

NASA DEVELOP National Program

Summer 2016 Project Proposal

USGS at Colorado State University Rocky Mountain Agriculture

Utilizing NASA Earth Observations to Reconstruct and Identify Historical Forest Disturbances in the Southern Rocky Mountains

Project Overview

Objective: To map historical disturbance events occurring in the northern Colorado and southern Wyoming Rocky Mountains between 2000 and 2016 and model their cause (fire, insect/disease outbreaks, or forest management activities) to enhance our partner's ability to predict the areas that will be most susceptible to disturbance in the future and to enable our partners to conduct similar analyses for disturbances occurring between 1985 and 1999.

Community Concern: In recent decades, the Rocky Mountains of northern Colorado and southern Wyoming have experienced extremely high levels of forest disturbance. Insect outbreaks of Douglas-fir beetle, mountain pine beetle, and spruce beetle have resulted in millions of acres of conifer mortality in Colorado. The study area has experienced extensive wildfires, some with levels of fire severity high enough to limit conifer regeneration, potentially resulting in long-term cover type conversion. Communities are attempting to manage fire risk by thinning ponderosa pine and Douglas fir forests. There are also concerns about the interaction of fire, insect outbreaks, and timber harvest. A complete record of the extent and timing of these disturbances across the region over the last two decades will provide valuable information to address these community concerns.

National Application Area Addressed: Agriculture
Study Location: Southern Rocky Mountains, CO, WY
Study Period: January 2000 to June 2016

Advisor: Dr. Paul Evangelista, Natural Resource Ecology Laboratory, Colorado State University

Source of Project Idea: Colorado Forest Restoration Institute (CFRI) staff approached the DEVELOP Fort Collins node about the possibility of mapping and labeling disturbance on the landscape level following a closeout seminar in 2014. At that time, methodologies to complete this type of analysis were not yet available. Recent literature and published methodologies make this project possible.

Partner Overview

Partner Organizations:

Organization	POC (Name, Position/Title)	Partner Type	Boundary Org?
National Park Service, Rocky Mountain National Park	Hanem Abouelezz, Landscape Ecologist	End-User	No
Colorado Forest Restoration Institute	Dr. Tony Cheng, Director	End-User	Yes
Feedstock Supply Team, Bioenergy Alliance Network of The Rockies	Ryan Anderson, Research Associate	End-User	No

End-User Overview

End-User's Current Decision Making Process:

The CFRI is a "bridging organization among researchers, land managers, and communities dedicated to advancing knowledge and practice of forest restoration and wildfire hazard reduction in the central Rocky Mountain region." The organization makes policy recommendations on forest management to federal, state, and local land management organizations. Policy recommendations are the result of extensive, on the ground research activities conducted directly by the organization. CFRI seeks to use historical data on fire and beetle outbreaks to better prepare land owners and managers for future disturbances.

Rocky Mountain National Park (RMNP) is a 415-square mile protected area in north central Colorado. Park staff currently tracks forest management practices in a geographic information system, but records going back to the year 2000 are incomplete and were not consistently collected over the past decade. RMNP seeks to use the reconstructed historical forest management data produced through this project to evaluate the effect forest treatments have had on the reduction of wildfire risk, beetle kill, and forest resilience.

The Bioenergy Alliance Network of the Rockies (BANR) Feedstock Supply Team is responsible for quantifying and locating live and dead forest biomass and for developing short-term predictions of bark beetle outbreaks. Knowledge of the feedstock supply will be used to assess the economic, social, and environmental feasibility of using beetle-killed wood as a feedstock for biofuel production.

End-User's NASA Earth Observations Capacity:

Colorado Forest Restoration Institute – This organization has relied primarily on field observations and dendrochronological reconstructions to carry out past research projects and to inform policy decisions. Although the organization has not used NASA Earth observations and does not have funding or staff to complete a project of this nature, CFRI staff are experienced in the use of geographic information systems and the integration of remotely sensed data products into their research project and decision support system should be seamless. This will build their capacity to integrate NASA Earth Observations into similar research projects in the future.

