**NASA DEVELOP National Program**

**2019 Summer Project Proposal**

**Idaho – Pocatello**

**Monongahela National Forest Ecological Forecasting**

*Forecasting Forest Restoration Using NASA Earth Observations to Support the US Forest Service Monongahela National Forest*

**Project Overview**

***Project Synopsis*:** This project will use the Landsat and Sentinel satellite series, as well as SRTM, to provide partners at the United States Forest Service (USFS) Monongahela National Forest and the [Northern Institute of Applied Climate Science](https://www.nrs.fs.fed.us/niacs/) (NIACS) with improved forecasting to identify and monitor the ongoing large-scale forest restoration and planting efforts of native red spruce (*Picea rubens*) populations. The team will utilize spectral classification-modeling techniques and employ *in situ* data collected by partners to create maps of mid-story vegetation. These maps will identify areas with native species, which will allow targeted removal of non-native vegetation that will maximize the growth potential of species such as the native red spruce. The DEVELOP team will create written and video tutorials outlining the specified repeatable methodology for partners to continue to use in future analyses. The partners will use these products as a means to improve their decision-making ability concerning habitat management and to support on-the-ground restoration efforts.

**Community Concern:** Landscapes in West Virginia, especially forests, have been significantly altered due to anthropogenic impacts resulting from excessive logging and mining practices over the past century. The Lambert Run Strip is an abandoned coal mine located in eastern West Virginia, which was acquired by the USFS in the 1980s. The USFS, along with various partners devised the Lambert Restoration Project to establish and restore native species of trees, shrubs, and herbaceous plants. The project has a short-term goal (5-20 years) of enhancing habitat suitability for early successional species, and a long-term goal of spruce ecosystem restoration. Gathering *in situ* data through field data collection to identify native vegetation over the whole of the national forest is both expensive and daunting as a task. Remote sensing and GIS techniques can enable identification over a wide field area inexpensively.

**Source of Project Idea:** Stephanie Connolly, a Monongahela National Forest Soil Scientist, and Patricia Leopold, a NIACS Climate Change Outreach Specialist, were introduced to NASA DEVELOP through conversations between former Center Lead Tim Mayer and other colleagues at the USFS. NASA DEVELOP saw an unmet need for the potential partner organizations at the USFS Monongahela National Forest and their collaborators at the NIACS, and contacted them to foster a partnership, which will expand their remote sensing and GIS capabilities.

**National Application Area Addressed:** Ecological Forecasting

**Study Location:** Monongahela National Forest, WV

**Study Period:** 1984 –2018 (May – October); Forecasting to 2040

**Advisors:** Keith Weber (Idaho State University, GIS Training and Research Center (TReC))

Dr. Catherine Jarnevich (USGS Fort Collins Science Center)

**Partner Overview**

***Partner Organizations:***

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

**End-User Overview**

**End User’s Current Decision-Making Process*:***The Monongahela National Forest is responsible for managing vast forests as well as improving and monitoring the ongoing restoration efforts within the Lambert Restoration Project. Currently, the USFS has historic land cover change data and relies primarily on field surveys for establishing monitoring plots. The organization has limited experience using NASA Earth observations to apply spatial and spectral data to their decision making.

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

*USDA, US Forest Service, Monongahela National Forest* – The resource managers at this national forest use spatial analysis and GIS for some decision-making but have not used NASA Earth observations to address management concerns.

**Boundary Organization Overview**

**Boundary Organization Support:**

*USDA, US Forest Service, Northern Institute of Applied Climate Science –* This organization fosters collaborative efforts among the US Forest Service, universities, conservation organizations, and the forest industry in order to provide information on managing forests for climate change adaptation and enhanced carbon sequestration. Our point of contact has some spatial analysis experience but little familiarity using NASA Earth observations in their research. This project will further build the collaborator’s capacity, and the NIACS organization as a whole to use NASA Earth observations.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The team will communicate with partners and collaborators on a bimonthly basis via teleconference. The Center Lead and Project Lead will be the primary points of contact with the partner organizations.

***Transition Plan*:** At the end of the term, the team will host a web-based seminar to disseminate project results and hand off decision support tools. A short training workshop on the use of the data and tutorial will follow the seminar.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | surface reflectance, normalized difference vegetation index (NDVI), normalized difference moisture index (NDMI), tasseled cap brightness, greenness, and wetness | This dataset will provide the temporal (16 days) and spatial (30 m2) resolution needed for environmental predictive variables employed via a spectral classification modeling approach to investigate focal species presence and land cover change analysis. |
| **Landsat 8 OLI** | surface reflectance, NDVI, NDMI, tasseled cap brightness, greenness, and wetness | This dataset will provide the temporal (16 days) and spatial (30 m2) resolution needed for environmental predictive variables employed via a spectral classification modeling approach to investigate focal species presence and land cover change analysis. |
| **Sentinel-1 C-SAR** | backscatter values, surface roughness, RADAR Vegetation Index | This dataset will provide high temporal resolution (6 days) imagery used to refine species classification modeling and land cover change analysis. |
| **Sentinel-2 MSI** | surface reflectance, NDVI, NDMI | This dataset will provide the spatial resolution (10-60 m2) imagery used to refine species classification modeling and land cover change analysis. |
| **SRTM** | elevation, slope, aspect, compound topographic index | This dataset will be used to derive topographic indices to use as predictors in representing important characteristics of focal species presence and land cover change analysis. |
| **SMAP** | soil moisture | This dataset will provide soil moisture data as a predictor for the focal species presence and used in the land cover change analysis. |

