A canopy level investigation of specific leaf area spectral responses from sagebrush shrublands in Reynolds Creek Experimental Watershed, Idaho, USA

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Introduction

Regionally calibrated vegetation structure and biochemistry maps are being developed from collection sites in the western US using field measurements and combinations of high resolution hyperspectral and lidar data. The main purpose of the map products is to constrain uncertainties associated with modeling carbon cycling in sparsely vegetated ecosystems.

Here we focus on canopy scale spectral responses to sagebrush leaf area and weight measurements at the Reynolds Creek Experimental Watershed (RCEW) and Hollister sites in Idaho, USA (Figure 1). AVIRISng flightlines are combined with field measurements of leaf mass per area (LMA) to determine the extent at which predictions at the canopy scale are degraded. Partial least squares regression (PLSR) is used to quantify prediction strength and identify influential AVIRISng wavelengths.

In sagebrush steppe, LMA and canopy cover field measurements have been combined to upscale foliar N content using hyperspectral imagery (Mitchell et al., 2012). Also, specific leaf area (SLA) has been combined with leaf area index (LAI) to estimate green biomass for individual shrubs (Olsoy et al, in review). Further, differences in fresh and oven dry leaf weights in combination with leaf area can be used to determine sagebrush live fuel moisture content and track proportional changes in dry mass (Qi et al, 2014).

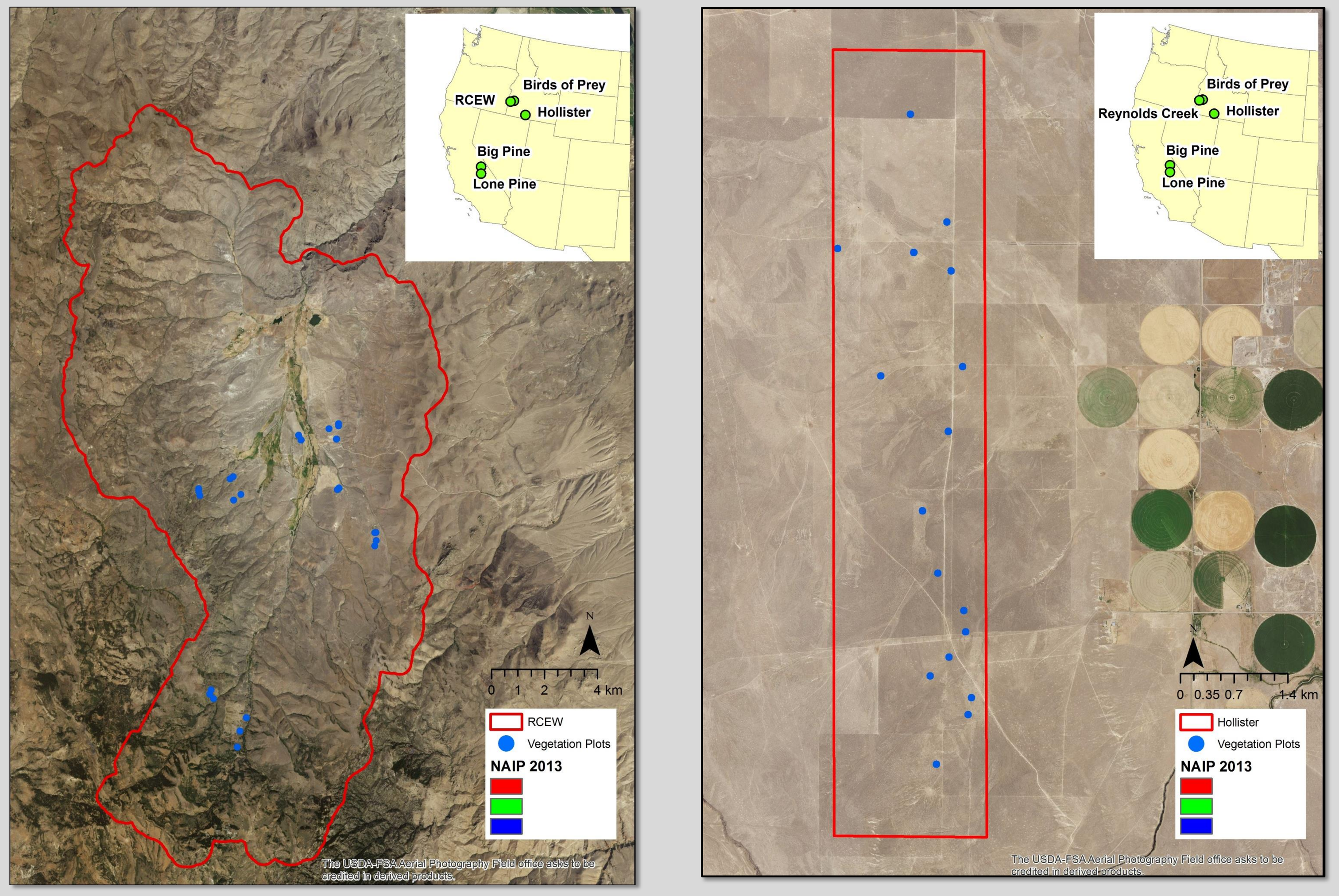

Figure 1. Reynolds Creek Experimental Watershed (RCEW) and Hollister collection sites where airborne AVIRISng and lidar full waveform data were acquired and vegetation was sampled on the ground.