Rocky Mountain National Park – This organization has not evaluated forest treatment effectiveness in recent time, and would be unable to conduct an analysis of this scale without the use of NASA Earth Observations and the support of the DEVELOP project. Although the organization as a whole has applied remotely sensed data products into their research in the past, our specific point of contact does not currently have the capacity, funding, or staff available to complete a project of this nature. This project will build RMNP's capacity to integrate remotely sensed data into their future research efforts by displaying the value these end products can have on evaluating forest management activity on the landscape scale.

Bioenergy Alliance Network of the Rockies – This organization is a diverse network of academic researchers, federal agencies, industry leaders, and policy makers. Although our specific point of contact has experience using NASA Earth observations in research, this project will build capacity for the BANR organization as a whole by showcasing the use and application of these observations across disciplines. This organization is also interested in extending a disturbance history mapping project beyond what would be possible in a DEVELOP term. As such, BANR staff will make use of the tutorial end product to be provided through this project to complete additional historical disturbance analyses for 1985-1999, which will build their capacity to apply NASA Earth Observations in future change detection analyses.

Collaborator & Boundary Organization Overview

Boundary Organization Dissemination:

Colorado Forest Restoration Institute – This boundary organization was involved in the development of this project, has field data that will be used in this project, and will provide mentorship to the DEVELOP team. CFRI seeks to expand their stakeholder's knowledge of current and potential future forest health issues and will share the results of this project widely through their "bridging activities", which seek to provide data and resources to forest management organizations throughout Colorado through their website, workshops, and presentations.

Project Communication & Transition Overview

In-Term Communication Plan:

The team will communicate with partners at NPS, CFRI and BANR on a biweekly basis. Since the partners of this project are based locally in Fort Collins, in-person meetings will be simple to plan and carry out. The Center Lead and Team Lead of this project will be the primary points of contact with both partner organizations.

Transition Approach:

At the end of the term, the team will host a 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. This project is unique in that the end-products will be integrated into existing forest management and research projects very quickly, and that it will build partner capacity to conduct similar change detection analyses using NASA Earth Observations between 1985 and 1999 through the use of the provided tutorial.

Earth Observations Overview

Earth Observations:

Platform & Sensor	Parameters	Use
Landsat 4/5 (TM)	Surface reflectance, differenced normalized burn ratio, tasseled cap brightness, greenness, wetness	This dataset provides the temporal (16 days) and spatial (30 m ²) resolution needed for mapping disturbance history, with images beginning in 1983. To ensure the availability of cloud and scanline free imagery, the team will use this dataset as a supplement to Landsat 7 ETM+ and Landsat 8 OLI. Depending on cloud-free image availability, 2000-2012 inputs to our models (a LEDAPS corrected composite and tasseled cap indices) will be generated using this platform and sensor.
Landsat 7 (ETM+)	Surface reflectance, differenced normalized burn ratio, tasseled cap brightness, greenness, wetness	This dataset provides the temporal (16 days) and spatial (30 m ²) resolution needed for mapping disturbance history, with images beginning in 1999. Landsat 7 imagery will be used as an ancillary dataset to Landsat 5 when cloud free imagery is not available.
Landsat 8 (OLI)	Surface reflectance, differenced normalized burn ratio, tasseled cap	This dataset provides the temporal (16 days) and spatial (30 m ²) resolution needed for mapping disturbance history, with images beginning in 2012. Landsat 8 imagery will be used to derive vegetation and burn indices

	brightness, greenness, wetness	that can be visually interpreted to identify and label disturbances.
MODIS Aqua/Terra	Surface reflectance, differenced normalized burn ratio, tasseled cap brightness, greenness, wetness	This dataset is an important component to the continuation of the disturbance time series through 2016. The bfastSpatial package can use MODIS imagery to fill in data gaps that are not available through the Landsat archive or are not compatible with available disturbance models.
Space Shuttle SRTM	Elevation, slope, aspect, compound topographic index	In combination with the visually interpreted training datasets produced by this project, this dataset will be used to derive topographic indices to be used as predictors to model attribution of disturbances.