***Ancillary Datasets:***

North American Land Data Assimilation System (NLDAS-2) Mosaic Precipitation, Soils, Surface Water –

Environmental Predictor Variables Data

USDA USFS Monongahela National Forest LIDAR – Point clouds used for highly detailed elevation models, potential to identify mid-story vegetation

USDA USFS Monongahela National *in situ* datasets – Location data for red spruce, other species to be used in classification

USDA USFS Resource Planning Act Assessment – Current land use datasets and future scenarios that influence resource projections, used for land cover forecast

USDA USFS Climate Change Tree Atlas 2014 – Current distribution of 134 tree species in the Eastern United States with detailed environmental factors, which define distribution to be used in forecast and classification model.

USDA National Agriculture Imagery Program (NAIP) – 1 m2 imagery to be used for digital ocular sampling

***Modeling:***

Random Forest Classification Model (POC: Keith Weber, GIS TReC, Dr. Catherine Jarnevich, USGS Fort Collins Science Center)

Support Vector Machines (POC: Keith Weber, GIS TReC, Dr. Catherine Jarnevich, USGS Fort Collins Science Center)

TerrSet Land Change Modeler (POC: Keith Weber, GIS TReC)

TerrSet Reducing Emissions from Deforestation and forest Degradation (POC: Keith Weber GIS TReC)

***Software & Scripting:***

Esri ArcGIS – Map end product generation

TerrSet – Raster processing and spectral classification and land cover change modeling.

R – Variable selection, statistical analyses and raster processing.

SNAP – RADAR image pre-processing.

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Map and Time Series Analysis of Forest Restoration Efforts** | The maps and time series analysis produced will elucidate the land cover change that has resulted from the Lambert Restoration Project. These products will, in turn, guide future monitoring and conservation efforts. | Supervised classification models trained using datasets from *in situ* data, SRTM, SMAP, NLDAS-2, LIDAR, Sentinel-1 and -2, Landsat 5 and 8, to create distribution maps and a time series analysis of the focal species and land cover change analysis. | I |
| **Land Cover Change Forecast Maps** | These maps will outline expected land cover change over time based on several input scenarios - management actions, public actions, and changes in ecological processes. These will be validated using historical data to delineate forecast confidence levels. Validated maps will inform land managers at Monongahela National Forest to make sound decisions. | Land cover time series, land use datasets, roads, elevation; combined in TerrSet Land Change Modeler to forecast red spruce distribution. | I |
| **Modeling and Mapping Tutorial and Video** | The tutorial will enable end users to replicate this study in future years. | The tutorial will cover data collection and processing, fitting statistical models to the data, and interpretation of the model output. | N/A |

***End-User Benefit*:** This project will allow the Monongahela National Forest to refine their monitoring and survey effort to identify locations likely to have red spruce. These areas can be targeted for removal of non-native vegetation, which will increase succession. The project enables an analysis of areas at scales that would not be feasible without the utilization of NASA Earth observations. End products will be integrated into the USFS decision making and conservation processes.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 1 Term: 2019 Summer

***Related DEVELOP Work:***

2017 Fall (CO) –Intermountain West Ecological Forecasting: Utilizing NASA Earth Observations to Forecast Forest Risk to Bark Beetle Attack in Support of a Forest Bioenergy Feasibility Assessment

2017 Spring (ID) – Intermountain West Ecological Forecasting: Using NASA Earth Observations to Identify Current Habitat Areas and Forecast Habitat Suitability for the Yellow-Billed Cuckoo in Semiarid Environments

**Notes & References:**

***Notes*:**

* Land cover change will be initially assessed using historical data, which will allow us to forecast to 5 years, with confidence levels and accuracy beyond that timeline outlined by levels of statistical uncertainty.
* Included previous DEVELOP project, which created habitat suitability models. Discussion from during development of SAD workshop our group hammered out the details of the important differences between habitat suitability, species distribution, overfitting models by using correlated variables as inputs, and finally the need for true presence and absence data sets.
* Keith Weber has experience with TerrSet, including the Land Change Modeler and Reducing Emissions from Deforestation and forest Degradation tools.
* Additional science advising and modeling support to be met by Dr. Catherine Jarnevich at the Colorado Node.

***References:***

Raczko, E., & Zagajewski, B. (2017). Comparison of support vector machine, random forest and neural network classifiers for tree species classification on airborne hyperspectral APEX images. *European Journal of Remote Sensing*, *50*(1), 144-154.

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.

Silbernagel, J., & Moeur, M. (2001). Modeling canopy openness and understory gap patterns based on image analysis and mapped tree data. *Forest Ecology and Management*, *149*(1-3), 217-233.

Richardson, J. J., & Moskal, L. M. (2011). Strengths and limitations of assessing forest density and spatial configuration with aerial LiDAR. *Remote Sensing of Environment*, *115*(10), 2640-2651.