Remote Sensing Data Collection

- Airborne AVIRISng imagery and full waveform lidar were acquired over collection sites during September 2014 at a nominal pixel resolution of 2 to 3 m (Figure 2).
- AVIRISng flightlines for RCEW and Hollister were transformed using Lagrangian derivative analysis and log transformed apparent reflectance spectra as input.

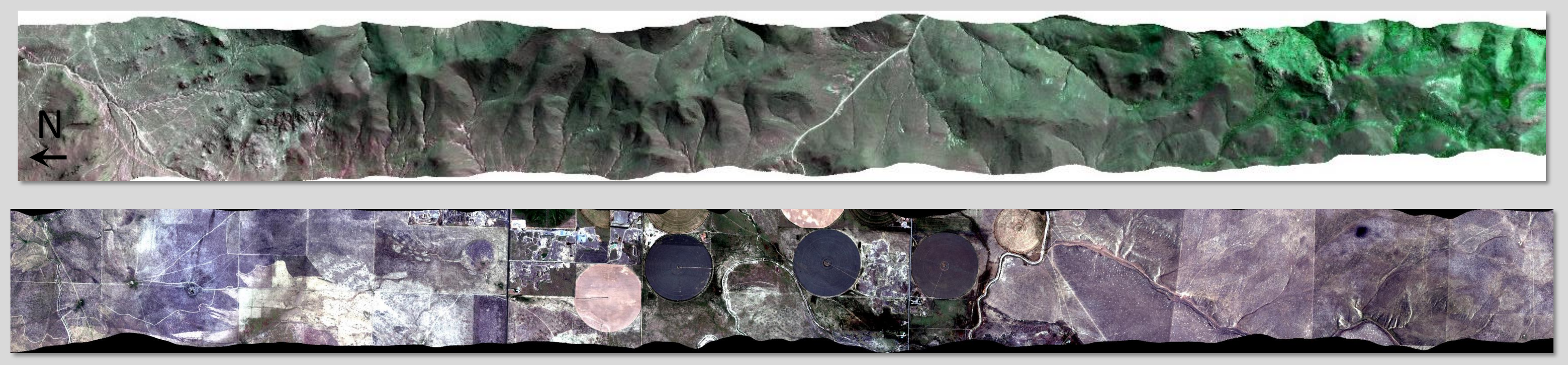

Figure 2. AVIRISng flightlines acquired over RCEW (top) and Hollister (bottom).

Field Data Collection

- In this analysis a total of 20 sagebrush dominant plots (10 m x 10 m) established in RCEW and Hollister were used to calculate shrub canopy cover and average LMA per plot.
- Line intercept methods were used to calculate shrub cover for each plot using transects spaced 1 m apart.
- Within each plot, 5 to 6 sagebrush were randomly sampled along each transect.

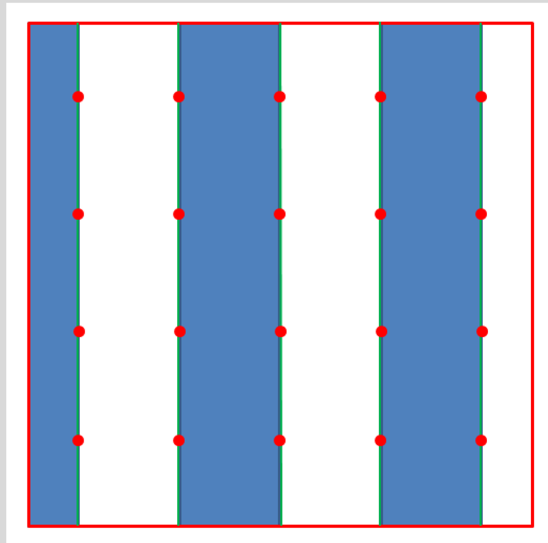

Figure 3. Sample plots 10 m X 10 m in dimension with 5 transects 1 m apart.

- Leaves were extracted from the branches of each randomly sampled shrub.
- Leaf area measurements were calculated from the digital scans using Photoshop.
- Each fresh leaf sample was weighed then coarsely ground (~ 2 mm), oven dried and weighed again.
- Additional measurements collected for each plot include density, LAI, biomass and N and C content.

Figure 4. Individual sagebrush leaf scans were used to calculate leaf area.

