**Monongahela National Forest Ecological Forecasting**

*Forecasting Red Spruce Restoration Using NASA Earth Observations to Support Decision Making in the USFS Monongahela National Forest*

**Project Team**

***Project Team:***

John Dialesandro (Project Lead)

Mason Bull

Tia Francis

Katherine Yut

***Advisors & Mentors:***

Keith Weber (Idaho State University, GIS Training and Research Center)

Dr. Catherine Jarnevich (United States Geological Survey, Fort Collins Science Center)

Joseph Spruce (Science Systems and Applications, Inc.)

**Project Overview**

***Project Synopsis:*** In the 1970s, the Monongahela National Forest was heavily mined, deforesting over a million acres in Appalachia. Initial reclamation efforts planted non-native vegetation, leaving grassland and shrubland where red spruce forests dominated and devastating the habitats of hundreds of rare plant and animal species. This project partnered with the Monongahela National Forest and Northern Institute of Applied Climate Science branches of the US Forest Service, utilizing NASA Earth observations to assess trends in the factors contributing to forest regrowth and employing a land change modeler to forecast regeneration to 2040 under specific management scenarios, such as rigorous or lax restoration.

***Abstract:***

Within the Monongahela National Forest (MNF), situated in the Allegheny Highlands of West Virginia, extensive logging and mining practices have significantly altered the structure and composition of flora and fauna over the past two centuries. Of particular concern to MNF land managers are red spruce (*Picea rubens*) stands, which provide shelter and food to several endangered and threatened species. To aid red spruce restoration, this study mapped current and historical stands and identified non-native stands with suitable habitats for red spruce in the Sharp Knob Red Spruce Restoration Area. Data from Landsat 5 Thematic Mapper (TM), Landsat 8 Operational Land Imager (OLI), and Shuttle Radar Topography Mission (SRTM) were input into classification tree and fuzzy logic algorithms. Furthermore, 2018 classification maps were utilized in the TerrSet Land Change Modeler to forecast red spruce extent up to 2040. As a product of these analyses, we produced three sets of maps: four time series maps of red spruce stands from 1989 to 2018, a map that identifies suitable stands for future restoration efforts, and a red spruce land cover change map up to 2040. Our results indicate that 562 hectares are suitable for future restoration in Sharp’s Knob, with an 8% gain in red spruce stands from 1989 to 2018. However, forecasting results indicate that management intervention will be necessary for this trend to continue.

***Keywords:***

Landsat 8 OLI, TerrSet, Land Change Modeler, Google Earth Engine API, forest restoration, red spruce

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

***Study Location:*** Monongahela National Forest, West Virginia

***Study Period:*** 1989 to 2018 (May to October), Forecasting to 2040

***Community Concerns:***

* Surface mining and logging have left the Monongahela National Forest depleted of natural red spruce (*Picea rubens*) canopy.
* Many native species to the Monongahela National Forest, including the northern flying squirrel (*Glaucomys sabrinus)* and the northern red salamander (*Pseudotriton ruber),* rely on the red spruce for their habitat.
* Red spruce is often associated with higher elevations (>2500 feet), thus placing stands at the headwaters of several watersheds have positive implications critical for urban drinking water (e.g. Pittsburg) and flood mitigation.

***Project Objectives:***

* Measure the extent of the land cover change between 1984 and 2018 in the Monongahela National Forest
* Identify the current extent of red spruce, non-red spruce tree, and grassy meadows in the study area
* Identify areas of dominant hardwoods that need to be removed to allow red spruce in the understory to grow
* Forecast red spruce extent with consideration given to restoration processes and climate

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, US Forest Service,****Monongahela National Forest** | Amy Coleman, South Zone Ecologist;Stephanie Connolly, Forest SoilScientist; Sam Lamie, ProjectManagement Professional, GISP | End User | No |
| **USDA, US Forest Service, Northern Institute of Applied Climate Science** | Patricia Leopold, Climate Change Outreach Specialist | Collaborator | Yes |

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

The US Forest Service (USFS) Monongahela National Forest and the Northern Institute of Applied Climate Science are committed to the Central Appalachians Spruce Restoration Initiative (CASRI) to assist in restoring red spruce trees in the region. Currently, the USFS Monongahela National Forest uses field observations to monitor current restoration sites and historical records to determine suitable sites for future restoration efforts. Spatial analyses and GIS are employed for some decision-making, with Esri ArcMap acting as the sole spatial analysis software. The partners have yet to integrate NASA Earth observations or modeling algorithms into their decision-making processes.

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

By introducing GIS and modeling algorithms to the end user’s workflow, this project’s products will provide a cost- and time-effective methodology for monitoring forest regrowth. Additionally, this project will give USFS land managers a blueprint for integrating remote sensing into their current decision-making techniques and software. As a result, field surveys or ancillary datasets can be used for validation techniques rather than being the sole method of data collection within the Sharp Knob Red Spruce Restoration Area. In addition, the results of this project can be extrapolated to various portions of Monongahela National Forest – and even West Virginia – to support the regional restoration of red spruce.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Surface reflectance, Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), tasseled cap transformations, Built-Up Index (BUI) | Landsat 5 Thematic Mapper (TM) data were used to analyze land change and create image derivatives such as NDVI and NDMI for forecast inputs.  |
| **Landsat 8 OLI** | Surface reflectance, NDVI, NDMI, tasseled cap transformations, BUI | Landsat 8 Operational Land Imager (OLI) data were used to analyze recent land cover and perform image analysis to create derivatives for forecast inputs. |
| **SRTM** | Elevation, slope, aspect | Shuttle Radar Topography Mission elevation data were used to derive topographic indices such as slope and aspect to use as predictors in land cover change analyses for red spruce habitat. |

