**Fisher’s Peak Ecological Forecasting**

*Mapping Biomass to Inform Conservation Planning of a Future State Park in Southern Colorado*

**Project Team**

***Project Team:***

Lauren Lad (Project Lead)

Scott Cunningham

Laura Krauser

Darby Levin

***Advisors & Mentors:***

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

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

Peder Engelstad (Colorado State University, Natural Resource Ecology Laboratory)

Nicholas Young (Colorado State University, Natural Resource Ecology Laboratory)

Dr. Tony Vorster (Colorado State University, Natural Resource Ecology Laboratory)

***Team POC:*** Lauren Lad, laurelad97@gmail.com

***Partner POC:*** Chris Pague, cpague@tnc.org

**Project Overview**

***Project Synopsis:***

Fisher’s Peak, formerly Crazy French Ranch, is set to become Colorado’s newest and second-largest state park. To support the park's creation, this project developed a model for estimating biomass using forest inventory data as well as NASA Earth observation data collected by active and passive sensors. The results produced a map of biomass in Fisher’s Peak State Park and a forecast of biomass change due to development that will aid in maximizing the future park’s recreation potential while conserving its unique natural habitat.

***Abstract:***

Fisher’s Peak is a 77.5 km2 property southeast of Trinidad, Colorado that is planned to become Colorado’s newest state park. The area has experienced limited anthropogenic disturbance and is home to an abundance of unique habitats and species. A rapid, approximately 900 m change in elevation over the extent of the area nurtures a variety of plants and animals, including the endangered New Mexico meadow jumping mouse. In 2019, the State of Colorado obtained Fisher’s Peak with plans to make it Colorado’s second largest state park. A diverse group of collaborators, including the Colorado State Forest Service and The Nature Conservancy, worked closely to design the state park to maximize recreation opportunity while conserving the property’s rich habitats and biodiversity. The Fisher’s Peak Ecological Forecasting Team utilized Light Detection and Ranging (LiDAR) surveys, *in situ* forest inventory data, and Earth observations from Landsat 8 Operational Land Imager (OLI), Sentinel-1 C-band Synthetic Aperture Radar (C-SAR), Sentinel-2 Multispectral Instrument (MSI), Advanced Land Observing Satellite 2 (ALOS-2) Phased Array type L-band Synthetic Aperture Radar (PALSAR-2) and the Shuttle Radar Topography Mission (SRTM) to quantify and map biomass over the extent of the study area. The results from modeling biomass had an out-of-bag root mean square error of 55 Mg/ha and an R2 of 12. The resulting map indicates areas where carbon storage on the property is high, informing decision-making processes for future park development. While more *in situ* training data may improve modeling capacity for biomass in the Fisher’s Peak area, this work represents a feasible attempt to better understand biomass distribution using earth observation.

***Key Terms:***

LiDAR, biomass, optical remote sensing, Landsat 8 OLI, Sentinel-1, carbon sequestration

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

***Study Location:*** Fisher’s Peak Ranch, Colorado

***Study Period:*** June 2019 – August 2019, Forecasting to Year 2021

***Community Concerns:***

* With the potential to provide a site on which to develop carbon credits, the economic and environmental aspects of Fisher’s Peak state park offer a new asset to the region. Because this area has yet to be fully inventoried, the full extent of the biomass, fuel loads, and carbon storage is not yet quantified—leaving the impact of park development on economic and conservation efforts uncertain.
* Concurrently, there are many unique species in the area that include bears, elk, mule deer, bobcats, mountain lions, and the federally endangered New Mexico meadow jumping mouse (Vogrin, 2019). As the park is developed for visitors and recreation activities, these localized species need to be protected.
* The park will need to balance the needs of local economic growth, recreation, and development with conservation and protection of the area’s lands and biodiversity.

