**Mark Twain National Forest Ecological Forecasting**

*Utilizing NASA Earth Observations to Classify Ground Cover Types in the Mark Twain National Forest*

**Project Team**

***Project Team:***

Kaitlyn Bretz (Project Lead)

Madison Bradley

Sarah Hafer

Grant Verhulst

***Advisors & Mentors:***

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

***Team POC:*** Kaitlyn Bretz, kbretz007@outlook.com

***Partner POC:*** Kyle Steele, kyle.steele@usda.gov

**Project Overview**

***Project Synopsis:***

The Mark Twain National Forest (MTNF) in southeastern Missouri has a complex forest structure of conifer, hardwood, and dense understory stands. To address restoration concerns, this project assisted the US Department of Agriculture (USDA) US Forest Service (USFS) MTNF to identify conifer species using Landsat imagery and ancillary data. Shortleaf pine is the only native pine species in Missouri, and is the target of many restoration projects. Eastern red cedar stands serve as a useful proxy for bare and shallow soils, and are considered an invasive species in MTNF’s glades. This project sought to spectrally separate cedar and pine stands from other cover types. These data will assist land managers in their efforts to identify tree diversity at a species level in the MTNF.

***Abstract:***

The Mark Twain National Forest (MTNF) encompasses 1.5 million acres of public land in the Ozarks region of southeastern Missouri. The industrial boom between the 1880s and 1920s had devastating effects on the shortleaf pine (*Pinus echinata*), Missouri’s only native pine species. The combination of fire suppression on this fire-dependent species and timber harvest of mature pine stands inhibited the development of pine seedlings and promoted the establishment of hardwood stands. Partners at the US Forest Service’s MTNF are currently involved in restoration efforts in two ranger districts, which includes removing invasive eastern red cedar (*Juniperus virginiana*) and prescribed burning. To expand spatial coverage for the MTNF beyond *in situ* observation sites, the NASA DEVELOP team analyzed land cover change from 1986 through 2019 and forecasted changes based on a ‘business-as-usual' scenario out to 2040. The team incorporated remotely sensed data from Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) into the random trees supervised classification tool in ArcGIS Pro. This tool spectrally separated pixels into five distinct land cover classes and produced classifications for 1986 and 2019, with kappa statistics of 0.87 and 0.81, respectively. Overall, there was a net decrease in conifer and meadow land cover between 1986 and 2019 along with a net increase in water, developed, and deciduous land cover. The team used TerrSet’s Land Change Modeler to forecast land cover through 2040. Results showed an increase in coniferous land cover and a decrease in deciduous cover, indicating a high probability that current restoration efforts will produce the intended effect.

***Key Terms:***

supervised classification, ecological forecasting, eastern red cedar, shortleaf pine, forest restoration, Landsat 5 TM, Landsat 8 OLI, Missouri

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

***Study Location:*** Mark Twain National Forest, MO

***Study Period:*** 1986 to 2020 (October to March); Forecasting to 2040

***Community Concerns:***

* Missouri’s Ozarks once held approximately 6 million acres of shortleaf pine-oak woodlands, but due to numerous disturbances since the turn of the century – including heavy logging, deforestation, and fire suppression – the historical habitat has been greatly altered, directly affecting the local tree, plant, bird, and mammal species.
* In 2009, the US Congress created the Collaborative Forest Landscape Restoration Program (CFLRP) to promote restoration of priority forest landscapes, including the MTNF shortleaf pine-oak woodlands.
* USFS is restoring areas of the forest by physically removing invasive red cedar trees and reinstating historical burn patterns. These interventions keep areas open and promote the spread of native grasses, wildflowers, and trees that enhance the local biodiversity, including pollinators, songbirds, and mammal populations.
* Many of the USFS’s restoration efforts take place in and around tourist areas, such as hiking trails and camping sites, bringing visitors in contact with the area’s history of disruption and change.
* The restoration efforts are projected to support an average of 138 jobs per year, generate $34 million in labor income, and add $44 million in value to the local 9-county economy.

***Project Objectives:***

* Create a land cover type analysis of MTNF that can be used to assist with species-level classifications, allowing land managers to better determine areas in need of restoration
* Forecast various land cover distributions out to 2040 to determine changes in land cover type based on current US Forest Service land management practices

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USDA, US Forest Service, Mark Twain National Forest** | Kevin Godsey, Soil Scientist; Kyle Steele, Forest Ecologist | End User | No |
| **USDA, US Forest Service, Geospatial Technology and Applications Center** | Nick Klein-Baer, Remote Sensing Analyst | Collaborator | No |

