**New York Ecological Forecasting II**

*Comparing Efficiency of Space-Based Imagery to AVIRIS Airborne Data for the Identification of Hemlock Forests to Mitigate Invasive Species Expansion*

**VPS Title:** Alien Invasion: Mapping Hemlock Forests for Hemlock Woolly Adelgid Management

**Project Team**

***Project Team:***

Rya Inman (Project Lead)

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***Advisors & Mentors:***

Dr. Ezra Schwartzberg (Adirondack Research, LLC)

Dr. Jennifer Pontius (University of Vermont Rubenstein, School of Environment and Natural Resources)

***Past or Other Contributors:***

Dr. Sara Lubkin

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**Project Overview**

***Project Synopsis:*** The invasive hemlock woolly adelgid (*Adelges tsugae*; HWA) threatens eastern hemlock (*Tsuga canadensis*), a keystone species, throughout the eastern United States. This project aimed to map the range of eastern hemlock in New York State to help land managers better detect the latest HWA infestations and conserve the hemlock species. This study assessed whether Earth observations from NASA space-based sensors can provide more accurate and cost-effective hemlock distribution maps compared to Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) data from a previous term project.

***Abstract:***

Hemlock woolly adelgid (HWA; *Adelges tsugae*) is an invasive species that threatens eastern hemlock (*Tsuga canadensis*) in US forests. Eastern hemlock has a greater capacity to store carbon, regulate stream temperatures, and provide habitat for wildlife compared to sympatric tree species. The New York Ecological Forecasting II team partnered with the New York State Department of Environmental Conservation’s Partnership for Regional Invasive Species Management, Adirondack Park Invasive Plant Program (APIPP) and Partnership for Regional Invasive Species Management, Saint Lawrence - Eastern Lake Ontario (SLELO PRISM), Adirondack Research, Cornell University, and the University of Vermont to support their hemlock conservation efforts. APIPP and SLELO currently lack detailed location data on hemlock stands. We created four hemlock distribution maps modeled using a random forest (RF) classifier in Google Earth Engine (GEE), each using data from either Landsat 8 Operational Land Imager (OLI) or Sentinel-2 Multispectral Imager (MSI), as well as variables closely linked to hemlock habitat (e.g. elevation, aspect, distance to nearest stream, soil moisture, soil acidity, land cover type). Ground-surveyed hemlock presence points allowed the team to train and validate these models and compare the accuracy of previous Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) models to satellite-based models. Our team then used ancillary datasets, including HWA presence data and distance to nearest stream, to predict hemlock mortality in New York and forecast forest stream resiliency through 2049. These maps aim to improve APIPP’s and SLELO’s current hemlock inventories and HWA early detection efforts. Hemlock distribution maps created from OLI and MSI provide more efficient, repeatable models of hemlock distribution than those created with AVIRIS data alone. Our forecasting model also supports predictions that HWA spread will result in decreased hemlock populations across NY through 2049.

***Keywords:***

remote sensing, Landsat 8, Terra ASTER, Sentinel-2, species distribution, eastern hemlock (*Tsuga canadensis*), hemlock woolly adelgid (*Adelges tsugae*)

***National Application Area Addressed:*** Ecological Forecasting

***Study Location:*** New York State (NY)

***Study Period:*** January 2016 to January 2019, Forecasting to 2049

***Community Concerns:***

* Eastern hemlock (*Tsuga canadensis)* is a key feature in forested ecosystems in the eastern United States.
* This late-successional species is considered a valuable resource to wildlife since it retains lower branches, creating complex vertical structures throughout the height of the tree.
* The introduction of HWA has the potential to eradicate this species from forested ecosystems.
* Previous studies of HWA have demonstrated the declining abundance of hemlock-associated species, such as the black-throated green warbler, blackburnian warbler, and hermit thrush, as hemlock declines.
* As long-lived trees, eastern hemlocks have the potential to store larger quantities of carbon through biomass, leaf litter, and soil for long periods of time compared to other species found in the same ecosystems. As hemlock is lost, total carbon storage of forests decreases.
* Hemlock helps regulate thermal and hydrologic regimes within forests. Streams co-located with hemlock stands tend to be cooler in summer and warmer in winter, leading to higher species richness in these streams and creating stable habitat for aquatic species, such as brook trout.

