**Southern Maine Health & Air Quality**

*Examining Tick-Borne Illness Risk by Evaluating Land Cover and Tick Habitat Suitability in Southern Maine*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:*** Tick-borne illnesses, including Lyme disease, are an increasing concern to communities in and around Cumberland County, Maine. To aid in prevention and mitigation efforts, this project examined the relationship between tick-borne illness, land cover type, and remotely sensed environmental parameters. This was completed through a land cover and environmental parameter analysis that communicates tick-borne disease risk at the town level. End products include tools that can evaluate the relationship between tick habitat suitability and the spatial distribution of disease incidence in Southern Maine.

***Abstract:***

Tick-borne diseases are a public health issue in southern Maine, and recent estimates completed by the State of Maine suggest that as little as 1 in 10 cases of Lyme disease are actually reported. There are three tick-borne diseases known to occur in Maine that can be transmitted by the deer tick (*Ixodes scapularis).* Due to the higher prevalence and attention from Maine public health institutions, Lyme disease was the predominant focus in this study. The Massachusetts – Boston NASA DEVELOP team partnered with the Maine Medical Center Research Institute, Lyme & Vector-Borne Disease Laboratory; Maine Vector-Borne Disease Working Group; and Bigelow Laboratory for Ocean Sciences to assist with Maine’s tick-borne disease mitigation efforts. The team utilized NASA data from Landsat 8 Operational Land Imager (OLI), Terra and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS), as well as ancillary datasets, from January 2008 to June 2019. Accurate land cover and tick-borne disease risk maps were created for Cumberland County, Maine. The land cover map allows for improved public awareness of areas conducive to tick encounter. The risk maps illustrate how variations in temperature and humidity contribute to the spatial distribution of tick-borne illness risk and determine the estimated number of actual Lyme disease incidents per year in every town. In addition, the team created a time series analysis that informs the end user’s research related to the impact of environmental parameters on tick distribution.

***Keywords:***

remote sensing, ticks, vector-borne illnesses, land cover, MODIS, Landsat

***National Application Area Addressed:*** Health & Air Quality

***Study Location:*** Cumberland County, Maine

***Study Period:*** January 2008 to June 2019

***Community Concerns:***

* Tick-borne illnesses, including Lyme disease, anaplasmosis, and babesiosis, are of increasing concern to communities and recreationists in Maine.
* The Maine Department of Health and Human Services reported 1,769 confirmed or probable cases of Lyme disease in the state during 2017.
* Recent estimates suggest that as little as 1 in 10 cases of Lyme disease are reported in Maine; this tendency to underreport often makes medical intervention difficult, and there remains a need for expanding public health efforts to prevent and mitigate contact with ticks that may carry disease.
* Efforts to identify community-level locations of high tick encounter risk are necessary to provide the public with informative disease risk advisories.

***Project Objectives:***

* Create a land cover map and corresponding Google Earth Engine code that helps target areas for tick monitoring efforts and advise the community on the location of land cover types predisposed to high risk of tick encounter
* Examine the relationships between remotely sensed environmental parameters and the distribution of tick-borne illnesses
* Improve public awareness of high disease risk locations while also informing future research related to tick-borne illness mitigation efforts

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Maine Medical Center Research Institute, Lyme & Vector-Borne Disease Laboratory** | Chuck Lubelczyk, Field Biologist; Dr. Rob Smith, Director and Co-Founder; Dr. Susan Elias, Staff Scientist  | End User | Yes |
| **Maine Vector-Borne Disease Working Group**  | Dr. Susan Elias, Staff Scientist | End User | Yes |
| **Bigelow Laboratory for Ocean Sciences** | Dr. Nick Record, Senior Research Scientist | Collaborator | No |

***Decision-Making Practices & Policies:***

The Maine Medical Center Research Institute (MMCRI) monitors the geography of tick-borne illness risk, researches ways to mitigate tick encounters, and conducts public health outreach to inform community members about what steps they can take to avoid tick-borne illness. The organization’s research and outreach efforts are completed in partnership with government and academic institutions. The Maine Vector-Borne Disease Working Group is a consortium of researchers and public health officials who leverage the resources of their organizations together to more holistically examine tick-borne illness in the State of Maine. Disease risk communicated to partner organizations and community members is completed predominantly with *in situ* data. MMCRI is familiar with spatial analysis; however, remote sensing is not currently involved in its decision-making practices.

