosquito Habitat Observations	Land Cover Observations	Cloud Observations	Tree Observations	TOTAL observations taken
15	15	4	24	58

Fig. 8.1 Total observations collected from Field Work broken down to category

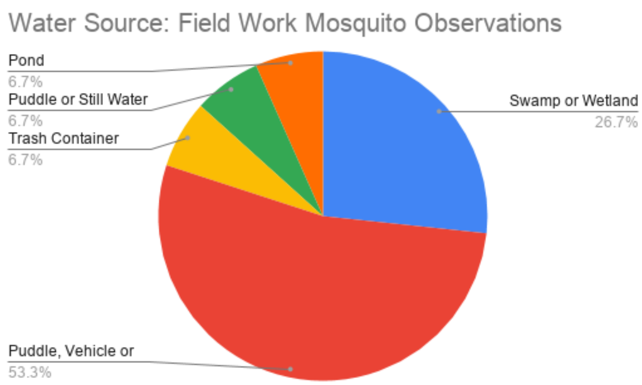

Fig. 8.2: Field work observations, water sources categories and percentage

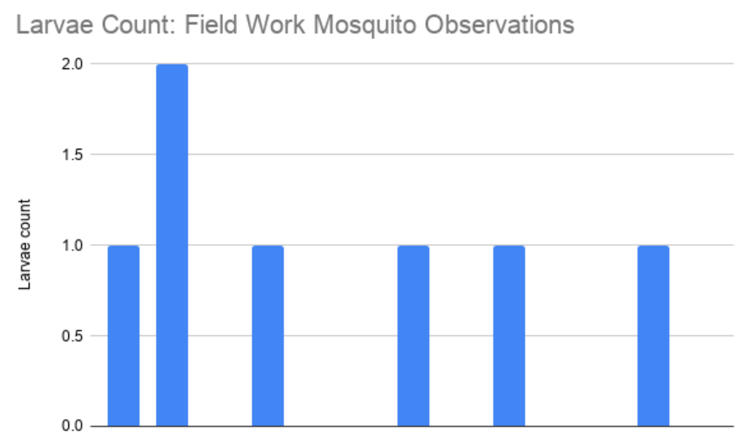

Fig. 8.3: Larvae count from the 15 total mosquito observations. 7 total Larvae found with a maximum of 2 and a minimum of 0

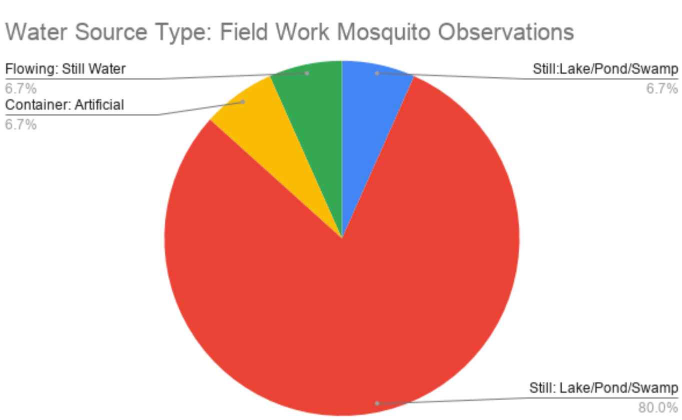

Fig. 8.4 Water Source Type categories and percentages from Field work Observations

6. Discussion

The fieldwork observations collected within the specified time frame (June-July) were not large enough to complete an accurate representation of the Mosquito Habitats in Florida. **Fig. 8.1** illustrates a total of 58 observations collected, 15 of which were Mosquito Habitat Mapper observations. And these were restricted to only Central Florida. **Fig. 8.3** illustrates the number of larvae collected, which ranges from 2 being the highest and 0 being the lowest. There was little to no success in the collection of Larvae. There is also a possibility of little success due to the sampling method. It usually followed sample collection, storage, and then later observation. The issue with that was that it could mean losing potentially successful samples of larvae since only one poor sample was collected and stored. Future fieldwork observations should be mindful of collecting useful samples and trying to complete them on-site, therefore in case of a sample not containing larvae, a second can be collected right away and this process can be repeated until a successful sample is obtained. Due to this issue and small sample size, it is necessary to collect GLOBE data on Mosquito Habitat Mappers from the entire state of Florida.

Fig. 3.1 illustrates that a little more than half (52.0%) of the types of water source found within the GLOBE Mosquito Mapper Habitat data is an artificial container and following right up with a little less than half (43.8%) of the observations were obtained in still water (lake/pond/swamp). When comparing this to Senegal, we find an interesting trend. **Fig. 4.1** shows the observations of water source types, an outstanding 96.1% of the samples were sampled from artificial containers, while only 1.7% was sampled from still water (lake/pond/swamp). Looking further into the data and breaking it down by water sources shows where the observations were obtained, illustrated by **Fig. 3.2** and **Fig. 4.2**. The majority of the observations in Florida from the data were collected from puddles, vehicle or animal tracks (24.9%) followed up by jars (15.8%) and can or bottle(14.1%). While on the other hand, already knowing that 96.1% of the water sources were artificial containers in Senegal, breaking it down by source gives us 48.1% of the observations contained in cement, metal or plastic tank along with 21.6% in a dish or pot followed up with 6.1% in tires. This shows the adaptive ability of mosquitos and how these two different regions can attract a huge population of mosquitos. Knowing this information is crucial as it allows for an understanding of which water sources are the main issues in the regions and how one can go about eliminating them.