Results

RCEW Plots	SLA (cm^2/g)	LMA (g/cm^2) dry weight	LMA (g/cm^2) fresh weight	Sagebrush Plot Cover (%)	Plot scale LMA (g/cm^2) dry weight	Plot scale LMA (g/cm^2) fresh weight	Other Plot Shrub Cover (%)
Sage 1	57.28	0.0175	0.0299	30.22	0.5292	0.9038	0
Sage 2	44.76	0.0223	0.0317	31.84	0.7113	1.0081	0
Sage 3	45.77	0.0218	0.0324	17.04	0.3723	0.5527	1.42
Sage 4	49.25	0.0203	0.03	14.82	0.3009	0.4452	0
Sage 5	53.26	0.0188	0.0297	7.9	0.1483	0.2350	1.04
Sage 6	48.62	0.0206	0.0294	25.12	0.5167	0.7383	2.34
Sage 7	50.68	0.0197	0.0333	24.68	0.487	0.8223	1.2
Sage 8	43.74	0.0229	0.0344	21.54	0.4925	0.7402	0
Sage 9	39.37	0.0254	0.039	35.78	0.9087	1.3946	28.2
Sage 10	48.79	0.0205	0.0379	28.04	0.5747	1.0638	1.86
Hollister							
Sage1_M	63.02	0.0328	0.0163	11.7	0.1903	0.3833	1.22
Sage2_M	57.95	0.0332	0.0177	30.8	0.5446	1.0229	0.00
Sage3_M	65.32	0.0299	0.0155	23.6	0.3655	0.7063	0.00
Sage4_M	70.63	0.0283	0.0144	21.3	0.3065	0.6024	0.00
Sage5_M	69.03	0.0275	0.0147	13.7	0.2015	0.3773	0.00
Sgge6_M	68.79	0.0289	0.0148	25.4	0.3750	0.7330	0.00
Sage1_R	69.87	0.0272	0.0145	20.9	0.3028	0.5705	0.00
Sage2_R	59.13	0.0303	0.0168	33.2	0.5568	1.0051	0.00
Sage3_R	68.65	0.0271	0.0148	12.7	0.1879	0.3452	0.00
Sage4_R	72.59	0.0263	0.0142	26.1	0.3704	0.6868	0.00
Sage5_R	58.27	0.0320	0.0174	19.7	0.3423	0.6316	0.00
Sage6_R	66.59	0.0264	0.0152	26.3	0.4004	0.6939	0.00
Sage7_R	60.54	0.0323	0.0167	31.5	0.5258	1.0179	0.00

- Average SLA calculations per plot are similar to SLA sagebrush values reported elsewhere in the Great Basin.
- Sagebrush cover varies at RCEW and many plots contain additional shrubs while sagebrush tends to uniformly dominate the Hollister site.
- Additional sample plots where sagebrush co-dominates (or is absent) were removed from analysis.

Partial Least Squares Regression

Model Selection and Validation for LMA at the plot scale (dry weight)

Components	X Variance	Error	R-Sq	PRESS	R-Sq (pred)
1	0.490	0.374	0.473	0.495	0.302
2		0.229	0.677	0.715	0.000
3		0.127	0.821	0.864	0.000
4		0.075	0.895	0.875	0.000
5		0.045	0.937	0.955	0.000
6		0.027	0.962	1.004	0.000
7		0.018	0.975	1.039	0.000
8		0.009	0.988	1.105	0.000

Important wavelength predictors selected on the basis of standardized coefficient values: **1664, 1669, 2044, 2235, 2265, and 1709 nm**.

Model Selection and Validation for LMA at the plot scale (wet weight)

Components	X Variance	Error	R-Sq	PRESS	R-Sq (pred)
1	0.487	1.249	0.273	1.647	0.042
2	0.627	0.906	0.473	1.886	0.000
3	0.668	0.310	0.820	2.707	0.000
4	0.730	0.167	0.903	1.891	0.000
5	0.804	0.119	0.931	1.459	0.151
6	0.832	0.037	0.979	1.354	0.212
7	0.847	0.012	0.993	1.469	0.145
8	0.859	0.004	0.998	1.403	0.184

Important wavelength predictors selected on the basis of standardized coefficient values: **1664, 1669, 497, 587, 1148, and 1228 nm**.

Conclusions

- As expected, it was more difficult to predict dry weight LMA, and important wavelength predictors for dry weight LMA were identified in the SWIR.
- The first two wavelength predictors are the same for wet and dried samples, which is consistent with reported challenges decoupling the two (Qi et al., 2014).
- Important wavelength predictors of fresh leaf weight tend to be associated with protein.

Future Directions

- Additional data collection to determine sensitivity of estimates to sagebrush cover.
- Hyperspectral + lidar can be used to generate cover maps (Mitchell et al., in press), which could be used to build uncertainty into LMA products.
- Pursue the discrimination of sagebrush from other shrub species based on plant defensive chemistry (Forbey, 2013) to extend LMA predictions to areas where sagebrush is mixed (rather than dominant).
- Combine with N leaf concentration data that is being collected.

References

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