**NASA DEVELOP National Program**

University of Georgia

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**Great Smoky Mountains Ecological Forecasting II**

*Utilizing NASA Earth Observations to Monitor Long Term Hemlock Decline Caused by*

 *Invasive Hemlock Woolly Adelgid in Great Smoky Mountains National Park*

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**Applied Sciences National Applications Addressed:** Ecological Forecasting

**Study Area:** Great Smoky Mountains National Park

**Study Period:** 2000-2013, concentrating within the leaf-off season (November - February)

**Community Concerns**

* Eastern Hemlock trees (*Tsuga canadensis L.*) play an ecologically vital role in cooling mountain streams and providing habitat for many diverse and endangered species. The loss of hemlock forests will put these species at increased risk.
* Hemlocks are under attack from an invasive insect called the Hemlock Woolly Adelgid (HWA, *Adelges tsugae*). With few native predators inside the park, the insect has dispersed by way of birds, wind, and infested horticulture material.
* Without successful intervention, HWA infestation can cause tree mortality within 3-5 years.
* The infestation has also impacted commercial and residential tree entities.
* The surrounding region has many factories, power plants, and other pollution creating industries which negatively impact air quality and are believed to further strain hemlock health.

**80-100 Word Blurb**

NASA Earth Observation data can be utilized to create vegetation indices to detect Eastern Hemlock defoliation and destruction caused by the Hemlock Woolly Adelgid infestation. GIS and remote sensing techniques, such as change detection, can be implemented to more efficiently identify infested areas and migration patterns, improving mitigation monitoring and planning procedures. A time series analysis illustrating healthy vegetation in the years prior to infestation and post infestation will also help identify problematic areas. Hemlock provides an important ecosystem for many endangered flora and fauna, therefore deterring the loss of Hemlock is particularly important.

**Abstract**

Evergreen Eastern hemlock (*Tsuga canadensis* L.) trees play an ecologically vital role within Eastern deciduous forests by providing a unique habitat for many species of flora and fauna. The hemlocks in the Southern Appalachian Mountain region are currently facing an infestation of the non-native Hemlock Woolly Adelgid (HWA, *Adelges tsugae*), which feeds on and causes tree mortality. Discovered in Great Smoky Mountains National Park (GRSM) in 2002, the HWA have rapidly spread through this biodiverse forest due to a lack of native predators. This project was designed to map the spatiotemporal onset, spread, and extent of hemlock defoliation using NASA Earth Observing System (EOS) data. Additionally, the project compared the results to those of the USDA Forest Service’s national forest disturbance monitoring system, ForWarn. Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) imagery were used to create yearly Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) datasets to evaluate health conditions of Eastern hemlocks in GRSM. Change detection methods, including image differencing and temporal segmentation algorithms, were used to identify spatiotemporal defoliation patterns. For the first time, trends in HWA forest decline in GRSM were created and compared to MODIS derived decline from ForWarn. The methodology and results from this project: 1) support forest management and insect control policies for the National Park Service, and 2) provide a reference data set for assessing forest damage in the Southern Appalachians.

**Partners/Collaborators**

 National Parks Service, Great Smoky Mountains National Park, Gatlinburg, TN (POC: Thomas Remaley – Inventory and Monitoring Coordinator and Ecologist)

 ForWarn, Eastern Forest Environmental Threat Assessment Center and USDA Forest Service, Asheville, NC (POC: William Hargrove, PhD)

**Current Management Practices & Policies**

Forestry personnel have investigated the adelgid infestation through expensive and time consuming field observations. Fixed and rotary wing aircrafts have also been used to collect aerial imagery to identify areas of hemlock decline within the park and surrounding areas. These methods are costly and lack temporal resolution capabilities. Additionally, they lack the continual-coverage data that NASA Earth observations provide.

Currently, the national park uses foliar and systematic treatments to kill the insects and treat the soil. They have also released predatory beetles into the park, but it will take years before the beetle population increases enough to control adelgid infestations. This study area is defined as a federal forest preserve, and it is considered the largest remaining virgin forest in the eastern USA.

**Benefit to End-User**

* Yearly VI maps to evaluate the general greenness of evergreen forests in GRSM
* Forest decline maps from infestation date to the present
* Methodologies for continued infestation mapping
* Report to compare the forest decline result of ForWarn and Landsat images
* Identify priority locations for future mitigation practices

**Decision Support Tools**

* Yearly VI maps to visualize and quantify greenness of hemlock in GRSM
* Forest change (decline and regrowth) maps within GRSM
* Methodology for continued monitoring of hemlock decline
* Time series analysis to track the long-term change of hemlock
* Statistical analysis for results comparison with ForWarn

**Earth Observations & Parameters**

Landsat 5 TM– Multispectral images and VI (NDVI, EVI)

Landsat 8 OLI – Multispectral images and VI (NDVI, EVI)

**Future Applicable NASA Missions**

Landsat 8 OLI – Multispectral images and VI (NDVI, EVI)

**Models Utilized**

ForWarn - collaborative effort by NASA, USDA Forestry Service, and EFETAC

**Ancillary Datasets Utilized**

GRSM boundary shapefiles

UGA vegetation classification dataset provided by Center for Geospatial Research (CGR)

Orthoimages of GRSM in leaf-off condition in 2011 provided by CGR

**Software Utilized**

ArcGIS 10.1 – Raster manipulation/analysis, spatial interpolation and map creation

ENVI 5.0 – Atmospheric correction, VI calculation and change detection

LandTrendr – Time series analysis of forest decline

R – Statistical analysis