**Boulder County Disasters**

*Mapping Forest Carbon Stocks to Understand Carbon Implications of Treatments and Wildfire*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Understanding the interaction between fire mitigation efforts and forest carbon preservation has been increasingly crucial in western US forests, especially under changing climatic conditions. This project explored the use of remote sensing data for post-wildfire forest carbon estimation and produced carbon maps of treated and untreated stands impacted by the 2020 Cal-Wood fire using field measurements and remotely sensed imagery. Through these mapping efforts, this project also conducted an analysis of treatment effectiveness with a focus on the preservation of forest carbon post-wildfire. The final maps and analyses will aid Boulder County Parks and Open Space (BCPOS) land managers in determining the effectiveness of fuels reduction treatments in the context of wildfire and carbon.

***Abstract:***

In recent years, record-breaking wildfire activities in the western US illustrate the need for fire mitigation efforts, such as forest fuels reduction treatments. Forests serve as crucial carbon sinks that combat the increasing effects of climate change while fuels treatment may remove carbon from forested systems. As a result, forest managers need to find a balance between fire mitigation and carbon preservation. This project partnered with Boulder County Parks and Open Space (BCPOS) and the University of Colorado, Denver, to investigate the 2020 Cal-Wood fire in Boulder County, Colorado. Using remote sensing data from Landsat 8 Operational Land Imager (OLI), Shuttle Radar Topography Mission (SRTM), Sentinel-2 Multispectral Instrument (MSI), and Light Detection and Ranging (LiDAR), we mapped post-fire forest carbon pools and compared these pools between treated and untreated areas. Results indicate post-fire aboveground live carbon (R2 = 0.76), aboveground dead carbon (R2 = 0.44), standing carbon (R2 = 0.44), and total carbon (R2 = 0.35) pools can be estimated based on remotely sensed and field-derived data. The analysis suggests fuels reduction treatments did not reduce carbon loss in the presence of wildfire enough to clearly distinguish the post-fire carbon in the treated and untreated areas. However, the final carbon maps still provide BCPOS and researchers with an opportunity to explore carbon estimation models based on remotely sensed data as well as a framework to evaluate fuels reduction treatment effectiveness and impact on forest carbon stocks for future wildfire events.

***Key Terms:***

random forests, remote sensing, LiDAR, forest management, wildfire

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

***Study Location:*** City of Boulder, Boulder County, and Jefferson County, CO

***Study Period:*** June 2020 – September 2021

***Community Concerns:***

* Residential and recreational areas across the Colorado Front Range are increasingly exposed to more severe and frequent wildfires due to changing climate that increases drought conditions and lengthens fire seasons.
* Community protection, invasive species spread, loss of recreational opportunities, and negative impacts to local economies are the driving concerns behind the management of Ponderosa pine forests along the CO Front Range.
* Increased interest in forests’ carbon sequestration abilities may help to reduce greenhouse gas concentrations and thus combat the negative effects of climate change on communities.

***Project Objectives:***

* Create post-fire carbon models for the Cal-Wood fire perimeter using forest inventory plot data, optical remote sensing imagery, high-resolution LiDAR data, and additional data
* Utilize models to map post-fire forest carbon in order to estimate the effects of fuels reduction treatments and wildfire on carbon preservation
* Communicate the purpose and effectiveness of fuels reduction treatments, using the Cal-Wood fire as a case study, by producing an Esri StoryMap

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Boulder County Parks and Open Space** | Nick Stremel, Forest Specialist | End User | No |
| **University of Colorado, Denver** | Dr. Brian Buma, Assistant Professor | Collaborator | No |

