**Black Hills Wildfires**

*Mapping Post-fire Conifer Regeneration Using Snow-on Imagery*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

The 2000 Jasper Fire was the largest wildfire to date in the Black Hills of South Dakota, burning 83,508 acres of ponderosa pine forest. Over 27% of the fire burned at high-severity, which resulted in near-total stand loss. Our project mapped conifer regeneration density across high-severity burn patches 20 years post-fire to inform forest recovery efforts. Snow-on satellite imagery was successfully tested as a novel approach to isolate conifer regeneration and monitor forest regrowth using a Random Forest Model.

***Abstract:***

The 2000 Jasper Fire in the Black Hills of South Dakota was the largest wildfire to date in the region, burning over 83,000 acres of ponderosa pine forest. In collaboration with partners from the United States Forest Service (USFS) Black Hills Experimental Forest, USFS Rocky Mountain Research Station, and United States Geological Survey Geosciences and Environmental Change Science Center, we characterized post-fire forest regeneration within high-severity burn patches. We accomplished this by implementing novel conifer detection techniques using a snow index mask to create a winter, snow-on image composite from Landsat 8 Operational Land Imager (OLI) and Sentinel-2 Multispectral Instrument (MSI) data. We utilized 2015 USFS stem maps of field-observed regeneration plots and ocularly sampled additional reforestation sites planted in 2001–2013. In Google Earth Engine (GEE), the field data and imagery were used to train a Random Forest (RF) model. The RF model classified 2021 conifer regeneration density as low, medium, or high across the high-severity burn area with an overall accuracy of 81.3%. Approximately 45.9% of the high-severity burn had low or no regeneration (0-40 trees per acre) 20 years post-fire. Given our partners' desire to find easily accessible low conifer regeneration zones, we identified 4,079 acres of priority planting sites that were within 1,500 feet of roads, had not been planted previously, and were larger than 50 acres. This method supports the use of snow-on imagery as a successful technique to identify conifer regeneration.

***Key Terms:*** random forest classification, forestry, conifer regeneration, snow-on composites, high severity fire

***National Application Area Addressed:*** Wildfires

***Study Location:*** Black Hills National Forest, SD

***Study Period:*** December 2014 – April 2022

***Community Concerns:***

* With increasing frequency of high-severity fire across the Western US and adverse post-fire growing conditions under climate change, analyzing patterns of post-fire forest recovery is critical to understanding and predicting future environmental conditions.
* High-severity burns have large ecological impacts, with potential to shift an ecosystem away from its historical composition. Forest managers in the Black Hills are working to return the forest affected by the Jasper Fire to a productive ponderosa pine dominated ecosystem.

***Project Objectives:***

* Assess the feasibility of using snow-on imagery to detect conifer species seedling regeneration
* Measure density of conifer regeneration in the high-severity burn areas of the Black Hills Jasper Fire
* Identify areas of low conifer regeneration to help prioritize feasible reforestation efforts

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **USDA, US Forest Service, Black Hills Experimental Forest** | Dr. Mike Battaglia,  Director | End User |
| **USDA, US Forest Service, Rocky Mountain Research Station** | Dr. Paula Fornwalt,  Research Ecologist | Collaborator |
| **USGS, Geosciences and Environmental Change Science Center** | Dr. Melanie Vanderhoof,  Research Scientist | Collaborator |

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

Land management following large-scale wildfire requires detailed and repeated forest inventories to ensure successful recovery. Forest managers need information on the status of forest regeneration to identify areas of ecological need, prioritize reforestation efforts, and develop long-term management plans. Current reforestation decisions within the Black Hills National Forest are based on field-collected forest inventories, which can be time consuming and costly. Furthermore, resource managers are limited in what reforestation they can prescribe based on planting feasibility, expense, and time required to manage the 83,508 acres burned by the Jasper Fire. The Black Hills Forest managers’ main focus is for the forest to return to its original ponderosa pine dominated ecosystem and continue pre-fire timber production. Forest managers need easily-scalable monitoring techniques to disseminate information across a network of USFS resource managers to better inform their decisions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Normalized Difference Vegetation Index (NDVI), Normalized Difference Snow Index (NDSI), Normalized Difference Forest Snow Index (NDFSI) | Selected snow-on images were used to detect conifer regeneration |
| **Sentinel-2 MSI** | NDVI, NDSI, NDFSI | Selected snow-on images were used to detect conifer regeneration |

***Ancillary Datasets:***

* Monitoring Trends in Burn Severity (MTBS) Thematic Burn Severity and Fire Perimeter – Map of Jasper Fire Burn Severity used to limit study extent to high severity burn areas and to examine regeneration patterns by burn severity
* USDA Forest Service, Rocky Mountain Research Station Post-Fire Regeneration Stem Maps – Six, 4 ha tree regeneration stem maps from 2015 were used to train and evaluate random forest model
* Natural Resource Manager’s (NRM) Forest Service Activity Tracking System (FACTS) - Database of USFS silvicultural activities used to identify areas of previous reforestation and add additional training data to the Random Forest model
* National Agriculture Imagery Program (NAIP) imagery – Imagery used to detect and digitize tree regeneration over known reforestation plantings
* NASA JPL NASADEM\_HGT Digital Elevation Model 30m – Elevation used as a variable in random forest model

***Modeling:***

* Random Forest (Contact: Anthony Vorster, Colorado State University) – Detect conifer regeneration in high severity burn areas and evaluate variable importance

***Software & Scripting:***

* Google Earth Engine API – Landsat 8 and Sentinel-2 data acquisition, image processing, random forest classification, and map creation
* Esri ArcGIS Pro 2.9.0 – training dataset creation, data visualization, and mapping
* R 4.1.3 – variable selection and data visualization

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observation Used** | **Partner Benefits & Use** | **Software Release Category** |
| **Evaluation of Snow-on Conifer Detection Method** | Landsat 8 OLI  Sentinel-2 MSI | The evaluation will provide confidence in the location/pattern of detected post-fire conifer regeneration using a novel technique. | N/A |
| **2021 Conifer Regeneration Map** | Landsat 8 OLI  Sentinel-2 MSI | This map will characterize forest recovery in high burn severity areas 20 years post-fire. This will improve our partner's understanding of natural regeneration dynamics and aid conifer reforestation management efforts | N/A |

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

This project will provide our partners with resources to support the Jasper Fire recovery effort. Characterizing the spatial pattern of forest regeneration will help resource managers prioritize reforestation efforts in the Black Hills. Additionally, this technique could be used to monitor and identify planting success long term. This project will help the partner organizations better leverage Earth observations to understand natural conifer regeneration and spectrally distinguish conifer growth from other vegetation. Providing a link between field data and coarse-resolution imagery will provide replicable, scalable, and affordable techniques for future post-fire recovery efforts.

**References:**

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