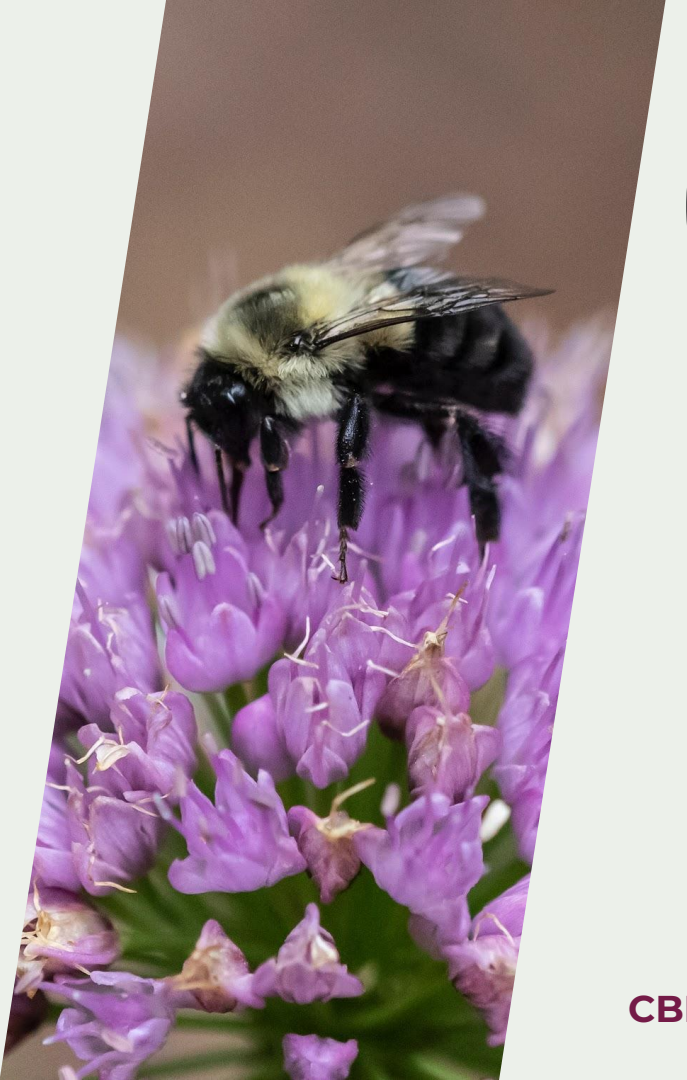
Mapping Conservation Reserve Program Lands

Remote sensing and machine learning to map CRP vegetation

Contact: Rebecca.Degagne@consbio.org



Conservation Biology Institute

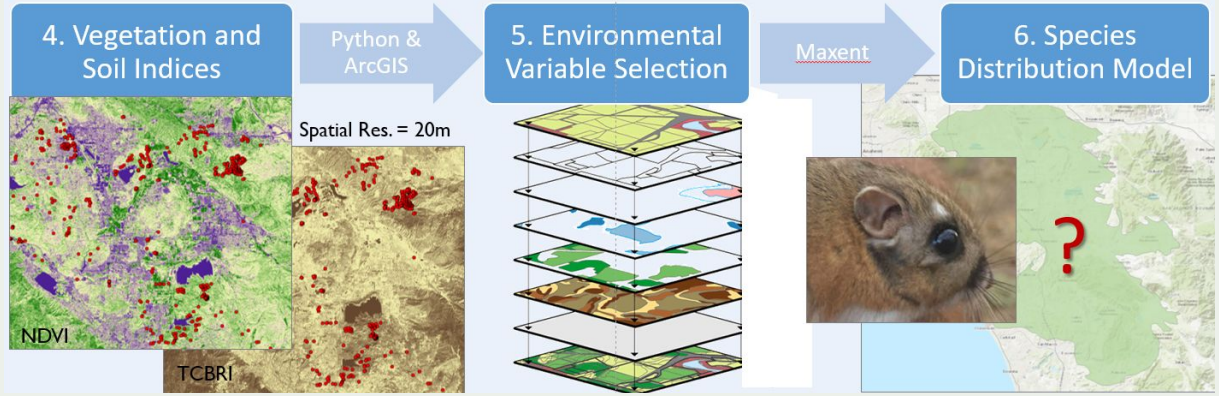
- Translating cutting-edge science into effective, real world solutions.
- Developing innovative tools to address complex issues and make better decisions.
- Providing customized products for conservation, restoration, and natural resource management.

CBI Team: R. Degagne, M. Gough, G. Joseph, D. Pizzino, C. Smith, J. Strittholt

Our Geospatial Team

Data-driven conservation planning:

- Advanced geospatial modeling, data integration, decision-support systems
- Remote sensing, Google Earth Engine
  - Landsat, Sentinel, MODIS, GEDI, Planet
- Machine learning for mapping and monitoring



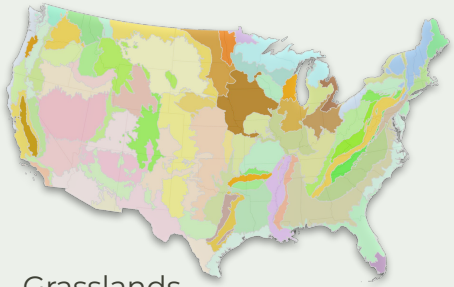
CRP Project Overview

Cutting-edge technology to map tree and grassland holdings

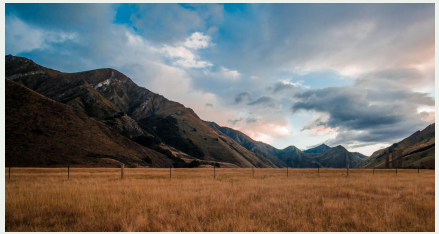
Piloting Cutting-Edge Tech for USDA's CRP

1. Select Study Areas

Forests

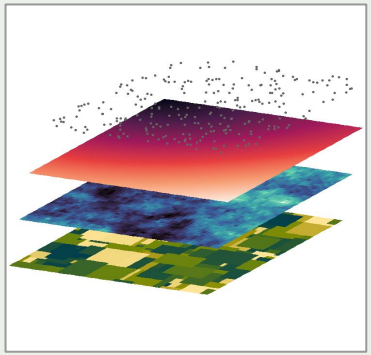


Grasslands



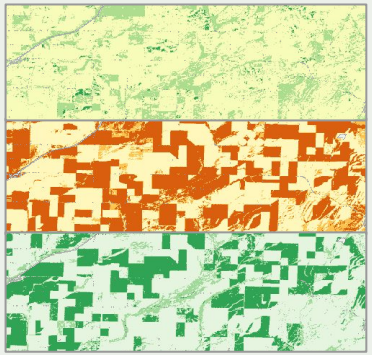
2. Combine:

Field Survey Data
Remote Sensing
Machine Learning



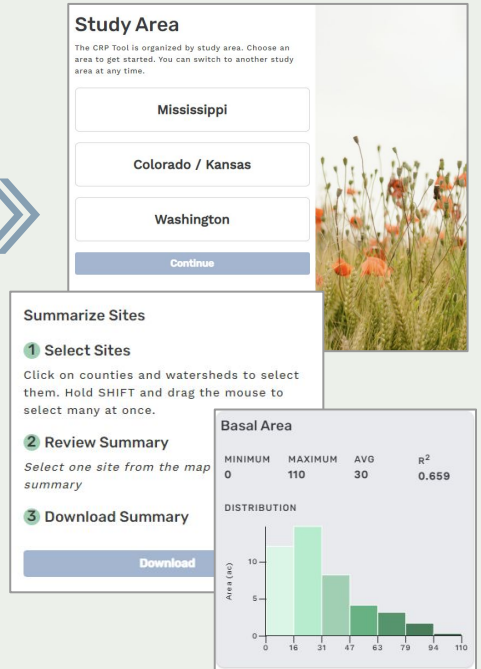
3. Calculate Vegetation Metrics

Vegetation Type
Percent Cover
Physical Structure



4. Incorporate Insights into Custom Web Tool

Maps
Metrics
Summaries



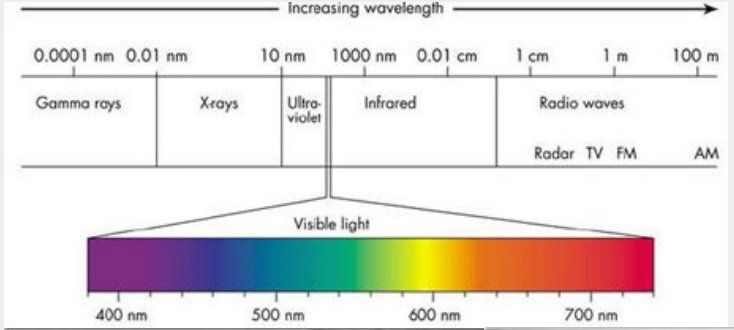

CONSERVATION BIOLOGY INSTITUTE
Remote Sensing
Machine Learning
Cloud Computing
Satellite data and cloud computing drive innovation

Cutting-Edge Tech: Remote sensing

1. Remote sensing: Satellites + Field Data + Computer Modeling = Maps

2. Quantitative information puts agencies, managers, & farmers in control

3. Online tool integration facilitates decision-making, evaluation of progress towards goals, land valuation (compensation for ecosystem services).



