Evaluation of Airborne Hyperspectral Imaging for Use in Nitrogen Use Efficiency Phenotyping in Hard Winter Wheat

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INTRODUCTION

- Nitrogen use efficient (NUE) crops are needed due to environmental impacts and high nitrogen (N) costs.
- Traditional phenotyping methods for NUE are labor intensive and destructive.
- Canopy spectral reflectance (CSR) can be used as a proxy for physical sampling.
    - Hyperspectral proximally based CSR is most useful in small studies.
    - Airborne (AB) hyperspectral imaging systems allow CSR in large studies with large plots but usefulness with small plots is unknown.

OBJECTIVES

- Test ability of airborne indices to discriminate genotypes in small plots.
- Examine relationship between airborne and proximal indices and measures of plant productivity for use in NUE phenotyping.

MATERIALS

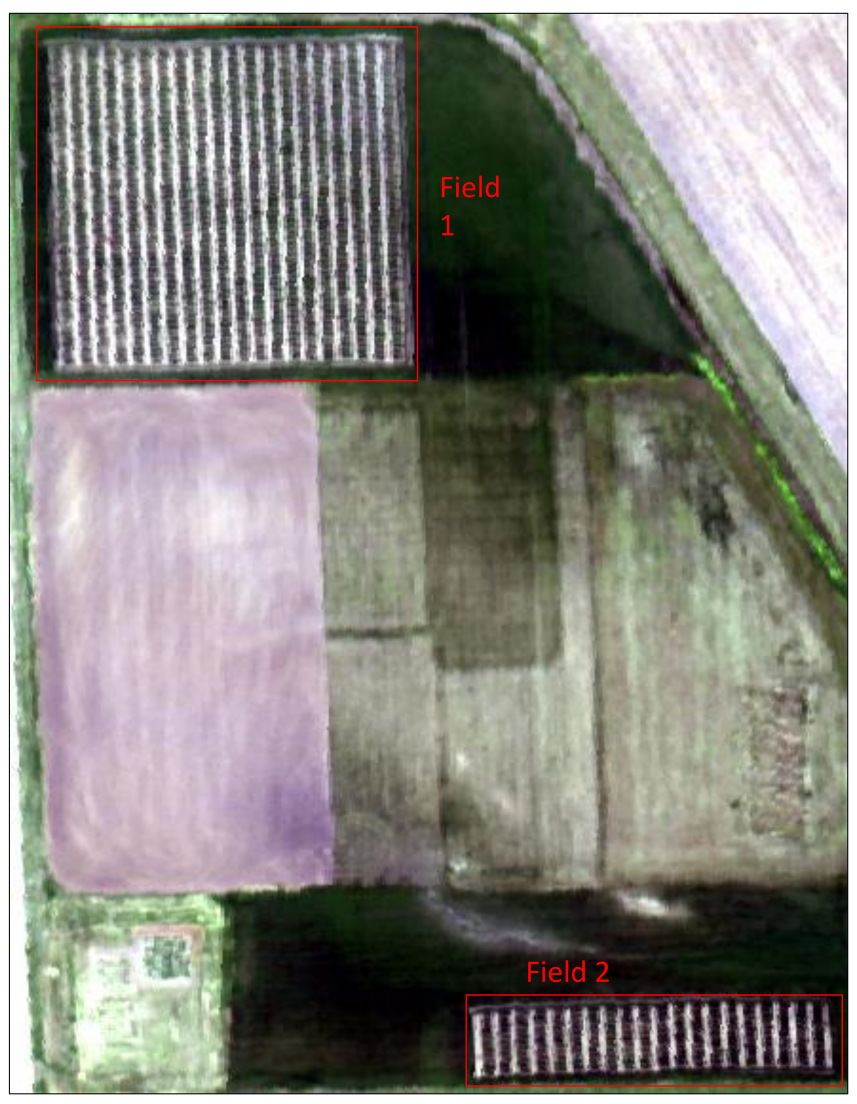

Figure 1: Two winter wheat trial areas

Study Area

Located in near Ithaca, NE in 2012 growing season. Two winter wheat trial areas (Figure 1) 1320 plots.

- Each plot is 4 rows, 3m long with 30.5 cm spacing.
- 120 plots were check cultivars (Jagger, Settler).

Data Sets

Hyperspectral Airborne Imagery

Two CALMIT AISA Eagle images

- Julian date 131 & 142, 2012
- 12 bands: VIS and NIR regions from 472.35 to 823.25 nm; Spectral resolution= 9.5 nm
- Spatial resolution: 0.5 m

Hyperspectral Proximal Sensing

- A two inter-calibrated Ocean Optics USB2000+VIS-NIR spectrometer system developed by CALMIT was used to measure downwelling and upwelling radiation simultaneously.
- Spectral Resolution: 0.4 nm; 350.02 to 1011 nm.
- Proximal CSR data was recorded in first replication of the trial.