***Project Objectives:***

* Utilize NASA Earth observations (EO) to map eastern hemlock distribution in New York State
* Determine pros and cons of each EO product tested to refine methodology for repeated future use
* Analyze the success of the 2017 Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) based hemlock distribution map using ground survey data
* Compare the success of mapping hemlock during leaf-on versus leaf-off periods

***Previous Term:*** 2017 Spring (GSFC) – New York Ecological Forecasting

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **New York State Department of Environmental Conservation, Partnership for Regional Invasive Species Management, Adirondack Park Invasive Plant Program (APIPP)** | Brendan Quirion, Program Manager; Zach Simek, Terrestrial Invasive Species Project Coordinator | End User | No |
| **New York State Department of Environmental Conservation, Partnership for Regional Invasive Species Management, Saint Lawrence - Eastern Lake Ontario (SLELO PRISM)** | Rob Williams, Invasive Species Program Coordinator; Megan Pistolese, Education and Outreach Coordinator | End User | No |
| **Adirondack Research LLC** | Dr. Ezra Schwartzberg, Director/Entomologist | Collaborator | No |
| **Cornell University, New York Invasive Species Research Institute** | Dr. Mark Whitmore, Entomologist; Carri Marschner, Invasive Species Extension Associate | Collaborator | Yes |
| **University of Vermont, Rubenstein School of Environment and Natural Resources** | Dr. Jennifer Pontius, Research Associate Professor | Collaborator | Yes |

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

APIPP and SLELO are two of eight Partnerships for Regional Invasive Species Management (PRISMs) in New York State (NYS). APIPP and SLELO coordinate efforts through the NYS Hemlock Initiative to mitigate the impending expansion of HWA into unaffected areas of the state. They gather the latest information relating to invasive species, coordinate actions among partner organizations, and communicate the current needs of the Adirondack Region regarding invasive species management. Through their expanding regional early detection network, APIPP and SLELO are able to identify, detect, and report new infestations and deploy rapid response teams to mitigate the spread of invasive species. Currently, they are not using NASA Earth observations and remote sensing techniques to inventory hemlock for early HWA detection. Rather, they are using on-the-ground observations to maintain their spatiotemporal database.

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

Conducting monitoring surveys for eastern hemlock can often be costly and time-consuming if not guided by accurate habitat distribution models. Hemlock stands tend to grow in dispersed patches that make hemlock difficult to identify solely through on-the-ground observations. The rapid pace at which HWA can impact hemlock demands the quick response of land managers. Therefore, hemlock distribution maps, an accuracy assessment of the 2017 AVIRIS-based hemlock distribution map, and a forecasting model will support APIPP and SLELO’s efforts to prioritize areas of hemlock for early HWA detection and prevention. The ability to identify all hemlock stands to focus monitoring surveys will help APIPP and SLELO deter the spread of HWA to unaffected forested regions. The ability to use spatial data to better predict the locations of hemlock stands will improve the ability of land managers to identify areas for conservation. An accurate habitat distribution model will give APIPP and SLELO the tools they need to narrow down hemlock stands to survey for signs of HWA damage.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Landsat 8 OLI** | Multispectral vegetation indices | The team used Landsat 8 OLI data to create a new predictive model of hemlock distribution in the state of New York. Multi-temporal and multispectral measurements were used to help identify evergreen species phenology and distribution in the modeling process. |
| **Terra ASTER** | Multispectral vegetation indices | The team assessed Terra ASTER data for use creating a new predictive model of hemlock distribution in the state of New York. |
| **Sentinel-2 MSI** | Multispectral vegetation indices | The team used Sentinel-2 MSI data to create a new predictive model of hemlock distribution in the state of New York. Multi-temporal and multispectral measurements were used to help identify evergreen species phenology and distribution in the modeling process. |
| **SRTM V3** | Elevation, aspect, curvature, topographic position, flow accumulation, soil moisture | The team used SRTM data to include each of the listed parameters in the classification model, in order to increase the complexity of the model. |
| **NASA ER-2 Jet AVIRIS** | Hemlock presence/absence | The team used new field survey points to evaluate the accuracy of the 2017 AVIRIS-based hemlock distribution map created by the previous New York Ecological Forecasting team. |