Then.

Now.

Cutting-Edge Tech:

GEDI
ECOSYSTEM LIDAR

- The first-of-its-kind Global Ecosystem Dynamics Investigation (GEDI) mission is producing global, high resolution, laser-ranging samples of forest canopy height, canopy vertical structure, and surface elevation.
- Can GEDI improve accuracy and reliability of forest structure model metrics, esp. biomass?

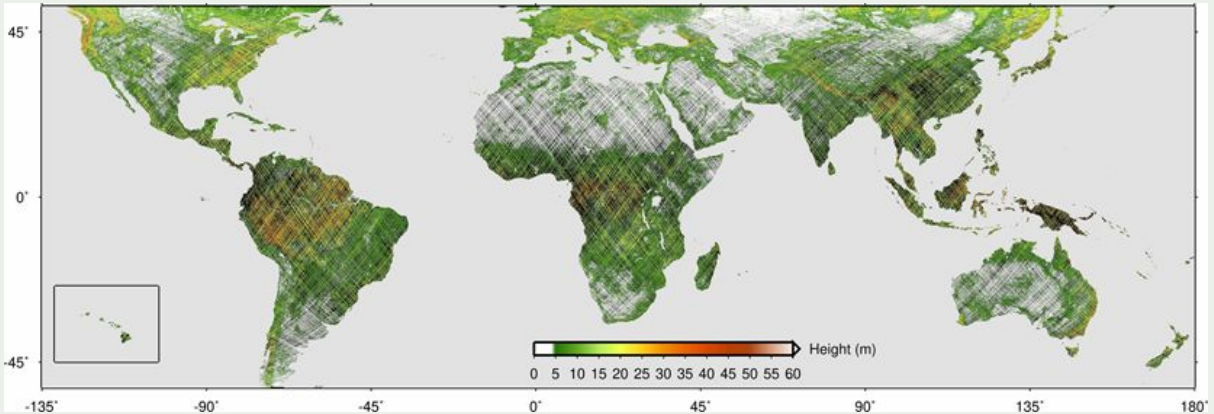
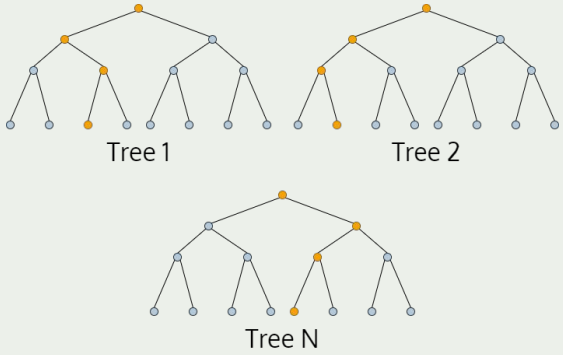


Image credits: NASA's Goddard Space Flight Center

Cutting-Edge Tech: Machine Learning

Pattern Recognition Power: From data to information!

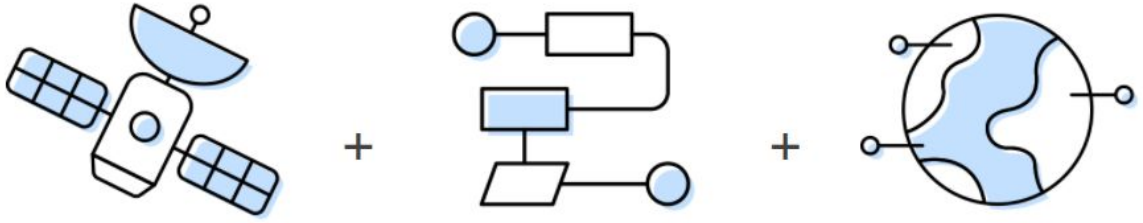


- Machine learning algorithms can handle lots of data
- Widespread use for ecological modeling & mapping (esp. random forest)
- **Ingredients** = Remotely sensed data + landscape/climate + field survey
- **Output** = Maps predicting the location of features of interest
- Can identify which variables are useful for predicting metrics
- Can deploy techniques locally and in the cloud to take advantage of:
    - Diversity of tools
    - Scalability
    - Model evaluation and validation
    - Visualization options

Cutting-Edge Tech: Cloud Computing

Meet Earth Engine

Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities and makes it available for scientists, researchers, and developers to detect changes, map trends, and quantify differences on the Earth's surface.



Satellite Imagery | Your Algorithms | Real World Applications

Learn More

Phase I: Forests

CRP Forest Metrics, Spatial Inventory, and Economic Analysis

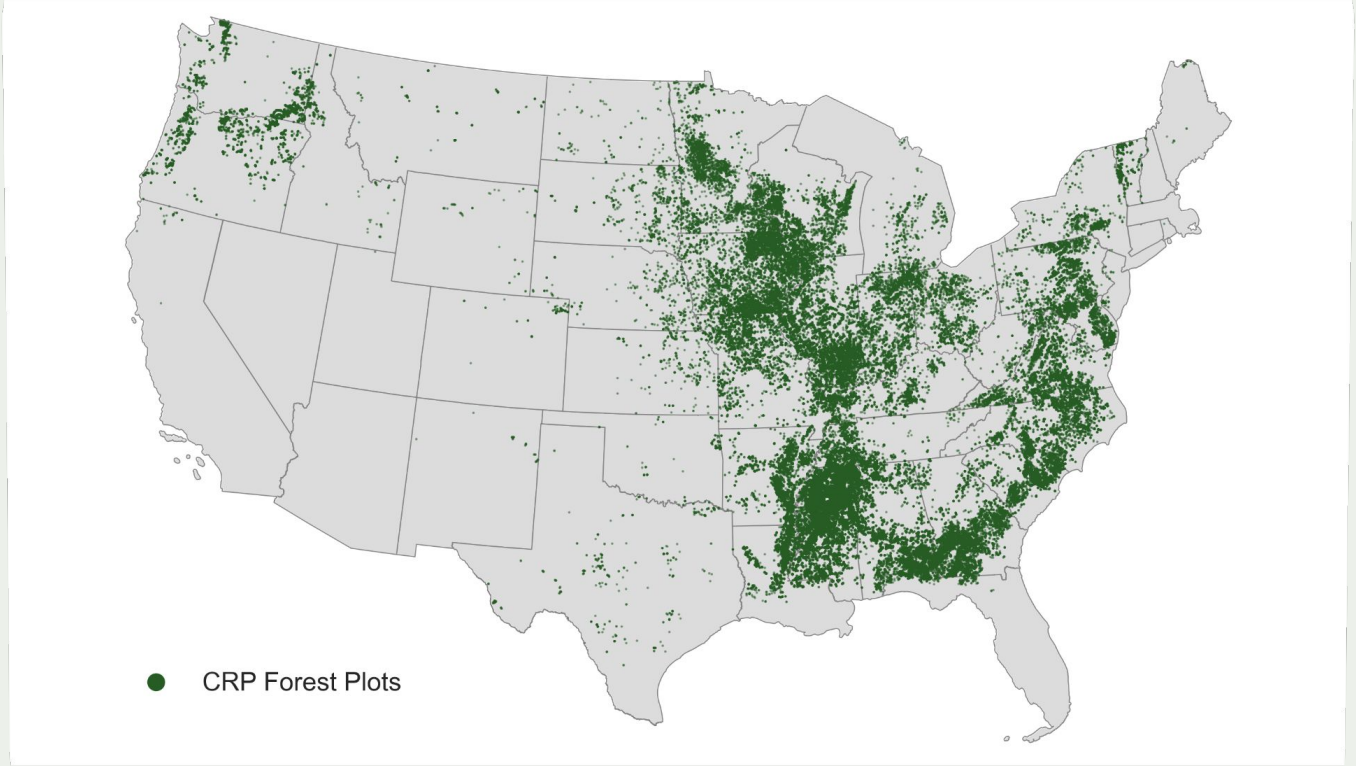
Spaceborne LiDAR data enhances biomass quantification

Phase I: Forests

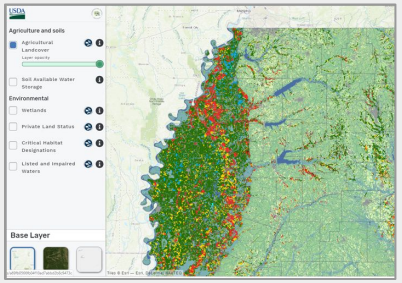
CRP Forest Metrics, Spatial Inventory, and Economic Analysis