***Project Objectives:***

* Develop a model for estimating biomass using *in situ* forest inventory data, high resolution LiDAR data, and optical remote sensing imagery
* Create a pre-development biomass map
* Predict potential for carbon market entry by designing an efficient way to estimate carbon storage
* Forecast high priority preservation areas by highlighting areas of old growth forest and high carbon storage

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **The Nature Conservancy** | Chris Pague, Senior Ecologist | End User | Yes |
| **Colorado State Forest Service** | Dr. Amanda Fordham, Science Information Manager | Collaborator | Yes |

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

Project partners at The Nature Conservancy (TNC) focus their efforts and resources on the conservation of the lands and waters on which all life depends. Their conservation efforts are driven through actions like purchasing high conservation-value land and providing conservation easements on other landowner’s properties. The TNC will have direct influence on the plan and ultimate development of Fisher’s Peak Ranch. The TNC’s primary objective is to conduct the most comprehensive assessment of the natural resources on the property so they can be considered in the planning and development of the area. However, the TNC has limited remote sensing capabilities and currently relies on field surveys.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **ALOS-2 PALSAR-2** | L-band HH, HV, and HH/HV | ALOS-2 PALSAR-2 data were used to distinguish forest biomass content and compared to passive remote sensing datasets.  |
| **Landsat 8 OLI** | Spectral vegetation indices, tasseled capped indices, top of atmosphere bands | Landsat 8 images were used to distinguish vegetation communities and their biomass content within the study area.  |
| **Sentinel-1 C-SAR** | Synthetic aperture radar C-band VV and VH | Sentinel-1 C-band data were used to distinguish forest biomass content and were compared to passive remote sensing datasets. |
| **Sentinel-2 MSI** | Spectral vegetation indices, tasseled capped indices, top of atmosphere bands | Sentinel-2 data were used to distinguish vegetation communities and their biomass content. Imagery will be compared to Landsat 8. |
| **SRTM** | Elevation, slope, aspect northness, aspect eastness | A DEM from SRTM was used to derive topographic indices to develop a biomass content map.  |

***Ancillary Datasets:***

* Colorado State Forest Service, forest prism plots – These plots trained and validated biomass quantification models.
* USGS FSA National Agriculture Imagery Program (NAIP), high resolution imagery – NAIP imagery aided in the evaluation of vegetation communities and derived training data for the supervised classification.
* MRLC National Land Cover Database (NLCD) – NLCD validated predicted vegetation distribution.
* Colorado State Forest Service provided Aerial LiDAR – This dataset helped distinguish vegetation communities via canopy height.

***Modeling:***

* Random Forest (POC: Nicholas Young, Natural Resource Ecology Laboratory) – This algorithm was used to run a regression model to estimate the biomass content of Fisher’s Peak Ranch and to evaluate future impacts on sensitive vegetation.

***Software & Scripting:***

* R Statistical Software – This software was used to organize and filter data and run Random Forest classification and Boosted Regression Trees modeling.
* Google Earth Engine – This platform was used to view, filter, derive and export Landsat 8 OLI, Sentinel-2 MSI, SRTM, and NAIP imagery.
* Esri ArcGIS 2.5.1 – This software was used to visualize model results and create map products.
* Python 3.0 – This programming language was used to automate data and raster processing.

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Biomass Content Map** | ALOS-2 PALSAR-2Landsat 8 OLISentinel-1 SARSentinel-2 MSI SRTM | This product provided a spatial inventory of the biomass content of vegetation communities in Fishers Peak Ranch. This map can be overlaid with planned recreation to predict impact on the area’s carbon sink and minimize impacts on areas with a high biomass content.  | N/A |
| **Predictions of Impacts of Planned State Park Development for Vegetation** | ALOS-2 PALSAR-2Landsat 8 OLISentinel-1 SARSentinel-2 MSISRTM | These predictions helped in the planning and development of Fisher’s Peak Ranch, supporting a quantitative and informed prioritization of potential planned development scenarios. | N/A |

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

Project end products were used by partners to make informed development decisions as they transition Fisher’s Peak into a state park. A modeled biomass map of the property provided knowledge on the density and ecological importance of vegetation communities. This map supported planning and management for the park’s development, while establishing a baseline of biomass that will be used for long-term monitoring. Additionally, this biomass map was used to estimate the property’s fuel loads and carbon storage, which will inform future conservation efforts.

**References**

Dubayah, R., Blair, J. B., Goetz, S., Fatoyinbo, L., Hansen, M., Healey, S., … & Silva, C. (2020). The Global Ecosystem Dynamics Investigation: High-resolution laser ranging of the Earth’s forests and topography. *Science of Remote Sensing, 1,* 1–14. doi: 10.1016/j.srs.2020.100002

Vogrin, B. (2019 Dec 19). Endangered N.M. meadow jumping mouse found on Fishers Peak property. *Colorado Parks & Wildlife*. Retrieved from: https://cpw.state.co.us/aboutus/Pages/News-Release-Details.aspx?NewsID=7177