**Colorado & New Mexico Disasters**

*Using NASA Earth Observations to Quantify Tree Mortality and Burn Severity to Inform Management on Ranches and Open Lands*

**VPS Title:** Hot Topic: Tree Mortality and Burn Severity in Southern Colorado

**Project Team**

***Project Team*:**

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***Advisors & Mentors*:**

Dr. Paul Evangelista (Colorado State University, Natural Resource Ecology Laboratory)

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

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**Project Overview**

***Project Synopsis*:** The severity and extent of insect outbreaks across the western U.S. have risen in recent years, leading to higher tree mortality in western forests. The resulting increase in standing dead trees equates to higher fuel loading across the landscape and may, in turn, increase the risk of catastrophic wildfire. To evaluate the link between insect outbreaks and fire severity, we used NASA Earth observations to: 1) analyze and map regional tree mortality caused by the western spruce budworm (*Choristoneura freemani*) prior to the 2018 Spring Creek Fire; 2) quantify burn severity for the Spring Creek Fire; and 3) explore tree mortality-burn severity interactions using a generalized linear model.

***Abstract*:**

Both wildfires and forest insect outbreaks have increased in frequency and severity in recent years. Western spruce budworm (Choristoneura freemani), a widespread defoliator in western U.S. forests, has affected over 6,000 hectares of forest in south-central Colorado since 1998. Aaron Swallow, an environmental ranch manager in southern Colorado, was concerned that fuel loading from budworm-related tree mortality would increase the risk of catastrophic wildfire on the lands he manages. To address this concern, we selected a study area encompassing the 2018 Spring Creek Fire footprint. Then, we used NASA Earth observations to 1) analyze and map regional tree mortality prior to the Spring Creek Fire, 2) quantify and map burn severity for the Spring Creek Fire, and 3) model the relationship between pre-fire tree mortality and burn severity of the fire. We identified key predictor variables with the Variable Selection Using Random Forests (VSURF) R package and modeled pre-fire tree mortality using the randomForest R package. Burn severity was mapped using the Relativized Burn Ratio (RBR). The maps created from this project provided our partners with a comprehensive assessment of tree mortality, facilitating future restoration and management efforts. Additionally, an accompanying methods tutorial teaches project partners how to replicate this analysis for other years, locations, and forest disturbances.

**Keywords:**

Remote sensing, western spruce budworm, randomForest, Relativized Burn Ratio, forest management, Landsat, digital ocular sampling

***National Application Area Addressed:*** Disasters

***Study Location:*** WRS-2 Path/Row: 33/34; Colorado (CO) & New Mexico (NM)

***Study Period:*** October 1998 – October 2018

***Community Concern:***

* In southern Colorado, both forest composition and structure have changed over the past century due to fire suppression management strategies, insect outbreaks, and drought conditions, making these forests more susceptible to catastrophic wildfires.
* The recent and severe 2018 Spring Creek Fire exacerbated regional land managers’ concerns over fuel loading and wildfire mitigation.
* Land managers do not know whether insect-related tree mortality will impact the severity of subsequent wildfires.
* The forest management team for southern Colorado’s Tercio and Trinchera ranches does not currently employ NASA Earth observations or remote sensing data, yet cannot thoroughly assess tree mortality through field monitoring alone.

***Project Objectives:***

* Model and map tree mortality within our study area prior to the 2018 Spring Creek Fire
* Quantify and map burn severity for the 2018 Spring Creek Fire
* Explore interactions between pre-fire tree mortality and burn severity using a generalized linear model

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Tercio and Trinchera Ranch** | Aaron Swallow, Environment and Forest Manager | End User | No |
| **Colorado State Forest Service** | Amanda West, Manager of Science and Information | Collaborator | No |

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

The Tercio and Trinchera ranches are cooperating with the Colorado State Forest Service to improve forest health and land management in southern Colorado. The two ranches currently use costly field surveys to monitor fuel loads as well as forest composition and structure on their properties. Inaccessible and remote ranch terrain spatially limits these surveys, hindering comprehensive management decisions.