Spaceborne LiDAR data enhances biomass quantification

CRP Forest Holdings



Phase I: Mapping CRP Tree Holdings

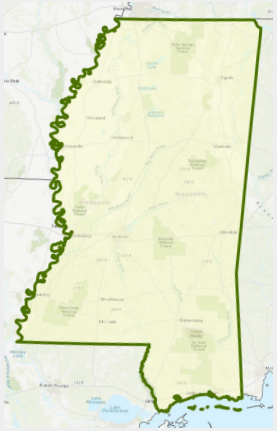


Field Training Data:
USFS FIA Plots

2nd

Machine Learning:
Random Forest Modeling

4th



1st

Study Area:
Mississippi

3rd

Input Variables:
Remote sensing
Sentinel-1, *Sentinel-2*
Topography
Soils

5th

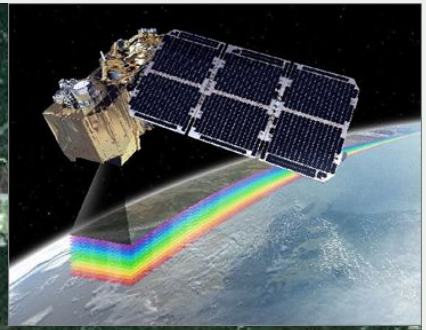
Outputs:
CRP Forests metrics
Economic value
Online tool maps
Tool reports

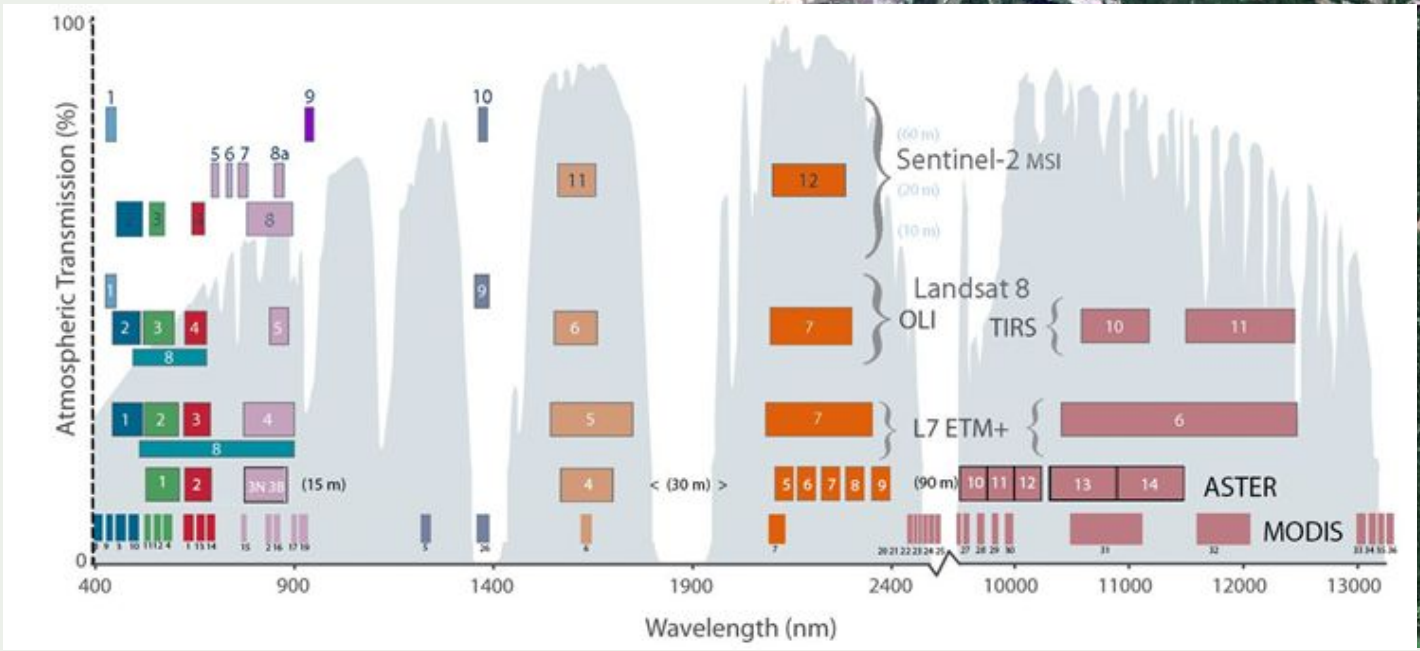
GEDI ECOSYSTEM LIDAR

CBI

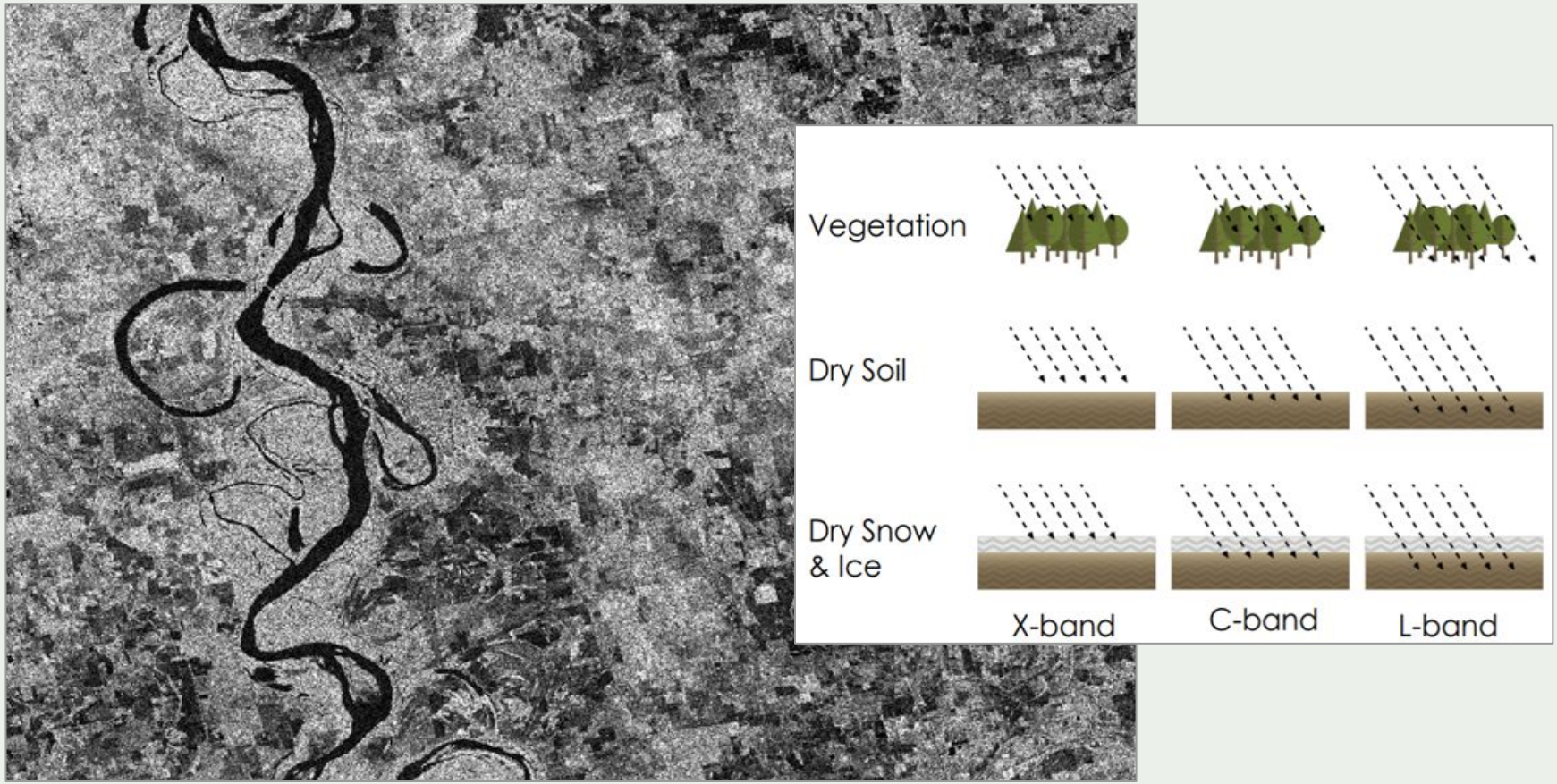
Satellite Data: Multispectral - Landsat, Sentinel-2

Name	Resolution	Wavelength	Description
B2	10 meters	490 nm	Blue
B3	10 meters	560 nm	Green
B4	10 meters	665 nm	Red