Looking at landcover obtained by satellite imagery allows one to take this a bit further. According to **Fig. 5.1**, the approximate majority of land cover in Senegal is Grassland (79.9%) followed up with cropland (12.8%) and savanna (3.8%). This data was retrieved from the AppEEARS Combined-MODIS Land cover type and it is a rough estimate of the area so this is a potential source of error. The figures cannot be exact since area extraction requires either manual input of coordinates or to draw around the region and since the boundary was drawn, there could be potential sources of error with rough borders cutting out certain land areas. Keeping this in mind for Florida, we see the majority of land cover types are Savannas (31.9%), Woody savannas (27.9%), and Evergreen Broadleaf forest (10.4%). Comparing permanent wetlands and bodies of water, Florida has 5.8% and 6.1% respectively and Senegal has 0.9% and 2.0% respectively. Viewing this allows for the assumption that one of the main reasons why Senegal has such a high value of mosquito habitats is due to many artificial containers as opposed to Florida hosting mosquitos due to its tropical climate and high value of land cover pertaining to water.

Although no data was found for urbanization and increase in human activity, it has been a causing factor in land change and land use which ultimately brings about new habitats and leads us to the data from above. Urbanization in Senegal has proven to be one large factor of these habitats, mainly due to the attraction of pollution, irrigation, and impoundments. According to Rose et al. (2020), rapid urbanization and human activity will most likely shift mosquito evolution and strongly suggests that human stored water provided breeding sites for mosquitos to survive in the hot seasons. This explains the large amounts of habitats found in artificial containers in Senegal. Florida doesn't lose water over the summer mainly due to its rainy season. This ties back into the original research question observing how different climates are able to still produce mosquito habitats and how mosquitos are able to adapt to the region and reproduce.

The Normalized Difference Vegetation Index (NDVI) chart in **Fig. 6.0** shows the two regions, Senegal and Florida, and their vegetation index. Making sure to only look from January 2018 up until 2020 in order to flow with the continuity of the data in the research, both seem to reach their peak in September but slowly fall back down the scale between February (for Florida) and May (for Senegal). None of them fall below 0.2. Florida overall seems to have dense vegetation (ranges from ~0.55 to ~0.7) while Senegal seems to have a majority of sparse vegetation (~0.2 to ~0.6).

The observations continue further into Land Surface Temperature using the AppEEARS Combined MODIS product. Comparing the LST Day data between Senegal and Florida, it appears that Senegal on average has a slightly higher temperature (mean and median averages) and a slightly higher standard deviation. Comparing LST Night data, Senegal has a slightly higher temperature (mean and median averages) but a slightly smaller standard deviation. With the combination of land cover, water sources for the observations, NDVI measurements, and land surface temperature for both day and night, one can finally come to the conclusion that despite the difference in the regions climates and environment, they are still able to attract a significant amount of mosquitos due to their ability to adapt, evolve, and survive.

Potential sources of error still include the data for land cover as well as Land surface temperature since they were obtained from AppEEARS and are subject to human extraction error. Data collection from fieldwork mosquito observations collected in central Florida are subject to human sampling error since obtaining samples from water sources was quite difficult to make sure larvae were captured, stored, and brought back to be observed.

7. CONCLUSION

Mosquito habitat likelihood of success is largely dependent on environmental factors including land cover, land-use, and climate, as well as human activity and urbanization. The reason why two different regions have huge mosquito populations is because of the mosquitos' ability to adapt to the region's climate, land cover type, and the human activity around them. Florida's climate is an ideal place for mosquitos to thrive with large numbers of water bodies including ponds, lakes, and it's year-long ideal weather allows them to thrive and reproduce. Areas in Africa such as Senegal may not be the generalized ideal climate since it tends to get hot and areas dry up, but their ability to have large amounts of artificial containers, pollution in cities, and rapid urbanization all lead to the influx of habitats. The findings from the research can be useful in understanding ways to reduce and eliminate mosquito habitats especially in Africa where mosquito-borne viruses run rampant. With Senegal's large exposure to Malaria, it would be ideal to try and eliminate such habitats by reducing pollution and informing citizens to try and reduce their water-filled containers, filling in sand and rain pools and trying to do so quickly after heavy rain since they take a while to dry up leaving mosquito larvae the chance to develop. Understanding how differing climates can still produce successful mosquito habitats will allow us to eliminate those habitats if we can figure out why they thrive. Prevention in Florida could also include informing citizens to take care of artificial containers as they can hold in water, especially during the rainy summer months where they can fill up and last for days. Improvements would include better data collection from remote sensing applications to try and produce results as accurate as possible. More improvements include sampling mosquito larvae, rather than collecting the sample and storing it, try and observe the sample at the location of the source so that way in case one sample returned empty of larvae there is the ability to return and grab another sample. Follow-on-research should include in-depth analysis and a large sample size of mosquito observations in the regions since it will allow for a wider perspective of habitat characteristics. Working with a project mentor allows for guidance and aid which helps sharpen research and data collection skills. Doing this alone would not have given such in-depth results. It also allows for a learning experience and understanding certain important aspects of research.

8. Resources

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