**Cherokee Water Resources**

*Mapping Forest Composition and Health in the Southern Appalachians Using NASA Earth Observations to Enhance Drought and Watershed Health-Related Forest Management for the Eastern Band of the Cherokee Indians*

**Project Team**

***Project Team:***

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***Advisors & Mentors:***

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**Project Overview**

***Project Synopsis:***

The Eastern Band of Cherokee Indians (EBCI) owns and manages over 55,000 acres of land in the Southern Appalachian Mountains of western North Carolina. The EBCI Natural Resources Program sought to expand its toolset for monitoring forest resources, especially in response to drought, wildfire, and other ecosystem disturbances. To enhance forest monitoring efforts, the DEVELOP team worked with the EBCI Natural Resources program to map changes in evergreen forest health using NASA Earth observations with a specific interest in the decline and suitability of hemlock species. This project also developed materials to help strengthen ECBI’s capacity to use remote sensing data for future use cases.

***Abstract:***

The Eastern Band of Cherokee Indians (EBCI) owns and manages more than 55,000 acres of land in the Southern Appalachian Mountains of western North Carolina. Most of these lands reside within the Oconaluftee River watershed. In this region and watershed, hemlock trees are a culturally significant foundation species that contribute to habitat biodiversity, regulate temperature and evapotranspiration of riparian environments, and provide economic value for tourism and recreation. The hemlock woolly adelgid (HWA), an invasive insect, has caused widespread hemlock mortality in recent decades, raising concerns about hemlock decline. Hemlock mortality leads to standing dead trees and increased evapotranspiration which can abet the spread of wildfires, especially during periods of drought. The DEVELOP team used satellite imagery from Landsat 5 Thematic Mapper (TM) to quantify and map possible hemlock decline by comparing changes in the normalized difference vegetation index (NDVI) values of winter season between 2003 and 2010. The project utilized the Shuttle Radar Topography Mission (SRTM) along with imagery from Landsat 8 Operational Land Imager (OLI) to create a weighted suitability analysis that maps topographic and environmental conditions favorable for hemlock habitat. This study found that 67% of evergreen and mixed forest cover in the Oconaluftee River valley exhibited a decrease in winter NDVI from 2003 to 2010. Additionally, the two-example weighted suitability analyses showed 4.5-9.5% of hemlock suitable land in 2018 in the Oconaluftee. The partners of this project can use the outputs to identify the extent of potential hemlock decline in the Oconaluftee and establish benchmark metrics for assessing changes in hemlock suitable areas over time.

***Key Terms:***

remote sensing, Normalized Difference Vegetation Index, Landsat, weighted suitability, hemlock, EBCI, hemlock woolly adelgid

***National Application Areas Addressed:*** Water Resources

***Study Location:*** Cherokee, Graham, Swain, and Jackson Counties, NC

***Study Period:*** June 2000 to June 2020

***Community Concerns:***

* EBCI Trust Land forests are less diverse and of lower quality than in the past due to a management history that includes high-grading, clear cutting, and a fire regime of prevention and suppression.
* Western North Carolina experienced more than 40,000 acres of burn from wildfires in 2016, impacting the health of the forest and its natural resources.
* Hemlock decline is of concern as an invasive insect, the hemlock woolly adelgid, has caused widespread hemlock mortality over the previous decades.
* Hemlock mortality leads to standing dead trees and increased evapotranspiration, which can abet the spread of wildfires, especially during periods of drought.
* Hemlocks are a crucial component of the environment as they provide numerous ecological services, important for maintaining shade and water quality in riparian environments. Hemlocks are also culturally significant, contributing to the economic vitality of the area.