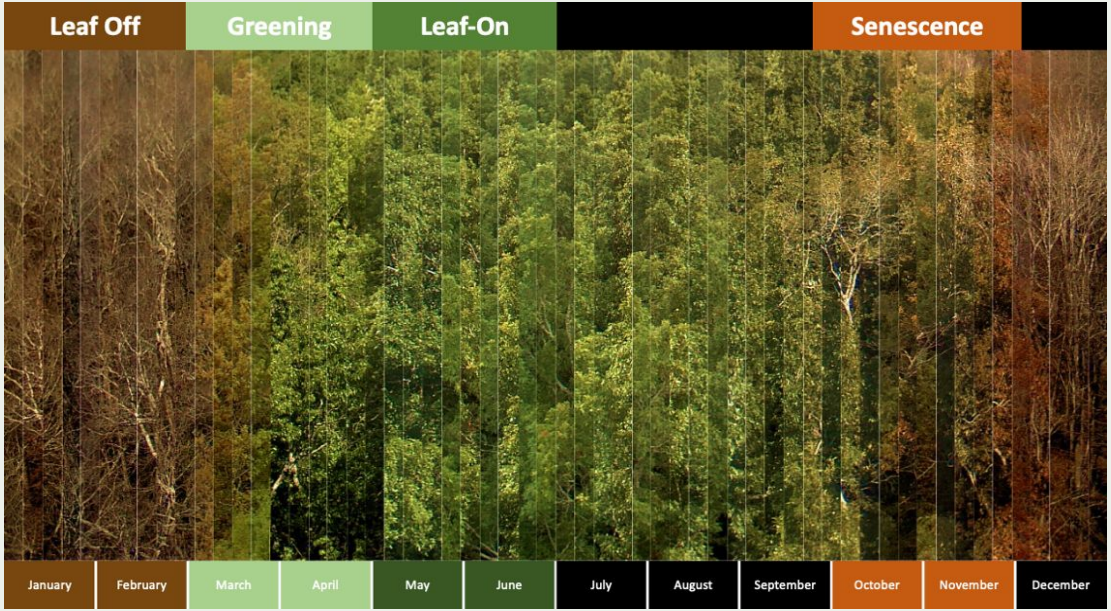
Satellite Data: Synthetic Aperture Radar (SAR), Sentinel-1



Seasonal Considerations

Landscapes change over time.
How can we capture phenology?

- Leaf Off (January-February)
- Greening (March-April)
- Leaf On (May-June)
- Senescence (October-November)

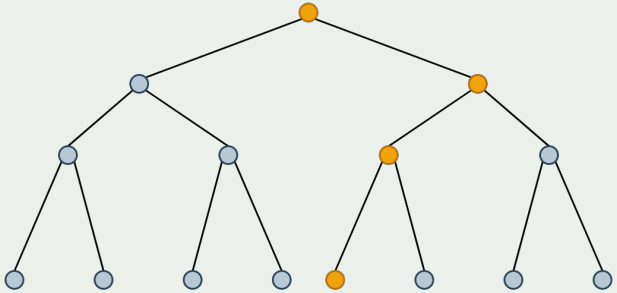


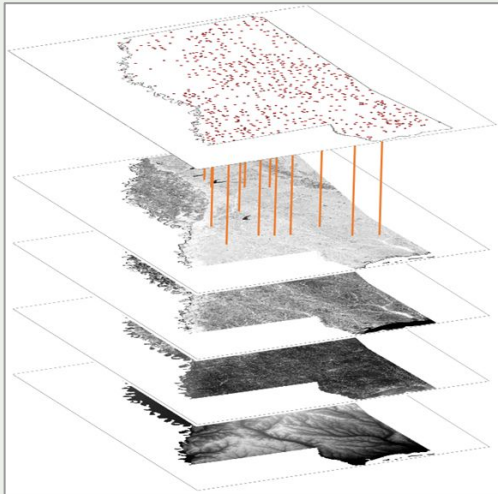
Random Forest Modeling

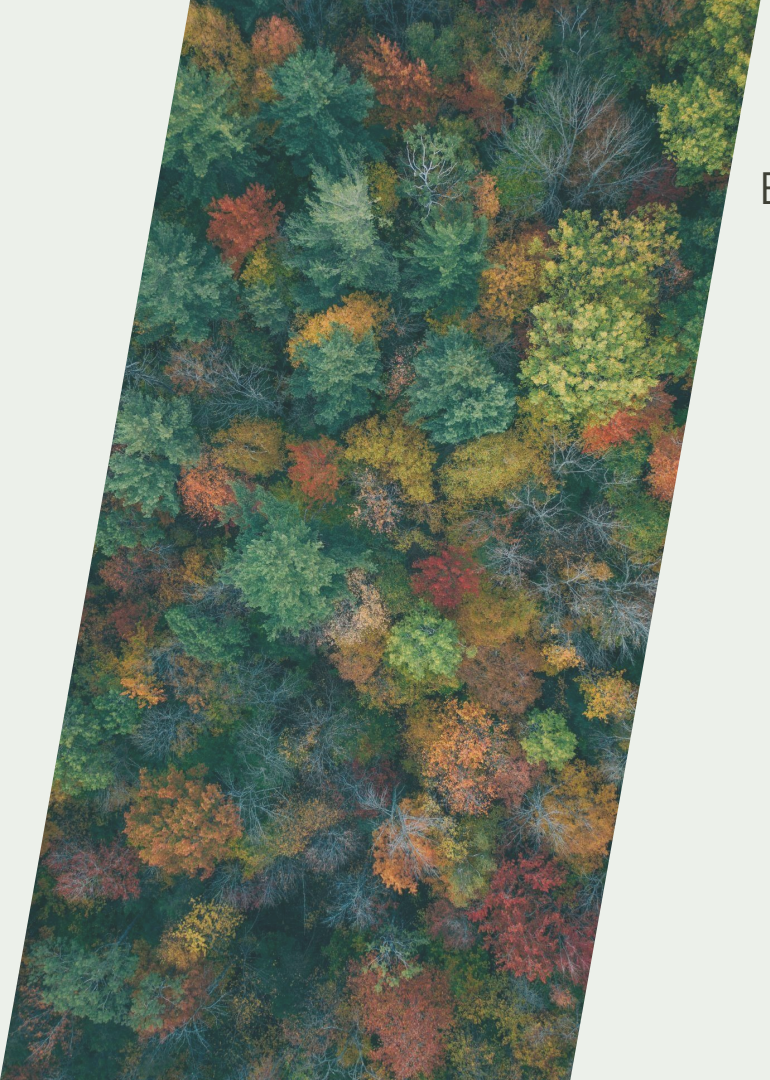
Machine Learning Creates Vegetation Metrics:

Forest Type, Basal Area, Tree Height, Tree Density, Biomass

- Ground training data = ~1400 FIA Plots, 2014-2017
- Satellite data combined with FIA, soils, and topography data
- Over 200 spatial data layers/variables included in model
- Input processing performed on custom Linux server
    - 50 days to process and download 2.5 terabytes of data
- Random Forest modeling performed in R software package





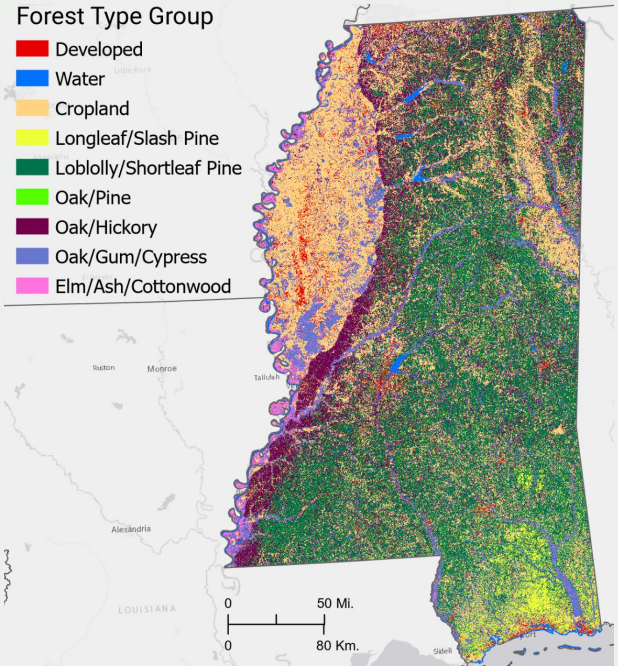


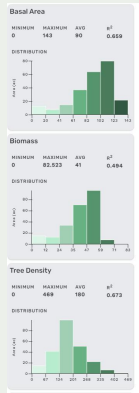
Modeling Results

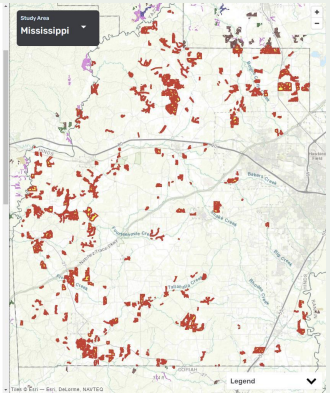
Established Baseline Forest Metrics

- **Forest Type, Basal Area, Tree Height, Tree Density, Biomass**
- Models tested on independent data
- Accuracy ranged from 49% - 90%
- Results incorporated into online tool