Ancillary Datasets:

Bioenergy Alliance Network of the Rockies – Forestry Field Measurements – Classification of Disturbances

USDA Farm Services Agency – National Agricultural Imagery Program – Classification of Disturbances

Rocky Mountain National Park – Fire History GIS Records – Classification of Disturbances

US Forest Service – Aerial Detection Surveys of Insect Outbreaks – Classification of Disturbances

Models:

LandsatLinkr (POC: Justin Braaten, Oregon State University)

bfast Statistical and Spatial Packages (POC: Darin Schulte, Colorado State University)

LandTrendr (POC: Dr. Robert Kennedy, Oregon State University)

Random Forests (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center)

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

Decision Support Tool & End-Product Overview

End Products:

End Products	Partner Use	Datasets & Analyses	Software Release Category
16 Year Categorized Disturbance History	Prediction of susceptibility of forested landscapes to insect and disease outbreaks in the future. Evaluating effectiveness of past forest management activities on forest health and fire severity and making recommendations to plan future management activities.	Landsat 4/5 TM, 7ETM+, 8 OLI and MODIS imagery will be integrated into the bfast Spatial and LandTrendr algorithms to detect magnitude, duration, and extent of past forest disturbances. These outputs will be classified by disturbance type (fire, harvest, or insect) using several lines of evidence from ancillary datasets.	1
Disturbance History	Prediction of susceptibility of	Summaries of spectral	1

Environmental Covariates	forested landscapes to insect and disease outbreaks in the future. Predicting areas that will be in greatest need of management in the future to reduce wildfire risk and support forest health.	characteristics of specific disturbance types, as well as topographic covariates produced using SRTM, will be provided to partners by analyzing the 31-Year Labeled Disturbance History end-product.	
Detailed Tutorial: Detecting and Categorizing Forest Disturbances Using Landsat	Our partners at the Bioenergy Alliance Network of the Rockies will use this tutorial to extend the categorized disturbance history back to 1985.	Detailed tutorial that will cover image acquisition, processing, change detection, and change label mapping.	1

End-User Benefit:

This project will save CFRI time and money over conducting similar fire history analyses in the field. It will also provide a new avenue for the organization to analyze the effectiveness of historical forest management treatments on forest health and to make recommendations on how forested landscapes should be managed in the future. Additionally, knowledge of where past fuels reduction treatments occurred can inform where future treatments should be placed on the landscape.

"We've wanted a labeled disturbance history to help predict future susceptibility of our forested landscape to beetle outbreaks for a long time, but we don't have the resources or funding to pursue a project of this scale. When I use predictive models, some of the most [important] information I can have is a good picture of what has happened in the past—this project will provide just that." (Personal communication with Ryan Anderson, BANR)

Project Timeline & Previous Related Work

Project Timeline: 1 Term: 2016 Summer

Related DEVELOP Work:

Spring and Summer 2014 (USGS at Colorado State University) - Colorado Agriculture:
Reconstructing Forest Harvest History Using Landsat Imagery for Enhanced Land Management

Project Needs/Requests

Participants Requested: 4-5

Software & Scripting:

ArcGIS- Image processing, end product generation
ENVI/IDL- Image calibration, LandTrendr coding
Program R- Statistical analyses, raster processing
Google Earth Pro- Visual interpretation of historical imagery

References:

Kennedy, Robert E., et al. "Attribution of disturbance change agent from Landsat time-series in support of habitat monitoring in the Puget Sound region, USA." *Remote Sensing of Environment* 166 (2015): 271-285.

Watts, Laura M., and Shawn W. Laffan. "Effectiveness of the BFAST algorithm for detecting vegetation response patterns in a semi-arid region." *Remote Sensing of Environment* 154 (2014): 234-245.