**NASA DEVELOP National Program**

**2019 Summer Project Proposal**

**Maryland – Goddard**

**New York Ecological Forecasting II**

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

**Project Overview**

***Project Synopsis*:** This study will use project-specific ground survey data, collected by Adirondack Research in 2018, to establish a repeatable methodology that creates distribution maps of hemlock stands in and around New York’s Adirondack Park. The methodology will prioritize space-based sensors (Landsat 8 OLI, Sentinel-2 MSI, ISS GEDI, and ICESat-2 ATLAS) over costly airborne AVIRIS data, filling gaps in hemlock maps that the 2017 Spring DEVELOP team could not fill due to limited data resources. Partners, including the Adirondack Park Invasive Plant Program (APIPP) and Adirondack Research, will then verify hemlock stands with ground-truth surveys, scheduled for fall 2019, to determine which sensors inform the best models of hemlock distributions across Adirondack Park. The APIPP and Adirondack Research need these models to guide their ground survey prioritization protocols and to assess whether or not emerging satellite technologies can provide data that are equally or more useful than data generated from costly AVIRIS flights.

***Community Concern:*** Eastern hemlock is a keystone species in many eastern US forests, providing food and habitat for native flora and fauna while also regulating temperatures within nearby streams. The hemlock wooly adelgid (HWA) is an invasive insect pest that has decimated populations of eastern hemlock in 18 states and whose range continues to spread northward. Detecting new HWA infestations at the leading edge of its range is critically important for slowing the spread of this destructive insect. Prioritization of ground survey locations is essential for cost effective early detection efforts and survey prioritization requires knowledge of where hemlock stands occur throughout the Adirondack Park. Accurate habitat modeling using spectral imagery is the only feasible method of doing this time- and cost-effectively, and a verifiable methodology is necessary to create accurate distribution maps of hemlock stands that can be utilized for cost effective management of HWA.

***Source of Project Idea:*** Dr. Ezra Schwartzberg reached out to leadership at the Maryland – Goddard Node to request a follow-on project to the 2017 Spring New York Ecological Forecasting project after further field collections were completed. These field surveys located pure and mixed hemlock stands over 60 m in diameter, providing increased presence data to bolster modeling efforts.

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

***Study Location:*** NY

***Study Period:*** January 2016 – January 2019; Forecasting to 2035

***Advisors:*** Dr. Jennifer Pontius (University of Vermont Rubenstein School of Environment and Natural Resources), Dr. Ezra Schwartzberg (Adirondack Research LLC).

**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 | 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 | No |

***End-User Overview***

***End User’s Current Decision-Making Process:***APIPP and SLELO PRISM coordinate actions among their founding partners to protect the Adirondack region from widespread damage by invasive species. These initiatives include prevention, education, early detection, and rapid response efforts. APIPP and SLELO also conduct data analysis for the region and use GIS tools to maintain a spatiotemporal database for both aquatic and terrestrial invasive species. These data points are collected through on-the-ground efforts by the program, its partners, contractors, and volunteers. They do not currently use satellite remote sensing techniques for mapping hemlock inventories or for early detection. While APIPP and SLELO collect data on invasive species, they do not have detailed location data for eastern hemlock stands. They recently initiated the New York State (NYS) Hemlock Initiative to mitigate the impending invasion of hemlock wooly adelgid to areas of the state that are currently unaffected. APIPP and SLELO PRISM’s early detection efforts would greatly benefit from hemlock distribution maps, making this a top priority.

***End User’s Capacity to Use NASA Earth Observations:***

*New York State Department of Environmental Conservation, Partnership for Regional Invasive Species Management, Adirondack Park Invasive Plant Program (APIPP)* – The Adirondack Park Invasive Plant Program (APIPP) uses invasive species geospatial data to prioritize early detection surveys and rapid response tactics, and to create long-term management plans for both aquatic and terrestrial invasive species. In 2017, NASA DEVELOP created initial models of hemlock stand locations for this purpose. In 2018, Adirondack Research and APIPP ground-truthed these models and determined that improved models, utilizing the newly collected hemlock data, are needed to guide prioritization planning for early detection and rapid response to the spread of HWA.