Metric	Accuracy
Forest Type	74%
Basal Area (square ft/acre)	66%
Tree Height (ft)	90%
Tree Density (trees/acre)	67%
Biomass (Dry Merchantable) (lbs/acre)	49%

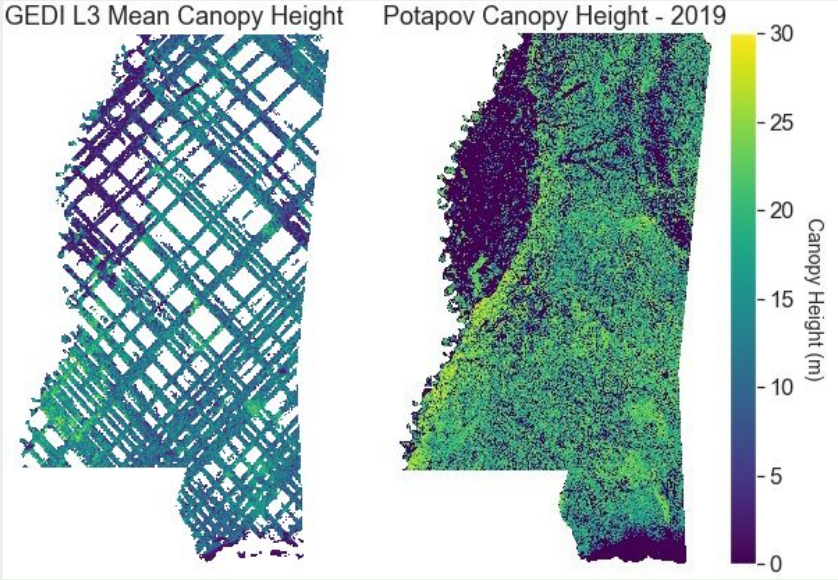


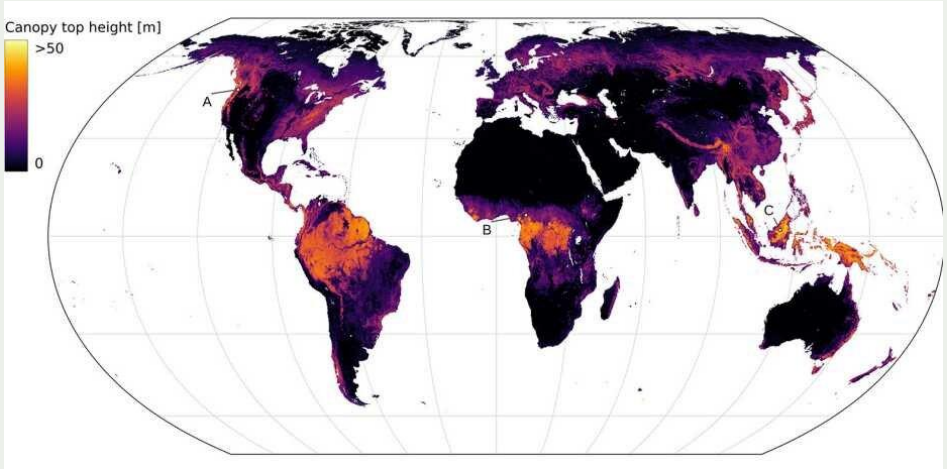




GEDI LiDAR data improves accuracy of forest structure biomass metrics.

- Incorporation of preliminary GEDI fusion data shows a **Biomass accuracy increase from 49% to 57%**
- GEDI only provides high resolution *samples* of forest structure
- Fusion products (e.g., Landsat x GEDI) can map wall-to-wall predictions of forest structure
- Improved fusion products continue to be developed and released





CRP Forests - What's next?

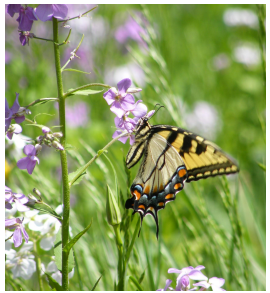
Incorporate new data, migrate to GEE, scale up

- **Add improved GEDI fusion data products**
- **Add higher-resolution climate data** (PRISM Climate)
- **Update FIA data** and refine processing
- **Test alternative machine learning approaches** to improve accuracy beyond the baseline established by Random Forest
- **Migrate additional workflows to GEE**, leveraging the power of cloud computing
- **Develop workflows to support scalability** to wider geographies

Phase II: Grasslands

CRP vegetation cover information for effective decision-making

Phase II: Mapping CRP Grassland Holdings



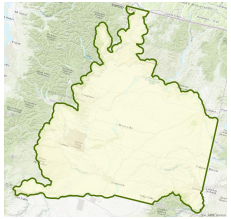
Ground Training Data:
NRCS NRI (National Resources Inventory)
BLM AIM (Assessment Inventory & Monitoring)

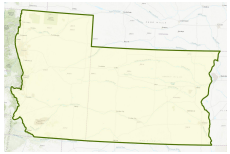
Cloud-Based Computing:
Google Earth Engine*
Random Forest Modeling

Google Earth Engine

2nd **4th**

1st **3rd** **5th**

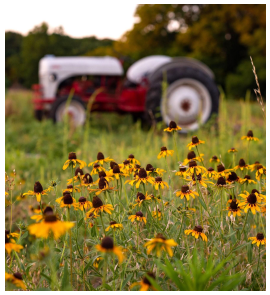




Study Areas:
Washington
Colorado-Kansas

Input Variables:
Sentinel-2, Landsat-8*
Climate*
Topography
Soils

Outputs:
CRP Grassland Metrics
Online tool maps
Tool reports



CBI

Other Grassland and Rangeland Mapping Products

Rangeland Analysis Platform (RAP)

- Uses emerging technologies and machine learning to map continuous estimates of grasslands cover, spatially and temporally.

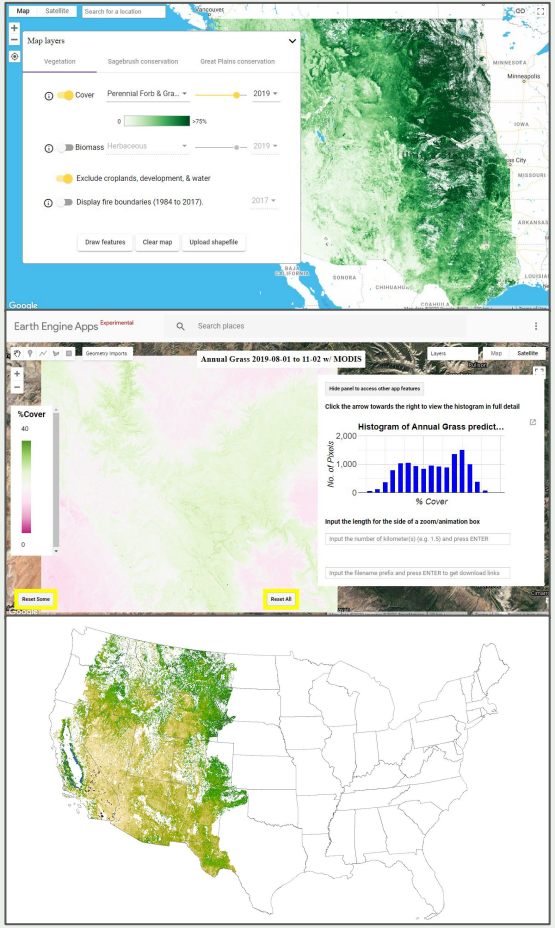
Landscape Cover Analysis and Reporting Tools (LandCART)

- Fuses BLM field data and NASA satellite data to manage resources on BLM lands (focus on drylands).

NLCD Grass/Shrub Component

- Provides a large-area sagebrush ecosystem component inventory.

