Mapping Conservation Reserve Program Grasslands in Washington, Colorado, and Kansas with Remote Sensing and Machine Learning

Executive Summary

The USDA Conservation Reserve Program (CRP) works with farmers and landowners to implement conservation management practices on enrolled lands, with paid contracts ranging from 10 to 15 years in length. The CRP Grasslands practices target restoration of agricultural grassland systems by augmenting native vegetation for pollinators, providing habitat for grassland plants and animals, increasing biodiversity, reducing soil erosion, and improving water quality.

The USDA's CRP has been successful in improving the conservation value of millions of acres of farmlands; however, the program currently lacks spatially explicit information on land cover and vegetation within CRP-enrolled tracts. In partnership with the USDA FSA program, the Conservation Biology Institute (CBI) used a combination of remote sensing and machine learning algorithms deployed on the innovative cloud-computing platform, Google Earth Engine, to map grassland characteristics. We used a rich suite of enviro-climatic data, multiple sources of satellite imagery, and Random Forest modeling techniques to predict land cover for study areas in Washington, Colorado, and Kansas, where CRP Grasslands holdings are most prevalent. We used machine learning to create predictive maps of vegetation type by leveraging an extensive set of satellite-derived variables, environmental layers, and federal survey data (from BLM's AIM and USDA NRCS's NRI programs). Our initial investigation utilized Landsat 8 satellite data to model vegetation cover across the Washington study area and then scaled up to the Colorado-Kansas study area. The Washington study site was selected for further model enhancements and an in-depth comparison of Landsat 8, Sentinel-2, and MODIS satellite imagery, to evaluate differences in model development and performance among sensor types. We generated vegetation cover predictions for the year 2019 using Random Forest classification models. Classified outputs for the five vegetation cover models - annual grass, perennial grass, annual forb, perennial forb and bare soil - were post-processed to exclude water and urban land cover and areas that were not relevant for mapping grasslands.

Credits

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For more info please contact: Rebecca.degagne@consbio.org

A comparison of the various satellite sensor model accuracies for the Washington study area reveals that Landsat 8 performed the best, on average (61%), followed by Sentinel-2 (57%), then MODIS (56%). Landsat 8's overall accuracy across both study areas ranges from 52% to 68%. Landsat 8 models demonstrated the best balance of spatial and spectral resolution, while temporally aligning with the highest number of suitable training data. The model with the highest overall accuracy was Bare Soil Cover, while the lowest was Perennial Forb. Overall accuracies for the Washington study area were higher for all five models than overall accuracies for the Colorado-Kansas study area. The Colorado-Kansas study area models relied more on spectral satellite predictor variables; whereas, the Washington study area models depended primarily on topographic or climatic variables. Another key finding for both study sites was that all vegetation cover predictions were driven by a wide array of input variables, with each variable contributing incremental amounts of information. This indicates our extensive suite of spectral and enviro-climatic input variables is necessary to maintain model predictive performance across grassland ecosystems.

Mapped outputs showing vegetation percent cover predictions from our pilot project have been integrated into CBI's CRP online decision support tool. This tool offers functionality for managers and landowners to view, filter, compare, and summarize geospatial information relevant for assessing CRP tracts in the study areas.

CBI will continue to develop our modeling approach in several ways. First, we will continue to refine our classification method by further customizing vegetation classes to enhance model performance and better align with CRP needs. Second, we will explore integrating advanced phenology and time-series metrics that may help models better characterize the temporal fluctuations of grassland vegetation. Third, we will explore using ESA's Sentinel-1 synthetic aperture radar, (which is sensitive to changes in soil moisture and can collect data through cloud cover), as an input variable to enhance discrimination of grassland vegetation structure. Finally, we intend to compare our Random Forest modeling approach to alternative techniques, such as Gradient Boosted Models and Deep Neural Networks, in order to select the best-performing method. Ultimately, we will work closely with CRP leadership to determine what approach and final implementation in the online tool best fits their program's needs.

One of the highest value-adds to this modeling effort would be additional field data from surveys conducted directly on CRP lands to train model predictions. We could work with the USDA to explore implementation of a simple process for landowners to document CRP vegetation on their lands via geolocated photos, thus collecting on-site data that could be aggregated, processed and used to validate or potentially train future models. We already have functionality in the online CRP tool for owners to take pictures, and with the right guidance and information, we may be able to gather data to make the model projections on grasslands more accurate and useful. In conclusion, a long-term, on-site CRP field survey program would add extensive benefit by increasing training data sample sizes and allowing further customization of models to CRP lands and needs.

CBI

For more info please contact: Rebecca.degagne@consbio.org