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

One challenge faced by land managers at our partner organization involves weighing the trade-offs between wildfire management and carbon storage. Wildfire management in the form of fuels reduction treatments, such as thinning and prescribed burning, removes carbon from the landscape as an upfront cost to mitigating larger carbon losses through combustion. Boulder County Parks and Open Space (BCPOS), which manages 30,000 acres of forest in the CO Front Range, showed an interest in better understanding these tradeoffs and what can be learned from the 2020 Cal-Wood fire. This agency is paving the way forward to understanding carbon under their jurisdiction and has composed a climate change mitigation plan. BCPOS is interested in enrolling in carbon markets. This is a new step for the agency, and they want to know how to keep carbon in natural systems and how management can encourage this. A handful of studies have explored greenhouse gases and land conversion effects on BCPOS’s property, but no studies have yet evaluated their fuels reduction treatments. While forest biomass is accounted for, without the resources to apply remote sensing capabilities, biomass estimates are made from time-consuming, field-derived surveys.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Tasseled capped indices | Indices, derived from Landsat 8 OLI imagery at 30 m2 spatial and 16-day temporal resolution, served as predictor variables in characterizing biomass across the study area. |
| **Sentinel-2 MSI** | Tasseled capped indices | Indices, derived from Sentinel-2 MSI data at 20 m2 spatial and 5-day temporal resolution, served as predictor variables in characterizing biomass across the study area. |
| **SRTM** | Digital Elevation Model (DEM) | SRTM derived DEM at 30 m2 resolution served to produce predictor variables to characterize biomass across the study area. |

***Ancillary Datasets:***

* University of Colorado, Denver 2021 Forest Carbon Field Data – Post-fire field measurements of biomass, carbon pools, and burn severity for 80 burned (130 total) (20 m2) treatment plots trained and validated the biomass model.
* Colorado State University, Natural Resource Ecology Laboratory Burn Severity – Refined raster of the Cal-Wood Fire burn severity, initially produced by Colorado Front Range Disasters Spring 2021, helped predict biomass quantities.
* Colorado State University, Vogeler Lab 2013 Gridded LiDAR Data – Forest structure metrics (i.e. canopy height) helped predict biomass quantities.
* Colorado State University, Colorado Forest Restoration Institute, BCPOS, NASA DEVELOP, and Colorado State Forest Service Forest Treatment Database – Collaborative database storing the type, location, and timing of forest treatments along Colorado’s northern Front Range distinguished the effects of treatment on biomass.
* USGS National Elevation Dataset (NED) – 30 m elevation data processed by the USGS and includes data from SRTM, dervied aspect, slope, curvature, northness, eastness, heat load index, roughness, Compound Topographic Index (CTI) predictor variables.
* USDA NRCS Web Soil Survey Data – Percentage clay, silt, sand, organic matter and pH data for soil in the Cal-Wood served as predictor variables.
* ORNL DAAC Soil Carbon Estimates – Soil carbon served as a predictor variable.

***Modeling:***

* Random forests (Contact: Anthony Vorster, Colorado State University) – Mapped forest carbon with inputs from ancillary data, field data, and remotely sensed data.

***Software & Scripting:***

* RStudio 4.1.1 – Random forests modeling, analysis, and mapping
* Google Earth Engine – Data acquisition and image processing
* ArcGIS Pro 2.9.0 – Data processing, visualization, and cartography

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Forest Carbon Maps** | Landsat 8 OLI  Sentinel-2 MSI  SRTM | These maps will be used by project partners to better understand forest carbon stocks across the landscapes they manage and to compare forest carbon stocks associated with different management and disturbance histories. | N/A |
| **Comparison of Forest Carbon in Treated and Untreated Areas** | Landsat 8 OLI  Sentinel-2 MSI  SRTM | This comparison will elucidate how forest management and disturbances are impacting forest carbon stocks, thus informing how fuels reduction treatments can be balanced with carbon preservation goals. | N/A |

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

The proper management of tradeoffs between fuels reduction treatments and important ecosystem services (i.e., carbon storage) is a key challenge for our partners at BCPOS. This project explores the feasibility of estimating post-fire forest carbon using readily available remotely sensed data alongside field-derived data.

The forest carbon maps will illustrate the distribution of post-fire forest carbon and help BCPOS evaluate the effect of wildfire and treatments. The comparison of post-fire forest carbon in treated and untreated areas will consider treatment implementation and age across this landscape. The final remote sensing analyses and map end products will provide access to data that are otherwise beyond the resources currently available to our partners at BCPOS.

**References**

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