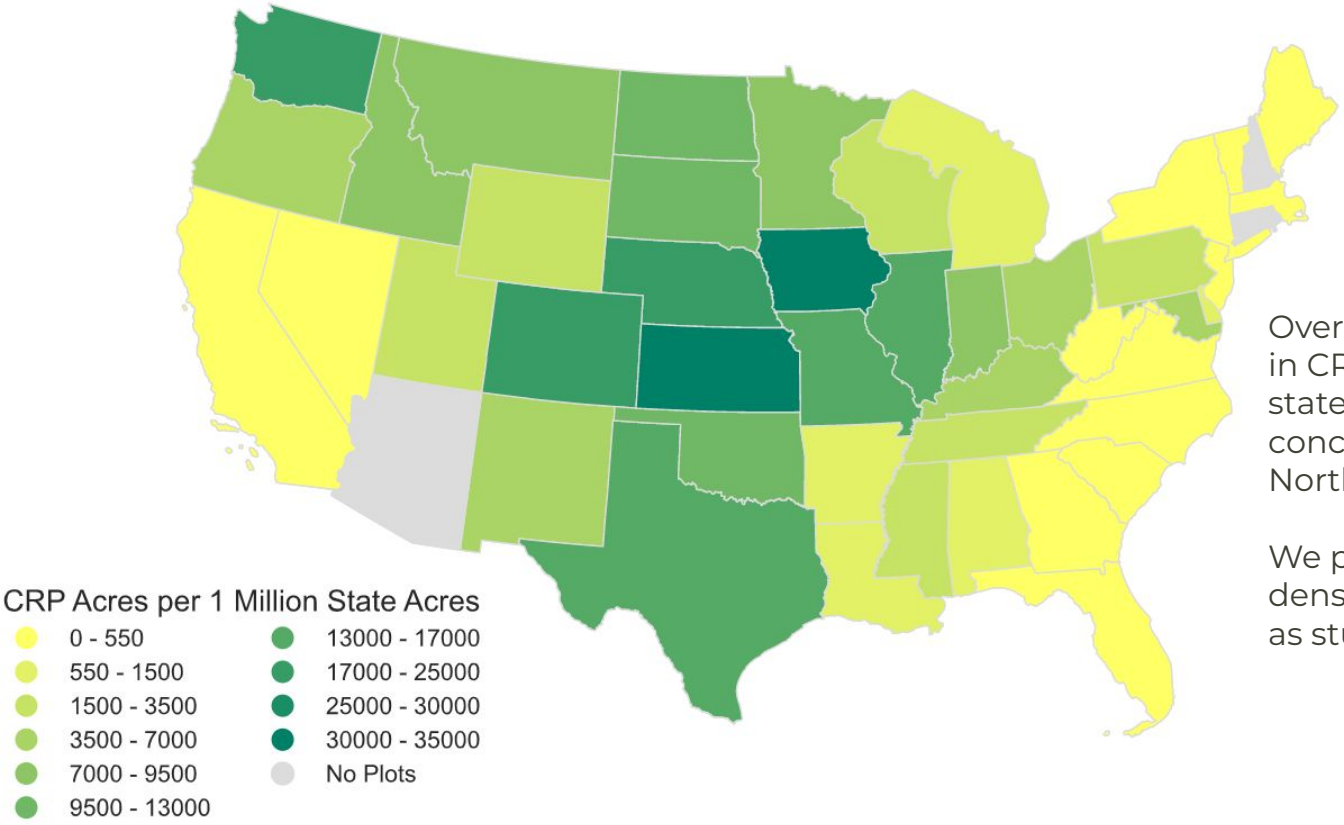
All produce outputs of grassland/rangeland indicators (i.e. % cover), with predictions from the mid-1980s to present day. Unfortunately, these do not offer sufficient discrimination among vegetation types to support program management and monitoring needs of CRP lands.



What differentiates CBI's approach?

- Customized regional models versus global model
- Decoupling forbs and grasses (annual and perennial)
- Customizing to CRP management needs
- Integration with CRP tool

USDA's CRP Grasslands Holdings

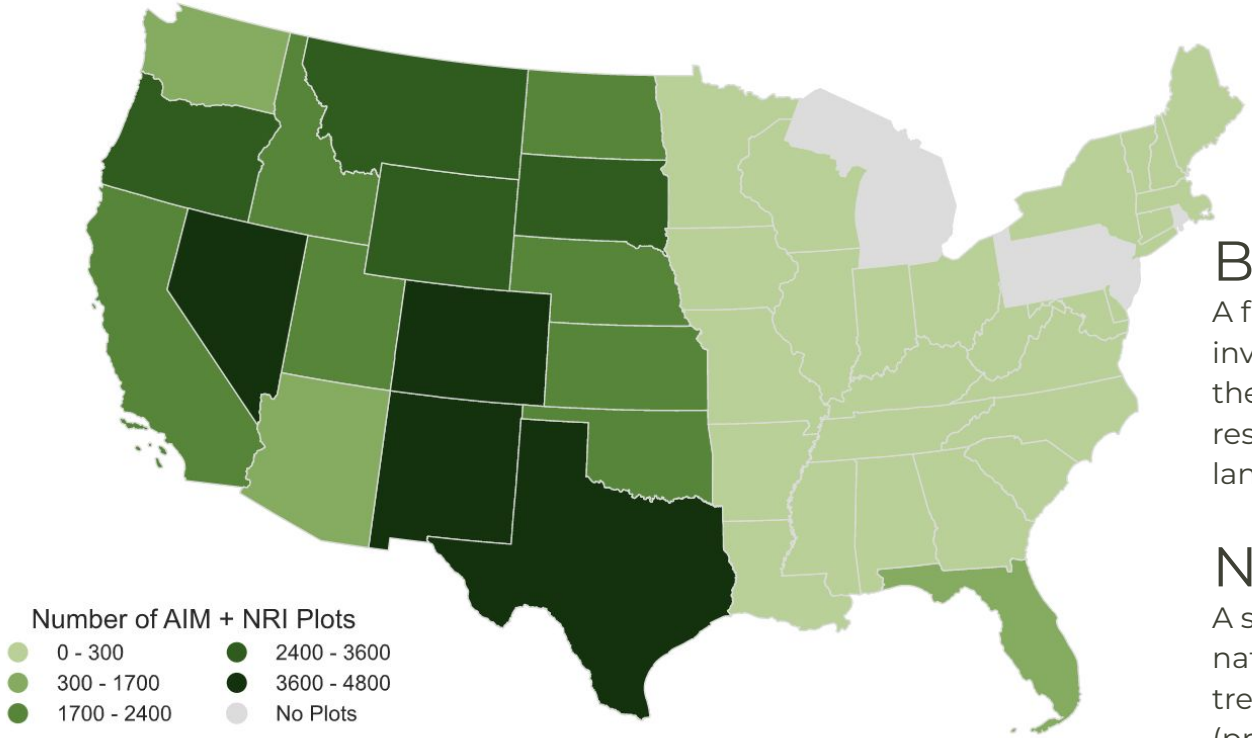


Over 15 million acres are enrolled in CRP Grasslands across 44 states. Spatially, holdings are concentrated across the Northwest to Plains states.

We prioritized areas with high densities of CRP-enrolled lands as study sites.

CBI

Field Plot Distribution
(Training Data)



BLM AIM (2011 - 2020)

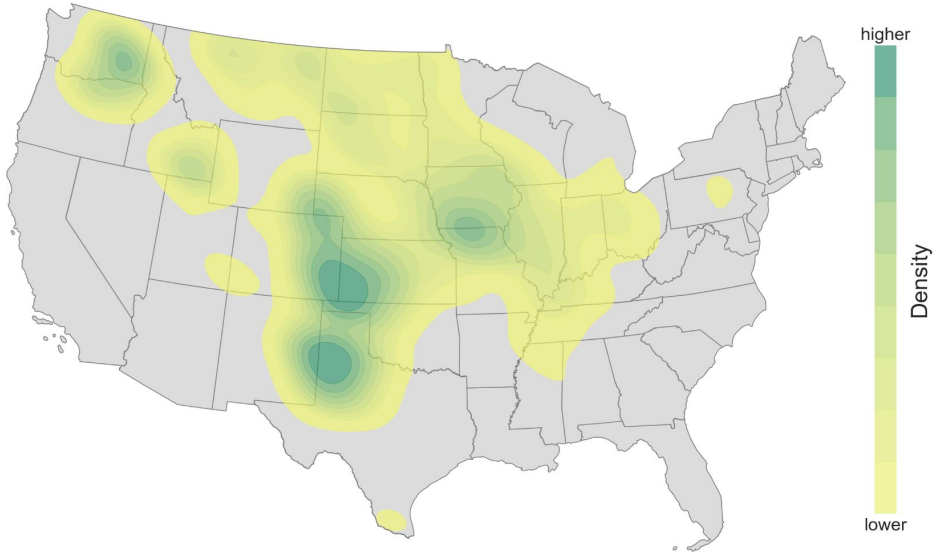
A framework for the BLM to inventory and quantitatively assess the condition and trend of natural resources on the nation's public lands.