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

Tree mortality is an indicator of forest health and may also impact wildfire risk and burn severity. This project provided forest managers of the Tercio and Trinchera ranches with a map quantifying tree mortality across the entirety of their ranch lands and a map of burn severity for the 2018 Spring Creek Fire. We also provided a model output that related burn severity to pre-fire tree mortality; additionally, this model allows managers to evaluate potential burn severity risks in other areas. In the future, these tools can enable more targeted, cost-effective ecological monitoring through forest management and fire mitigation strategies, such as insecticide application, tree thinning, or fuels removal.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | surface reflectance, NDVI, NDMI, dNBR, RdNBR, RBR, tasseled cap, evapotranspiration, and vegetation brightness, greenness, and wetness | This satellite was used to generate predictor variables to model tree mortality. |
| **Landsat 7 ETM+** | surface reflectance, NDVI, NDMI, dNBR, RdNBR, RBR, tasseled cap, evapotranspiration, and vegetation brightness, greenness, and wetness | This satellite was used to generate predictor variables to model tree mortality. |
| **Landsat 8 OLI** | surface reflectance, NDVI, NDMI, dNBR, RdNBR, RBR, tasseled cap, evapotranspiration, and vegetation brightness, greenness, and wetness | This satellite was used to quantify burn severity and to generate predictor variables to model tree mortality. |
| **SRTM** | elevation, slope, aspect | This sensor was used to calculate topographic indices, which were used as predictors to model tree mortality. |

***Ancillary Datasets:***

Colorado State Forest Service Aerial Detection Surveys – stratification layers used to inform sampling time periods and for ocular sampling of tree mortality

USDA National Agricultural Imagery Program – high resolution (1 m) imagery used for ocular sampling and image interpretation

Earth Engine Evapotranspiration Flux – map of evapotranspiration for the study area

Landscape Fire and Resource Management Planning Tools Program (LANDFIRE) – used to mask study area based on vegetation types potentially influenced by western spruce budworm

***Modeling:***

Random Forest Classification Model (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – creates binary and continuous models of tree mortality

Generalized Linear Model (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – explores the relationship between tree mortality and burn severity

***Software & Scripting:***

Esri ArcGIS – image processing and end product generation

ENVI/IDL – image calibration and LandTrendr coding

R – VSURF variable selection, randomForest two-step modeling

Google Earth Engine API – digital sampling to create training dataset, calculating spectral indices, large-scale image processing, and analysis

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Tree Mortality Map** | Landsat 8 OLI, Landsat 7 ETM+, Landsat 5 TM, SRTM | Partners can use this in conjunction with The Burn Severity Map to evaluate the health of their forests. It allows for strategic ecological planning to effectively target future management efforts, such as wildfire fuels mitigation. | N/A |
| **Burn Severity Map** | Landsat 8 OLI | Partners will use this to understand how the 2018 Spring Creek Fire affected regional forests. It can facilitate strategic ecological planning and targeted management efforts when used in conjunction with the Tree Mortality Map. | N/A |
| **Modeling Workflow Tutorial** | Landsat 8 OLI, Landsat 7 ETM+, Landsat 5 TM, SRTM | This modeling tutorial of our methodology for modeling and mapping tree mortality and burn severity will allow our partners to reproduce our methodology for other dates, locations, or fire events. | N/A |

**Project Handoff Package**

**Transition Plan:**

The maps, map interpretation, and project video were emailed to Aaron Swallow, the Environment and Forest Manager of the Tercio and Trinchera ranches, the week of November 12th-16th. The complete handoff package was emailed to our partners at the Colorado State Forest Service during this same week. The partners also remotely attended the team’s closeout presentation at this time.

**Team POC:** Sophia Leiker, sophia.leiker@gmail.com

**Partner POC**: Aaron Swallow, aaron.swallow@tercioranch.com

**Handoff Package:**

* Tree Mortality Map for the study area classified by percent mortality
* Burn Severity Map of the 2018 Spring Creek Fire
* Modeling Workflow Tutorial of our methodology for modeling and mapping tree mortality and burn severity
* Project Video
* Project Presentation
* Project Technical Paper

**References:**

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