**Colorado Eastern Plains Agriculture**

*Rangeland Monitoring to Inform Grazing Management in Eastern Colorado*

**Project Team**

***Project Team:***

Sarah Hettema

Jillian Joubert

Deni Ranguelova

TR Ingram

Max Stewart

***Advisors & Mentors:***

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

Dr. Catherine Jarnevich (USGS, Fort Collins Science Center)

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

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

Christopher Choi (Colorado State University, Natural Resource Ecology Laboratory)

***Fellow:***

Sarah Hettema (Colorado)

***Team Contact:*** Sarah Hettema, sarah.hettema@ssaihq.com

***Partner Contact:*** JJ Autry, jj.autry@tnc.org

**Project Overview**

***Project Synopsis:***

Virtual fencing is a novel technology being adopted by cattle ranchers to help promote biodiversity and increase efficiency of cattle movement across pastures. This project utilized Agricultural Research Service (ARS) and Rangeland Analysis Platform (RAP) data derived from Landsat (7, 8, 9) and Sentinel-2 to track and quantify range conditions on roughly 80,000 acres of rangeland belonging to Red Top Ranch in Eastern Colorado. Locally calibrated standing biomass and bare ground maps were delivered from 1986 to 2022 and summarized by pasture. Additionally, many statistical parameters were extracted from these sources in order to understand the effectiveness of ARS and RAP datasets on the landscape of Red Top Ranch, in support of virtual fencing experiment.

***Abstract:***

Adaptive management on cattle ranches requires rangeland managers to decide the location and duration of the cattle grazing activity across different pastures. Biodiversity, forage availability, and cattle health are all affected by rangeland management. Virtual fencing is a tool that rangeland managers can use to potentially increase biodiversity and improve ranching operations. NASA DEVELOP and Colorado State University (CSU) collaborated with the Nature Conservancy (TNC), and Red Top Ranch to demonstrate the efficacy of virtual fencing. We sought to identify annual and monthly biomass patterns on the ranch (through the creation of monthly max biomass productivity maps). We utilized a dataset from the Agricultural Research Service (ARS) to calculate biomass on the ranch. To validate our remotely-sensed results, we compared model-predicted biomass values to field-collected biomass clipping data and an additional biomass dataset from the Rangeland Analysis Platform (RAP). We used satellite imagery from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), Landsat 9 Operational Land Imager - 2, and Sentinel-2 MultiSpectral Instrument (MSI) for 2021 and 2022. We found that there was heterogeneity in biomass across the ranch, with higher biomass on the western side. The highest peak of biomass was in the summer months, with a smaller peak in mid-September. The ARS biomass dataset had a significant relationship with RAP for 2021. ARS biomass did not have a significant relationship with the biomass field data collected in 2022. The results of our study are aimed to support rotation management, ranch production, biodiversity, and conservation management.

***Key Terms:***

cattle, rangeland, biomass, bare ground, virtual fencing, conservation, Colorado

***National Application Area Addressed:*** Agriculture

***Study Location:*** Red Top Ranch, Pueblo County, CO

***Study Period:*** January 2021- October 2022

***Community Concerns:***

* Stakeholders have a vested interest in the feasibility of virtual fencing applications in rangeland management.
* Red Top Ranch is interested in forage availability and utilizing their land to its fullest potential.
* TNC is interested in pasture control for its potential in meeting biodiversity and conservation goals.

***Project Objectives:***

* Track and quantify range conditions spanning roughly 80,000 acres of Red Top Ranch in the Eastern Colorado plains
* Evaluate existing products of standing biomass
* Support a larger, long-term collaboration project between CSU, TNC, and Red Top Ranch

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **The Nature Conservancy in Colorado** | JJ Autry, Southeast Colorado Project Director | End User |
| **Red Top Ranch** | Davie Brooks, Ranch Manager | End User |