*New York State Department of Environmental Conservation, Partnership for Regional Invasive Species Management, Saint Lawrence - Eastern Lake Ontario (SLELO PRISM)* - SLELO PRISM plays a similar role to APIPP as one of New York’s eight PRISMS. The organization will utilize prioritization models created from these data products within its region. They are located to the west of APIPP and encompass hemlock habitat as well as past AVIRIS flight band data. They also use GIS tools to maintain a spatiotemporal database for both aquatic and terrestrial invasive species found within the state.

***Collaborator & Boundary Organization Overview***

***Collaborator Support:***

*Adirondack Research LLC* – In 2018, Adirondack Research performed ground surveys of pure and mixed hemlock stands as part of an ongoing United States Department of Agriculture-funded project related to the 2017 Spring NASA DEVELOP team project. Adirondack Research plans to conduct additional ground verification surveys utilizing the 2019 Summer NASA DEVELOP team project results to inform future survey locations.

*University of Vermont, Rubenstein School of Environment and Natural Resources* – Dr. Jennifer Pontius aided in the design of ground-truthing surveys, which collect data on hemlock stands and composition. These surveys are being utilized for the 2019 Summer NASA DEVELOP team project. Dr. Pontius will also be advising on AVIRIS data modeling for comparison to the other space-based sensors.

*Cornell University, New York Invasive Species Research Institute* – The mission of the New York Invasive Species Research Institute (NYISRI) is to coordinate invasive species research to help prevent and manage the impact of invasive species in New York State. Its main role is to coordinate researchers and experts in advising APIPP’s prioritization of early detection and rapid response control tactics aimed at mitigating the spread of HWA in New York State.

***Dissemination by Boundary Organizations*:**

*Cornell University, New York Invasive Species Research Institute* – The mission of the New York Invasive Species Research Institute (NYISRI) is to coordinate invasive species research to help prevent and manage the impact of invasive species in New York State. Its main role is to coordinate researchers and experts in advising APIPP’s prioritization of early detection and rapid response control tactics aimed at mitigating the spread of HWA in New York State. In addition to the organizations listed above, NYISRI disseminates information to the NYS Invasive Species Council and the NYS Invasive Species Advisory Committee.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** Dr. Ezra Schwartzberg will be the primary POC for communication with the DEVELOP Project Lead and other partners. Weekly or biweekly teleconference calls and email exchanges will be maintained throughout the course of the term.

***Transition Plan*:** Prior to the completion of the project, model outputs and maps will be handed off to partners during a detailed project review seminar. The products will be used by partners to determine prioritization of future survey protocols. The code written to run the hemlock stand distribution models will undergo the NASA software release process prior to being shared with the project partners for future replication and advancements.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | multispectral vegetation classification and indices | Multi-temporal and multispectral measurements will be used to help identify evergreen species phenology and distribution in the modeling process. |
| **Sentinel-2 MSI** | multispectral vegetation classification and indices | Multi-temporal and multispectral measurements will be used to help identify evergreen species phenology and distribution in the modeling process. |
| **ISS GEDI** | forest vertical structure | Forest vertical structure will be used to delineate hemlock species distribution in the modeling process. |
| **ICESat-2 ATLAS** | forest vertical structure | Forest vertical structure will be used to delineate hemlock species distribution in the modeling process. |
| **AVIRIS** | hyperspectral imagery | Hyperspectral imagery will be used to help identify evergreen species distribution in the modeling process. |

***Ancillary Datasets:***

iMapinvasives Invasive Species Distribution Data – ground observations of HWA (presence and absence) will be used for model inputs and cross-validation

World Wildlife Fund Hydrological Data and Maps Based on Shuttle Elevation Derivatives at Multiple Scales (HydroSHEDS) – georeferenced river data will be used as model inputs

United States Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) streets – georeferenced street data will be used as model inputs

United States Department of Agriculture Soil Survey Geographic Database (SSURGO) – soil inputs will be used for classification and regression tree analysis

United States Department of Agriculture Cropland Data Layer (CDL) – land cover data will be used as model inputs

United States Department of Agriculture New York State Tree Distribution Model – supplementation, verification, and comparison to models, *in-situ* data, and Earth observations

United States Geological Survey National Land Cover Database Land Cover Collection – land cover data will be used as model inputs

NASA Earth Exchange NEX-DCP30 Downscaled Climate Model – climate scenarios will be used in forecasting

New York Natural Heritage Program Stacked Distribution Models – conifer presence/absence data will be used for supplementation, verification, and comparison to models

Adirondack Research Hemlock Cover Class – 2018 hemlock cover class from ground observations will be used as model inputs and comparisons