***Project Benefit to End User:***

An accurate land cover map and visualizations of tick-borne disease risk will allow for improved public awareness for areas conducive to high tick abundance and disease risk. The time series tool will inform the end users’ research related to the impacts of environmental parameters on tick distribution. These end products will ultimately save the end users time, money, and resources that would be spent creating land classifications and attempting to utilize NASA Earth observation data products without the assistance of a DEVELOP team. Overall, the end users will use these tools to improve their current tick-borne illness mitigation efforts and explore further research options utilizing NASA Earth observations.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface reflectance | Landsat 8 Operational Land Imager (OLI) data were used in order to complete land cover classifications for mapping Cumberland County.  |
| **Terra MODIS** | Land surface temperature (LST)  | Terra Moderate Resolution Imaging Spectroradiometer (MODIS) was used to incorporate LST data into the land cover and relationship analysis. The relationship analysis between environmental parameters and disease risk was used to assess risk.  |
| **Aqua MODIS** | LST | Aqua MODIS was used to incorporate LST data into the land cover and relationship analysis. The relationship analysis between environmental parameters and disease risk was used to assess risk.  |

***Ancillary Datasets:***

* Parameter-elevation Regressions on Independent Slopes Model (PRISM) – incorporating precipitation data into the land cover and relationship analysis
* University of Idaho Gridded Surface Meteorological Dataset (gridMET) – incorporating humidity data into land cover and relationship analysis
* State of Maine Tracking Network Tick-Borne Disease Data – estimating the relationship between land cover, environmental parameters, and disease incidence
* Unites States Department of Agriculture (USDA) Forest Inventory and Analysis (FIA) – refining and ground-truthing land cover classifications
* USGS National Land Cover Database (NLCD) – incorporating impervious surface data into land cover classifications

***Modeling:***

* Boston University Ecological Forecasting Lab Simple Bayesian Modeling using JAGS (Just Another Gibbs Sampler) (POCs: John Foster & Tess McCabe, Boston University) – incorporating land cover and environmental parameter data into modeled risk assessments

***Software & Scripting:***

* Google Earth Engine (GEE) API – data acquisition and processing, land cover classification and mapping, and time series analysis
* R – data processing, time series analysis, geospatial statistics, and modeling
* Esri ArcGIS Pro – mapping and data visualization

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Cumberland County Current Land Cover Maps and GEE Code for Supervised Land Cover Classification (SLaCC) Tool** | Landsat 8 OLI  | The partner will use these maps to target areas for tick monitoring efforts and advise community members on the location of land cover types predisposed to high risk of tick encounter. The code will be shared with the partner for future land classification efforts. | III |
| **Hydrologic Inputs Tool (HIT)** | Terra MODISAqua MODIS | This tool is a modified version of HIT, integrating different datasets over the new study area and study period. The partner will use this adapted time series tool to see how variations in environmental parameters contribute to the spatial distribution of tick-borne disease risk.  | V |
| **Modeled Tick-Borne Disease Risk Maps and Figures** | Terra MODISAqua MODIS | Tick-borne disease risk maps and figures will be used by the partner in public health outreach efforts to communicate the locations of high tick-borne disease risk areas within Cumberland County, ME. | N/A |
| **Tutorial for HIT and SLaCC Tool** | N/A | This tutorial will walk the end user through the SLaCC tool code and modified version of HIT, ensuring that each will remain usable for future land classification and environmental monitoring efforts. | N/A |

**Project Handoff Package**

***Transition Plan:*** A handoff took place in week 10 of the term at the Maine Medical Center Research Institute. The team presented the results of the project to partners, walked through all end products, and answered questions. Maps and the time series analysis outputs were set to be immediately integrated into the end user’s public awareness activities and research. Code for the SLaCC Tool and HIT are to be shared with partners after the NASA Software Release Process is complete, along with tutorials on the use of each tool. The partner can use this code to create land cover maps and monitor environmental conditions in future years.

***Software Release Plan:*** The partners were informed that the SLaCC code and HIT code will undergo the NASA Software Release Process, resulting in a delay in their ability to access it. NASA’s Software Release team will review the software and its accompanying components for approval; once approved, the products will be delivered to the partners via GitHub, along with a tutorial that will walk the end user through the code.

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***Partner POC:*** Dr. Susan Elias, susan.elias@maine.edu

***Handoff Package:***

* Cumberland County Current Land Cover Maps
* Modeled Tick-Borne Disease Risk Maps and Figures
* Technical Paper
* Poster
* Presentation

**References**

Kalluri, S., Gilruth, P., Rogers, D., & Szczur, M. (2007). Surveillance of arthropod vector-borne

infectious diseases using remote sensing techniques: A review. *PLoS Pathogens, 3*(10),

e116. <https://doi.org/10.1371/journal.ppat.0030116>

Maine Medical Center Research Institute. (2017). *Prevention & control*. Retrieved June 20, 2019, from

<http://mmcri.org/ns/?page_id=3623>

Ozdenerol, E. (2015). GIS and remote sensing use in the exploration of Lyme disease epidemiology.

*International Journal of Environmental Research and Public Health, 12*(12), 15182-15203.

<https://doi.org/10.3390/ijerph121214971>

State of Maine. (2019). *Tickborne diseases*. Retrieved June 20, 2019, from https://data.mainepublichealth.gov/tracking/ tickborne-content