***Ancillary Datasets:***

* USDA National Agriculture Imagery Program (NAIP) – 1-meter spatial resolution imagery used for more accurate estimates of tree canopy and percent impervious surface cover
* Multivariate Adaptive Constructed Analogs (MACA) Global Climate Model Datasets (Growing Degree Days, Frost free days, Annual Mean Temperature, Annual Mean Precipitation) 2010 to 2039 – Future climate scenario predictions for forecasting model inputs
* USDA US Forest Service Monongahela National Forest Red Spruce Points Shapefile – *In situ* gathered location data for red spruce and other species used in the land cover classification
* USDA US Forest Service Resource Planning Act Assessment – Current land use datasets and future scenarios that influence resource projections were used for land cover forecasting

***Modeling:***

* Clark Labs TerrSet Land Change Modeler (POC: Keith Weber, Idaho State University, GIS Training and Research Center) – Forecast land cover changes
* Clark Labs TerrSet Classification Tree Analysis (POC: Keith Weber, Idaho State University, GIS Training and Research Center) – Classification of land covers within our study area
* Fuzzy Logic (POC: Keith Weber, Idaho State University, GIS Training and Research Center) – Algorithm applied in ArcMap used to assess site suitability for red spruce restoration

***Software & Scripting:***

* Esri ArcMap – Map generation and vector data management
* Google Earth Engine API – Raster data processing and analysis and tool development
* Harris Corporation ENVI – Raster preprocessing and spectral classification
* Clark Labs IDRISI TerrSet – Run models and classifications

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Time Series of Map Classifications of Red Spruce and Other Land Cover Types**  | Landsat 5 TMLandsat 8 OLI SRTM | These maps can guide future monitoring and conservation efforts in the Sharp Knob Restoration Project area while also tracking regrowth and reclamation that have already taken place in the area. | I |
| **Land Cover Change Forecast Maps** | Landsat 5 TMLandsat 8 OLI SRTM | Partners can use these maps to highlight the changes that will occur in red spruce regeneration over the next 5 to 20 years.  | I |
| **Suitability Analysis Map of Red Spruce Restoration Sites** | Landsat 5 TMLandsat 8 OLISRTM  | This map helped the end user not only know the extent of red spruce but the areas where red spruce restoration can be optimally prioritized.  | I |
| **Modeling and Mapping Tutorial** | N/A | The tutorial enables end users to replicate this study in future years for new study areas and similar projects. | N/A |

**Project Handoff Package**

***Transition Plan:*** The Monongahela National Forest Ecological Forecasting Team presented project results via teleconference with the project partners during week 10 of the 2019 summer DEVELOP term. The handoff package was transferred over the NASA Large File Transfer system with all items listed in the Handoff Package below.

***Team POC:*** John Dialesandro, jdiales@ucdavis.edu

***Partner POC:*** Amy Coleman amy.f.coleman@usda.gov

***Handoff Package:***

* Time Series of Map Classifications of Red Spruce and Other Land Cover Types
* Land Cover Change Forecast Maps
* Suitability Analysis Map of Red Spruce Restoration Sites
* Modeling and Mapping Tutorial
* Project Summary
* Technical Paper
* Poster
* Presentation

**References:**

Hart, S. J., & Veblen, T. T. (2015). Detection of spruce beetle-induced tree mortality using high- and medium-resolution remotely sensed imagery. *Remote Sensing of Environment, 168*, 134-145. <https://doi.org/10.1016/j.rse.2015.06.015>

Nowacki, G., & Wendt, D. (2010). The current distribution, predictive modeling, and restoration potential of red spruce in West Virginia. In J. S. Rentch, & T. M. Schuler (Eds.), *Proceedings from the conference on ecology and management of high-elevation forests in the central and southern Appalachian Mountains* (pp. 163-178). Retrieved from https://www.nrs.fs.fed.us/pubs/gtr/gtr-p-64papers/16-nowacki-p-64.pdf

Reddy, C. S., Singh, S., Dadhwal, V. K., Jha, C. S., Rama Rao, N., & Diwakar, P. G. (2017). Predictive modelling of the spatial pattern of past and future forest cover changes in India. *Journal of Earth Systems Science, 126*(8), 1-8. https://doi.org/10.1007/s12040-016-0786-7

Rentch, J. S., Schuler, T. M., Nowacki, G. J., Beane, N. R., & Ford, W. M. (2010). Canopy gap dynamics of second-growth red spruce-northern hardwood stands in West Virginia. *Forest Ecology and Management, 260*, 1921-1929. <https://doi.org/10.1016/j.foreco.2010.08.043>

Savage, S. L., Lawrence, R. L, & Squires, J. R. (2017). Mapping post-disturbance forest landscape composition with Landsat satellite imagery. *Forest Ecology and Management, 399*, 9-23. https://doi.org/10.1016/j.foreco.2017.05.017

Stanton, J. M. (2009). *Modeled red spruce distribution response to climate change in Monongahela National Forest* (Master’s thesis). Marshall University, Huntington, West Virginia. Retrieved from https://mds.marshall.edu/ cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=2079&context=etd