NRCS NRI (2004 - 2018)

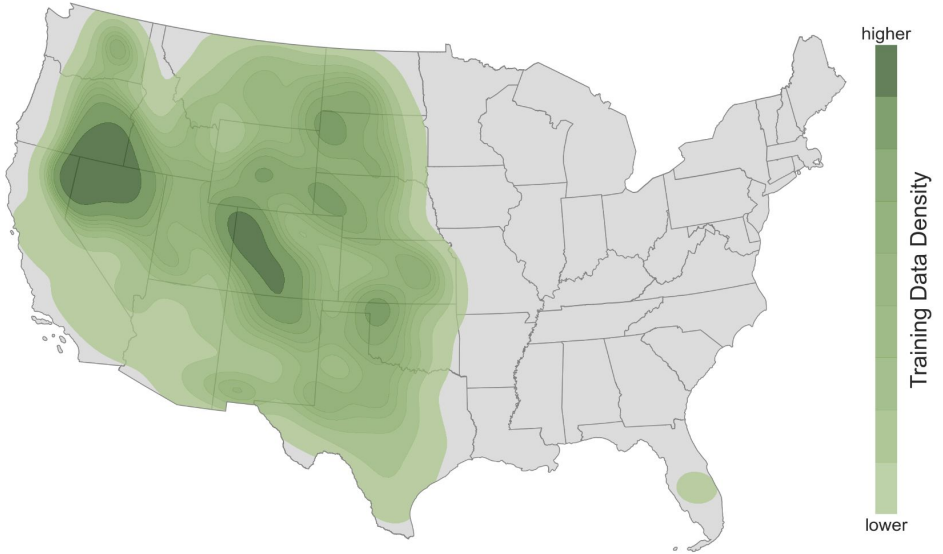
A statistical survey of land use and natural resource conditions and trends on U.S. non-Federal lands (private lands).

CBI

CRP Grasslands Vs. Field Data Density



CRP Grasslands



Field Training Plots (NRI +AIM)

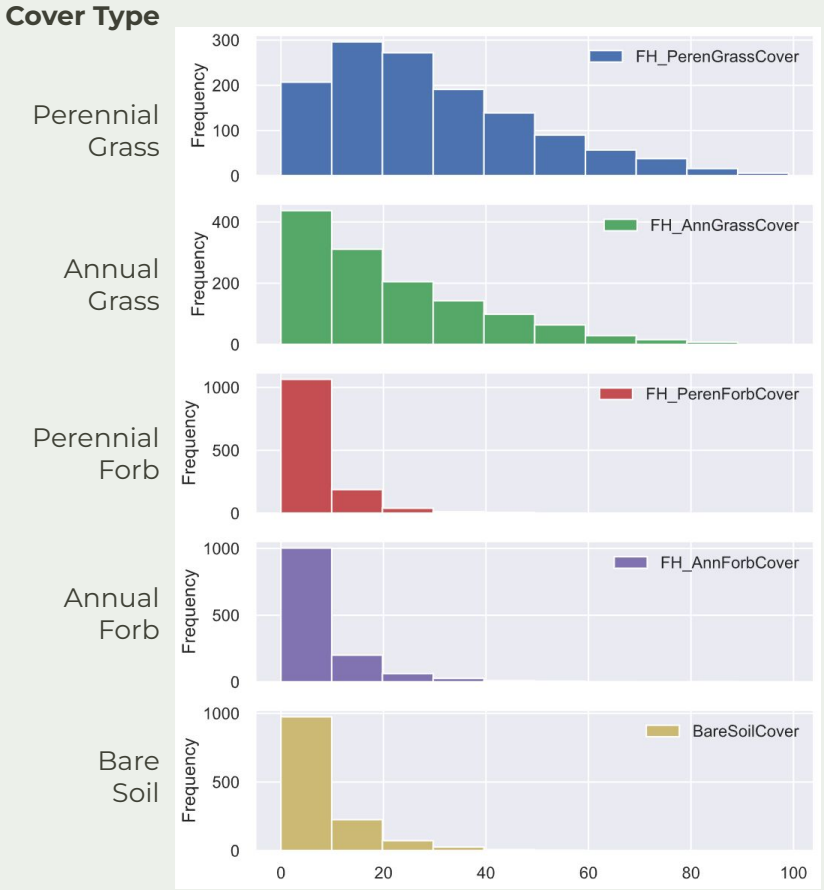
CBI

Predicting Grassland Vegetation

Grasslands Mapping Challenges:

- Grasses and forbs are hard to differentiate with satellite imagery
- Less structure & predictable phenology than forests
- Presence & structure varies across seasons
- Reactive to temperature and precipitation
- Sampling & training data limitations

Image credits: Konza Prairie LTER Program

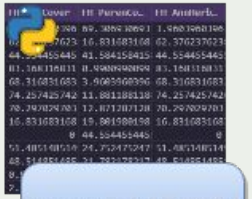


Remote Sensing & Modeling Workflow

Process Satellite, Climate, and Soils Data

Cloud

Local



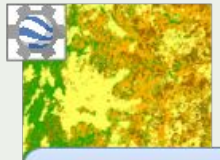
Process NRI/AIM Training Data

WA: 1,312 Pts (2004-2018)
CO-KS: 2,709 Pts (2004-2018)

Modeling performed in parallel, on Google Earth Engine and locally in Python, leveraging all the tools available.

Extract Values, Variable Selection

Random Forest Modeling



Model Prediction to Output Rasters

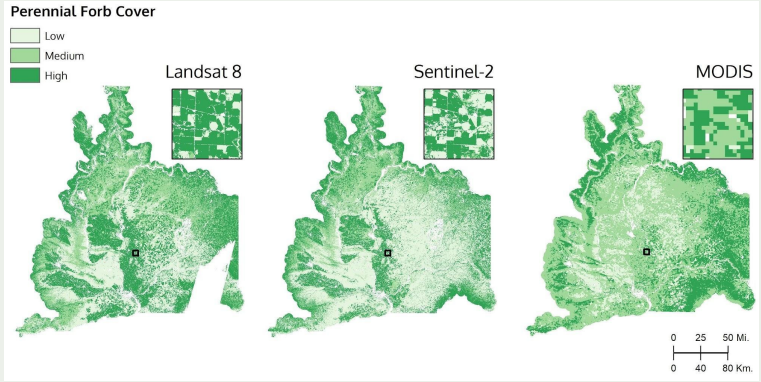
CRP Tool

Over 500 Input layers tested!
Sentinel-2: Seasonal, 2-month intervals, 2018
Landsat-8: Seasonal, 2014-2018
Climate: Seasonal and annual, 2014-2018
Topography
Soils

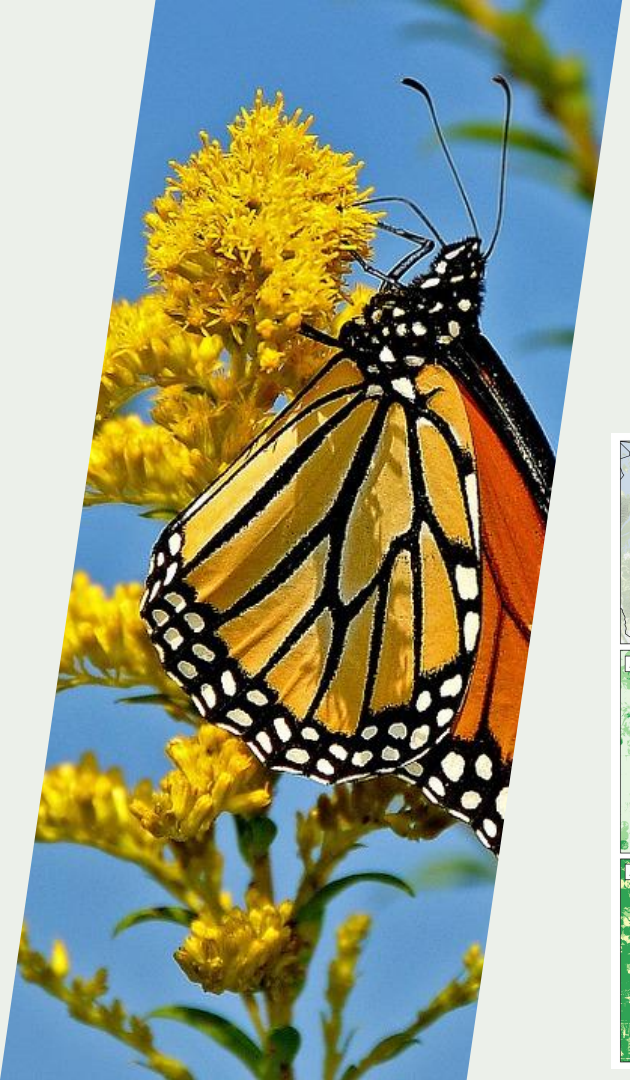
Modeling Results

Satellite Data Comparison

- **In-depth comparison of Landsat 8, Sentinel-2, and MODIS for WA**
- Temporal alignment of imagery and field survey data important
- Landsat 8 overall highest performing
- Sentinel-2 still promising (esp. for forbs!) but lacks historical archive
- MODIS resolution too coarse
- Comparison shows **need for more field survey data to train models**