PRISM Climate Group 30-Year Normals – January average minimum temperature from 1981 to 2010 will be used as model inputs

***Modeling:***

Clark Labs TerrSet Habitat and Biodiversity Modeler

***Software & Scripting:***

Esri ArcGIS – image processing, classification, raster manipulation/analysis, map creation

Google Earth Engine Application Programming Interface – data acquisition, mapping, classification of imagery

Clark Labs TerrSet – species distribution modeling

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Hemlock Stand Distribution Models** | These models will guide partner ground survey prioritization protocols and help determine if emerging satellite data technologies are equal to or better than costly AVIRIS flights at gathering data for these models. | Landsat 8 OLI, Sentinel-2 MSI, ISS GEDI, and ICESat-2 ATLAS measurements will be compared against AVIRIS hyperspectral imagery to determine the best sensors for the modeling of hemlock distribution. Partners will ground-truth these models to determine which sensors inform the best models of hemlock distributions across Adirondack Park. | III |
| **Hemlock Stand Distribution Maps** | These present day and forecast maps will be derived from the distribution models and used to guide partner ground survey prioritization protocols. | Landsat 8 OLI, Sentinel-2 MSI, ISS GEDI, and ICESat-2 ATLAS data will be combined with ancillary datasets to create distribution maps for partner visualization. | N/A |

***End-User Benefit*:** This project will demonstrate a comparison between space-based Earth observations and airborne AVIRIS flight data in modeling hemlock distribution. The end users will verify stands in the field, then use accurate hemlock distribution data to coordinate cost effective management of HWA, including the creation of early detection and rapid response survey prioritization maps. APIPP and SLELO will use these prioritization maps to process HWA reports and to alert nearby regions to be ‘on-watch’ as new populations are discovered. These maps will also help APIPP and SLELO respond to new infestations by targeting the most vulnerable perimeter of an infestation.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 2 Terms: 2017 Spring to 2019 Summer

***Multi-Term Objectives:***

* **Term 1:** 2017 Spring (GSFC) – New York Ecological Forecasting
  + The goal of the first term was to model hemlock stand distribution using existing AVIRIS data to determine the feasibility of utilizing space-based and plane-mounted sensors. In 2018, Adirondack Research utilized these models to verify stands and to collect location data for pure and mixed hemlock stands. This information will inform additional models for the 2019 Summer NASA DEVELOP team who will be utilizing various space-based sensors. Adirondack Research, University of Vermont, and APIPP designed the ground surveys of 2018 and the (scheduled) verification surveys of 2019 to test the accuracy of the proposed models.
* **Term 2 (Proposed Term):** 2019 Summer (GSFC) – New York Ecological Forecasting II
  + This project will demonstrate a comparison between space-based Earth observations and airborne AVIRIS flight data in modeling hemlock habitat distribution. By incorporating new ground surveys of pure and mixed hemlock stands, this project will result in distribution models of hemlock stands for the partners to use in HWA survey prioritization mapping. By comparing models after a virtual product handoff webinar, APIPP and SLELO will be able to determine which model works best to predict hemlock stand locations as alternatives to costly AVIRIS flyovers.

***Previous Term:***

2017 Spring (GSFC) – New York Ecological Forecasting: Utilizing NASA Earth Observations to Map Eastern Hemlock for Hemlock Wooly Adelgid Management in Adirondack Park and Tug Hill State Forest, New York

***Related DEVELOP Work:***

2018 Spring (LaRC) – Amistad Ecological Forecasting: Using Landsat and Sentinel to Identify and Detect Giant Cane in Amistad National Recreation Area for Future Invasive Species Land Management

2018 Spring (CO) – Minnesota & Texas Agriculture & Food Security: Employing NASA Earth Observations to Model Current and Historic Distribution of Crop Wild Relatives, in Support of USDA ARS Genetic Resource Conservation Efforts

**References:**

***References:***

Ruid, M., Lubkin, S., McCartney, S., Soobitsky, R., Walcutt, A. (Spring 2017). New York Ecological Forecasting Utilizing NASA Earth Observations to Map Eastern Hemlock for Hemlock Woolly Adelgid Management in Adirondack Park and Tug Hill State Forest, New York. NASA Goddard Space Flight Center. <https://www.dropbox.com/s/q0ce34laww6mans/2017Spring_GSFC_NewYorkEco_TechPaper_FD.docx?dl=0>