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

Cattle ranching is highly dependent on annual and inter-annual vegetation trends. These trends dictate pasture movements, time spent grazing, herd capacity, as well as breeding and branding times at Red Top Ranch. For centuries, physical fencing was the most practical means of moving cattle across pastures. Physical fencing presents a controversial subject that has negative implications in many fields. The Nature Conservancy is testing a novel virtual fencing technology which would increase efficiency and herd movements to optimize biodiversity and conservation management. The Nature Conservancy often partners with universities to gain data and research to inform their project planning.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 – TM** | Vegetation | Imagery from this sensor was used to create the ARS biomass raster dataset that we applied to our study area. |
| **Landsat 7 ETM+** | Vegetation | Imagery from this sensor was used to create the ARS biomass raster dataset that we applied to our study area. |
| **Landsat 8 OLI** | Vegetation | Imagery from this sensor was used to create the ARS biomass raster dataset that we applied to our study area. It was also used to create the RAP biomass dataset that was used to compare to ARS biomass calculations. |
| **Sentinel-2 MSI** | Vegetation | Imagery from this sensor was used to create the RAP biomass raster dataset that was compared to our ARS biomass calculations. |

***Ancillary Datasets:***

* Colorado State University Field Data – Field data measured during summer 2022 was used to train and evaluate models
* Red Top Ranch Infrastructure – Spatial data of the ranch infrastructure (e.g., water tanks, pasture boundaries) were used to summarize and interpret maps of rangeland production and condition
* LANDFIRE Existing Vegetation Type (EVT) and Existing Vegetation Cover (EVC) - Vegetation layers were used to find timber stands and other vegetation distributions that create extremely high biomass values. In order to develop a mask, this data was utilized to separate extremely high biomass areas from raster analysis

***Software & Scripting:***

* ESRI ArcGIS Pro version 3.0.2 – LandFire EVT Analysis and Masking
* RStudio version 2022.07.1 – ARS and RAP Analysis

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Monthly Biomass Maps** | Landsat 8 & Sentinel 2 Harmonized | Visually and quantitatively compare rangeland conditions across the ranch to inform virtual fencing planning. | N/A |
| **Max Annual Biomass Map by Day of Year** | Landsat 8 & Sentinel 2 Harmonized | Maximum annual biomass with latest data can be used to understand difference in biomass production amount and timing across the ranch. | N/A |
| **RAP vs. ARS Comparison** | Landsat 5 TM, 7 ETM+, and 8 OLI, Sentinel 2 | Future research can use this comparison between biomass datasets to conduct more analysis. | N/A |

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

Red Top Ranch can use the maps and data to inform their managerial practices, grazing rotations, and virtual fencing planning. From the standpoint of the managerial roles, data collected and analyzed will be used to forecast biomass productivity to aid ranch decisions. The Nature Conservancy will gain an initial understanding of virtual fencing effectiveness and outcomes.

***Project Continuation Plan:***

The team will evaluate how the cows utilize the landscape relative to attributes mapped in Term I. They will use resource selection functions to map the probability of use across the landscape, relating the herd population to rangeland habitats. The Nature Conservancy and Red Top Ranch are especially interested in these results, and plan to apply findings to adaptively manage the cattle herds with virtual fencing. The final project handoff will occur at the end of this term.

**References**

Boyce, M. S., & McDonald, L. L. (1999). *Relating populations to habitats using resource selection functions.* Trends in ecology & evolution, 14(7), 268-272. <https://doi.org/10.1016/S0169-5347(99)01593-1>

Campbell, D. L. M., Marini, D., Lea, J. M., Keshavarzi, H., Dyall, T. R., & Lee, C. (2021). *The application of virtual fencing technology effectively herds cattle and sheep*. Animal Production Science, 61(13), 1393-1402. <https://doi.org/10.1071/AN20525>

Kearney, S. P., Porensky, L. M., Augustine, D. J., Gaffney, R., & Derner, J. D. (2022). *Monitoring standing herbaceous biomass and thresholds in semiarid rangelands from harmonized Landsat 8 and sentinel-2 imagery to support within-season adaptive management*. Remote Sensing of Environment.

<https://doi.org/10.1016/j.rse.2022.112907>