***Project Objectives:***

* Apply Earth observation data to aid in forest health monitoring and change detection
* Analyze winter NDVI decline to identify areas of evergreen and potential hemlock decline
* Explore and identify hemlock suitable areas through weighted suitability analysis
* Produce a tutorial package to guide and strengthen EBCI’s capacity to use remote sensing

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Eastern Band of Cherokee Indians, Natural Resources Program** | Caleb Hickman, Supervisory Fisheries & Wildlife Biologist; Tommy Cabe, Tribal Forest Resource Specialist; Maria Dunlavey, Outreach Coordinator | End User | Yes |
| **USDA, US Forest Service, Eastern Forest Environmental Threat Assessment Center** | Steve Norman, Research Ecologist | Collaborator | No |

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

The EBCI National Resources Program works to regulate the environment through the Air Quality, Fish and Wildlife, Forestry, Horticulture, and Water Quality and Watershed Management programs. EBCI utilizes a forest management plan (FMP) to characterize the practices and policies relevant to the management of forest lands held in trust via the Bureau of Indian Affairs and under individual ownership. The overarching goal of the FMP is to apply adaptive land management practices for the maintenance of healthy and diverse forest resources. With the decline of the hemlock populations affecting the regional ecosystems, the EBCI program has interest in using remote sensing to identify hemlocks change and suitability in the region and apply geospatial data for future management.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 5 TM** | Surface Reflectance | Landsat 5 surface reflectance data were used to calculate NDVI values for the study area from 2003-2010. |
| **Landsat 8 OLI** | Surface Reflectance | Landsat 8 surface reflectance data were used to calculate NDVI values for the study area from 2013-2020. |
| **SRTM** | Slope, Aspect, Elevation | SRTM data were used as the base raster for outputs. Original collection from 2000 and upgraded data from 2013 were used. |

***Ancillary Datasets:***

* United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) – High-resolution aerial imagery (1m) for comparison to evergreen decline maps and identification of tree mortality
* United States Census Bureau TIGER/Line Shapefiles – Vector files of urban areas for delineation study area and input into weighted suitability analysis
* Multi-Resolution Land Characteristics (MRLC) Consortium National Land Cover Database (NLCD)– Land cover classification to delineate different forest types (evergreen, mixed, and deciduous)
* Hemlock Restoration Initiative (HRI) Hemlock Conservation Areas (HCA) – Polygon files for areas of hemlock treatment in the Great Smoky Mountains National Park and surrounding regions to inform suitability criteria

***Software & Scripting:***

* Esri ArcGIS Pro 2.5 – Raster analysis and computation, data processing, model building
* RStudio 4.0.2 – Data manipulation and visualization
* Microsoft Excel – Compute statistics from ArcGIS Pro tabular data
* Google Earth Engine – Satellite data acquisition and processing

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Hemlock Weighted Suitability Maps** | Landsat 8 OLI  SRTM | These maps can help the ECBI prioritize restoration efforts for hemlocks by assembling and mapping the known criteria favorable for hemlock environments. | N/A |
| **NDVI Winter Change Map** | Landsat 5 TM | The NDVI maps identify areas of evergreen and potential hemlock decline, which can be used to indicate locations of forest stands experiencing hemlock decline. | N/A |
| **Remote Sensing & Forest Change Detection Tutorial** | Landsat 5 TM  Landsat 8 OLI  SRTM | The tutorial covers acquisition, processing data, and how to interpret outputs. The tutorial will enable the end user to replicate this study and for additional projects. | N/A |

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

The EBCI can use this information to prioritize hemlock restoration efforts and to further investigate the consequences of hemlock decline on the ecosystem. The knowledge of hemlock suitability and decline in the region can aid their management efforts and increase community awareness of local hemlock health. The project provided the partners with resources that can expand their ability to conduct future projects using NASA Earth observations and other geospatial technologies for continued approaches to forest health monitoring. As the partners of this project look toward expanding their management practices, remote sensing provides an additional toolset—one that can help the partners build more autonomy in understanding and, therefore, managing their landscape.

**References**

Forest Stewards. (2016). *Forest Management Plan: Eastern Band of the Cherokee Indians Trust Lands.*

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