***Ancillary Datasets:***

* iMapinvasives Invasive Species Distribution Data – ground observations of HWA (presence and absence) were used for model inputs and cross-validation
* World Wildlife Fund Hydrological Data and Maps Based on Shuttle Elevation Derivatives at Multiple Scales (HydroSHEDS) – georeferenced hydrological data were used as model inputs
* United States Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) Dataset – georeferenced street data were used as model inputs
* USDA Soil Survey Geographic Database (SSURGO) – soil inputs were used for classification and regression tree analysis
* USDA Cropland Data Layer (CDL) – land cover data were used as model inputs
* USDA New York State Tree Distribution Model – supplementation, verification, and comparison to models, *in situ* data, and Earth observations
* USGS National Land Cover Database (NLCD) Land Cover Collection – land cover data were used as model inputs
* NASA Earth Exchange NEX-DCP30 Downscaled Climate Model – climate scenarios were used in forecasting
* New York Natural Heritage Program Stacked Distribution Models – conifer presence/absence data were used for supplementation, verification, and comparison to models
* Adirondack Research Hemlock Cover Class – 2018 hemlock cover class from ground observations were used as model inputs and comparisons
* Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group 30-Year Normals – January average minimum temperature data from 1981 to 2010 were used as model inputs

***Modeling:***

* Random forest (RF) classification model in Google Earth Engine for predicting hemlock distribution (POC: Dr. David Lagomasino, Post Doctoral Scientist, NASA Goddard Space Flight Center)

***Software & Scripting:***

* Esri ArcMap – final map creation and formatting
* Google Earth Engine API – acquisition and mapping of Landsat 8 OLI, Terra ASTER, Sentinel-2 MSI, and ancillary data
* Harris Corporation ENVI – analyzing spectral signatures of mapped classes from Landsat 8 OLI, Terra ASTER, and Sentinel-2 MSI maps

***End Product(s):***

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| --- | --- | --- | --- |
| **End Product(s)** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Hemlock Distribution Map (per sensor)** | Landsat 8 OLI  Sentinel-2 MSI  Terra ASTER  SRTM V3 | Partners will use this map to better focus monitoring of HWA invasions on hemlock stands. Having a species distribution map will reduce the time it takes for managers to identify and respond to invasions. | I |
| **Hemlock Distribution Forecasting Map** | Landsat 8 OLI  Sentinel-2 MSI  Terra ASTER  SRTM V3 | Partners will use this assessment to track projected changes in hemlock distribution over time. This will help land managers better anticipate where to focus conservation efforts and best management practices. | I |
| **Mapping Methodology and Tutorial** | Landsat 8 OLI  Sentinel-2 MSI  Terra ASTER  SRTM V3 | Partners can apply the methodology employed in this study for continual use in their efforts to combat HWA infestation. This methodology and tutorial will cover our Hemlock Distribution Map and Hemlock Distribution Forecasting Map. | III |
| **2017 AVIRIS-based Hemlock Distribution Map Accuracy Assessment** | NASA ER-2 Jet AVIRIS | Partners will use this assessment to determine the accuracy of maps created using airborne data. They will compare these results to maps created with satellite data to determine if satellites offer a cheap and reliable alternative for identifying hemlock stands. | N/A |

**Project Handoff Package**

***Transition Plan:*** Our team held a Week 10 video teleconference with all project partners attending remotely. We reviewed the team’s findings from all tested sensors and discussed validation of the 2017 AVIRIS map and the new hemlock distribution maps derived from space-based sensors with the field data collected by Dr. Ezra Schwartzberg’s team.

***Software Release Plan:*** Our team has notified all project partners that code utilized in Google Earth Engine will need to go through the NASA Software Release Process. As this process extends beyond the duration of the term, Project Lead Rya Inman has been appointed as the long-term POC to maintain contact with the partners and deliver the final code.

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***Software Release POC:*** Rya Inman, ryainman16@gmail.com

***Partner POC:*** Ezra Schwartzberg, ezra@adkres.org

***Handoff Package:***

* Project Summary
* Technical Paper
* Poster
* Presentation
* Project Video
* Hemlock Distribution Map (per sensor)
* Hemlock Distribution Forecasting Map
* 2017 AVIRIS-based Hemlock Distribution Map Accuracy Assessment

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