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

In 2005, the USFS published a forest-wide plan for the MTNF that directed individual ranger districts to determine restoration priorities. In 2009, the US Congress passed the CFLRP, a federal initiative to encourage the restoration of natural forest landscapes across the United States. This catalyzed a collaborative project between private landowners and the USFS MTNF focused on the restoration of shortleaf pine-oak woodlands. The CFLRP manages only 8% of MTNF land, which falls within two of the six ranger districts. Management decisions regarding restoration efforts are determined on a case-by-case basis for individual ranger districts (e.g., Eleven Point, Poplar Bluff, and Ava districts), rather than for the MTNF as a whole. Remotely sensed and geospatial data are not a requirement within the USFS’ 2005 forest-wide plan or the CFLRP. Although the USFS operates the Geospatial Technology and Applications Center (GTAC) in Utah, forest managers are not required to utilize this resource, and they must reach out to GTAC directly. LiDAR has been flown over approximately a quarter of MTNF in recent years, and first-return data have been used to study the canopy in select ranger districts. However, GTAC and other remote sensing data resources are generally used on a limited basis and are not comprehensive across the MTNF.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Composite images,Spectral vegetation indices | Landsat 5 TM imagery from 1986 to 2012 was used to create composite images and vegetation indices (NDVI, EVI, NDWI) to classify land cover. |
| **Landsat 8 OLI** | Composites images,Spectral vegetation indices | Landsat 8 OLI imagery from 2012 to 2020 was used to create composite images and vegetation indices (NDVI, EVI, NDWI) to spectrally separate eastern red cedar and shortleaf pine trees from other forest cover and to classify land cover. |

***Ancillary Datasets:***

* USDA National Agriculture Imagery Program (NAIP) Imagery – Validate imagery selection on a very fine spatial resolution (1m) and create training data for supervised classification
* USGS Digital Orthophoto Quadrangle (DOQ) Imagery – Validate imagery selection on a very fine spatial resolution (1m) and create training data for supervised classification
* USGS National Elevation Dataset – Raster product derived from DEMs to visualize elevation data, which may be used during classification to identify different land cover types

***Modeling:***

* Random Tree classifier – Classify the MTNF into distinct land cover classes
* Land Change Modeler (POC: Keith Weber, Idaho State University, GIS TReC) – Used to forecast land cover change of the MTNF out to 2040

***Software & Scripting:***

* ESRI ArcGIS Pro – Creation and analysis of vector and raster data
* IDRISI TerrSet – Land change modeler

***End Product:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Land Use and Land Cover Classification Maps** | Landsat 5 TM Landsat 8 OLI | Partners will use these maps to more efficiently identify areas for restoration and areas requiring further research to discern species-level identification of tree stands. | I |
| **2040 Forecasted Forest Cover Maps** | Landsat 5 TM Landsat 8 OLI | These maps will help partners understand the potential distribution of different land cover types estimated by models out to 2040. | I |
| **Tutorial for Classification and Forecasting Analysis Workflow** | N/A | This will be used to allow partners to recreate the methodology to map current and forecasted land cover in the future, if need be. | N/A |

***Product Benefit to End User:***

Land cover classification maps will allow MTNF land managers to efficiently identify areas in need of restoration, specifically areas where red cedar stands have replaced historical shortleaf pine-oak woodlands and grasslands. Forecasting land cover to the year 2040 helps managers estimate changes in land cover types if they maintain current management practices. This will allow the USFS MTNF to evaluate and tailor their management decisions, such as removal of red cedar stands, reforestation of shortleaf pine trees, and prescribed burns.

**References**

Fassnacht, F. E., Latifi, H., Stereńczak, K., Modzelewska, A., Lefsky, M., Waser, L. T., ... & Ghosh, A.

(2016). Review of studies on tree species classification from remotely sensed data. *Remote Sensing of*

*Environment*, *186*, 64-87. DOI: 10.1016/j.rse.2016.08.013

Kabrick, J. M., Dey, D. C., & Gwaze, D. (2007). Shortleaf pine restoration and ecology in the Ozarks:

Proceedings of a symposium. *Gen. Tech. Rep. NRS-P-15. Newtown Square, PA: US Department of Agriculture, Forest Service, Northern Research Station.* 215 p., 15.

Song, N., & Aguilar, F. X. (2015). Economic impacts of the implementation of the Missouri Pine–Oak

Woodlands Restoration Project at the Mark Twain National Forest, 2012-2019: A Project of the Collaborative Forest Landscape Restoration Program. *Report to the US Department of Agriculture Forest Service, Mark Twain National Forest, Rolla, Missouri, USA*.

Zhang, Y., He, H. S., Dijak, W. D., Yang, J., Shifley, S. R., & Palik, B. J. (2009). Integration of satellite

imagery and forest inventory in mapping dominant and associated species at a regional scale. *Environmental Management,* *44*(2), 312-323. DOI: 10.1007/s00267-009-9307-7