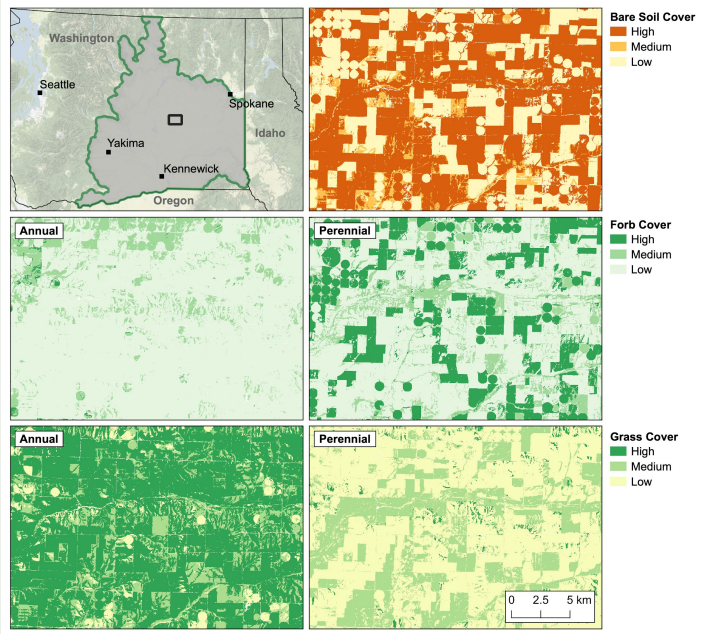
Vegetation Cover Model	Landsat 8	Sentinel-2	MODIS
Bare Soil	68	57	56
Annual Forb	60	53	56
Annual Grass	64	57	54
Perennial Forb	55	58	57
Perennial Grass	58	61	58
Temporal Period	2014 - 2018	2016 - 2018	2004 - 2018
Total Field Survey Observations	736	484	1,308



Modeling Results

Grassland Vegetation Predictions for 2019 (Landsat)

- **Bare Soil, Annual Forb, Perennial Forb, Annual Grass, Perennial Grass**
- Models tested on independent data (52% to 68% overall accuracies)
- Overall accuracy for Washington higher than Colorado-Kansas
- Results incorporated into online tool

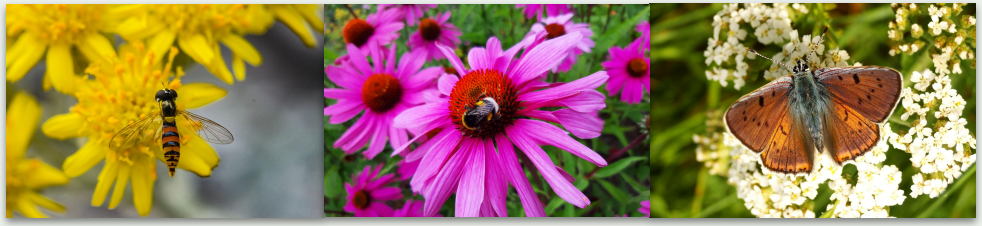


Vegetation Cover Model	Study Area	Overall Accuracy
Bare Soil	WA	68%
	CO-KS	64%
Annual Forb	WA	60%
	CO-KS	60%
Perennial Forb	WA	55%
	CO-KS	52%
Annual Grass	WA	64%
	CO-KS	55%
Perennial Grass	WA	58%
	CO-KS	53%

What's next?

Customize metrics for CRP, incorporate new data

- **Update classification method to better align with CRP** and enhance performance.
- **Explore integrating Sentinel-1 synthetic aperture radar**, advanced phenology/time-series metrics, alternative approaches to machine learning.
- **Include field data from CRP-specific surveys** to increase training data sample sizes, validate predictions, and allow customization to CRP lands.



CBI

Tool Integration & Future Directions

Accessible, comprehensive metrics for effective decision-making

Online Decision Support System Integration

Study Area

The CRP Tool is organized by study area. Choose an area to get started. You can switch to another study area at any time.

Mississippi

Colorado / Kansas

Washington

Continue

Photo by Henry Be on Unsplash

Summarize Sites

1 Select Sites

Click on counties and watersheds to select them. Hold SHIFT and drag the mouse to select many at once.

2 Review Summary

Select one site from the map to view summary

3 Download Summary

Download

2 Review Summary

81 sites selected

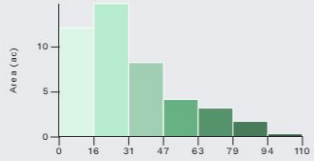
zoom | clear selection

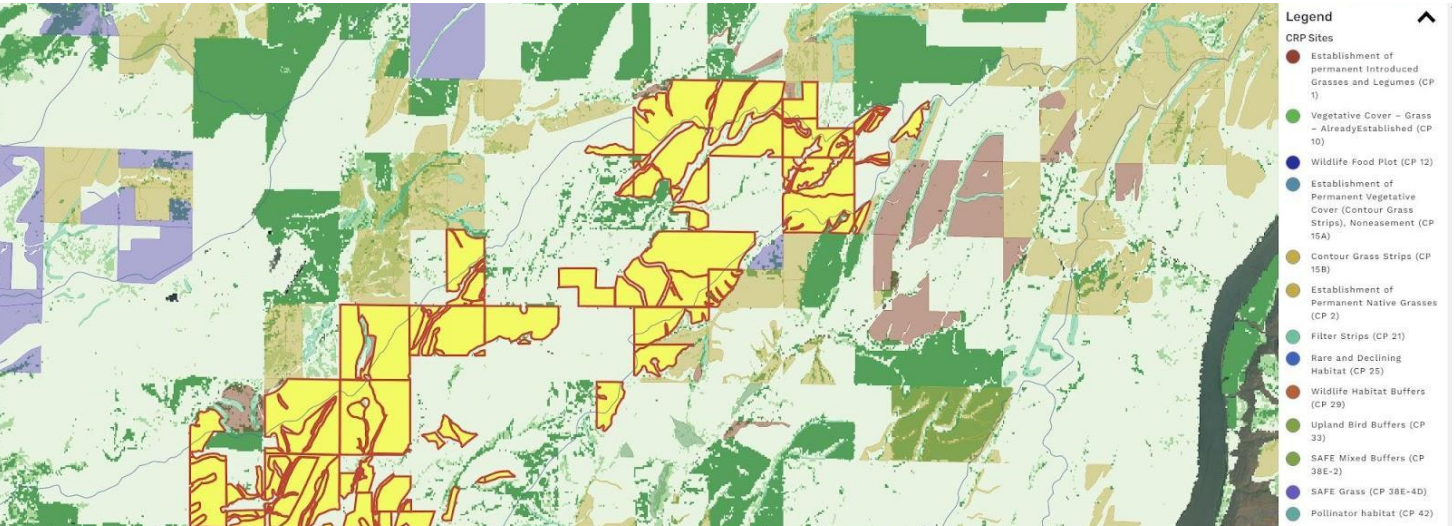
Biometric

Basal Area

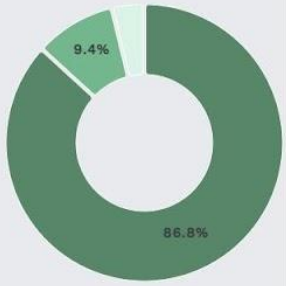
MINIMUM	MAXIMUM	AVG	R^2
0	110	30	0.659

DISTRIBUTION

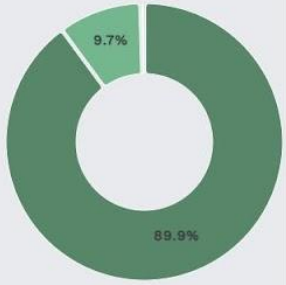




Perennial Forbs



Perennial Grass



3 Download Summary

Download

Conclusions

Pilot outcomes, lessons learned, next steps to scale up

- **Data & modeling enhancements**
- **Simplify & further customize vegetation classification to CRP** to better serve USDA staff and farmers.
- **Propose launching mobile phone app** and simplified CRP survey for widespread training data collection and photos, **to collect data representative of CRP lands.**
    - Systematic surveys to gather data - FSA staff, county committees, university extension services
    - Increased training data will allow scaling up with more accurate results; workflows & data sources already allow for scalability
- **Include field data from CRP-specific surveys** to increase amount of training data, validate predictions, and tailor results to CRP lands.
- **Integrate updated maps into online CRP Decision Support System**. Add other relevant information, customized for CRP, (e.g. grasslands productivity). Expansion to wetlands.

CBI

Questions?

FSA Webinar Slides & Recordings:
https://www.fsa.usda.gov/programs-and-services/economic-and-policy-analysis/natural-resources-analysis/webinars/index

Contact: Rebecca.Degagne@consbio.org

United States Department of Agriculture