Measures of Plant Productivity

- Anthesis biomass: 2 x 30cm row
- Maturity biomass: 1-m row
- Grain yield: grain threshed from maturity biomass
- Grain N yield = (grain yield) x (N concentration)

Figure 2: AISA 12-band placement compared with 2000+ band proximally sensed vegetation spectra

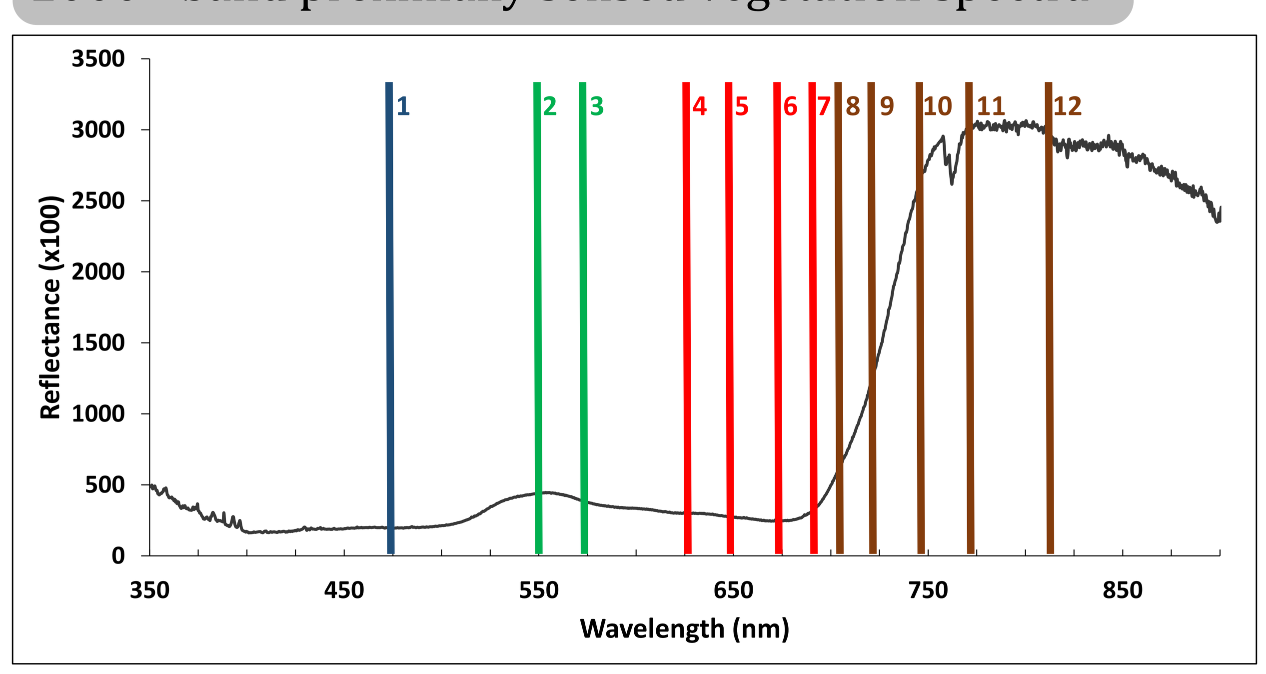

Table 1: Indices used with AISA band formula

Acryonym	Index	Formula	AISA Formula	Reference
NDVI	Normalized difference vegetation index	$\frac{R_{890} - R_{670}}{R_{890} + R_{670}}$	$\frac{Band\ 12 - Band\ 6}{Band\ 12 + Band\ 6}$	Rouse et al. (1973)
NDVIg	Green normalized difference vegetation index	$\frac{R_{750} - R_{550}}{R_{750} - R_{550}}$	$\frac{Band\ 10 - Band\ 2}{Band\ 10 - Band\ 2}$	Gitelson et al. (1996)
EVI	Enhanced vegetation index	$2.5(R_{NIR} - RRED)/(RNIR + 6RRED - 7.5RBLUE + 1)$	$2.5(Band\ 12 - Band\ 5)/(Band12 + 6Band\ 5 - 7.5Band\ 1 + 1)$	Huete et al. 2002
CI	Chlorophyll index	$\left(\frac{R_{NIR}}{R_{GREEN}}\right) - 1$	$\left(\frac{Band\ 12}{Band\ 2}\right) - 1$	Gitelson 2003,2005

METHODS

Image processing

All image processing completed in ENVI 4.8.

1. Two fields are separated by spatially subsetting the images.
2. Pixels with NDVI values ≥ 0.5 selected to remove pixels representing soil.
3. Band math functions for selected indices (Table 1) created and applied to subsetted images.
4. Index images for each field and date were layered to create four layer stacked images.
5. GPS vectors collected during the growing season by traversing the plot area were overlaid on the images to facilitate alignment of pixels with plot.
6. Polyline regions of interest (ROIs) for each planter pass were identified (Figure 3). Each ROI included 20 plots.
7. Data exported from ROI were assigned to planter pass, and central pixels for each plot were identified as the three maximum pixels and central pixels were averaged.

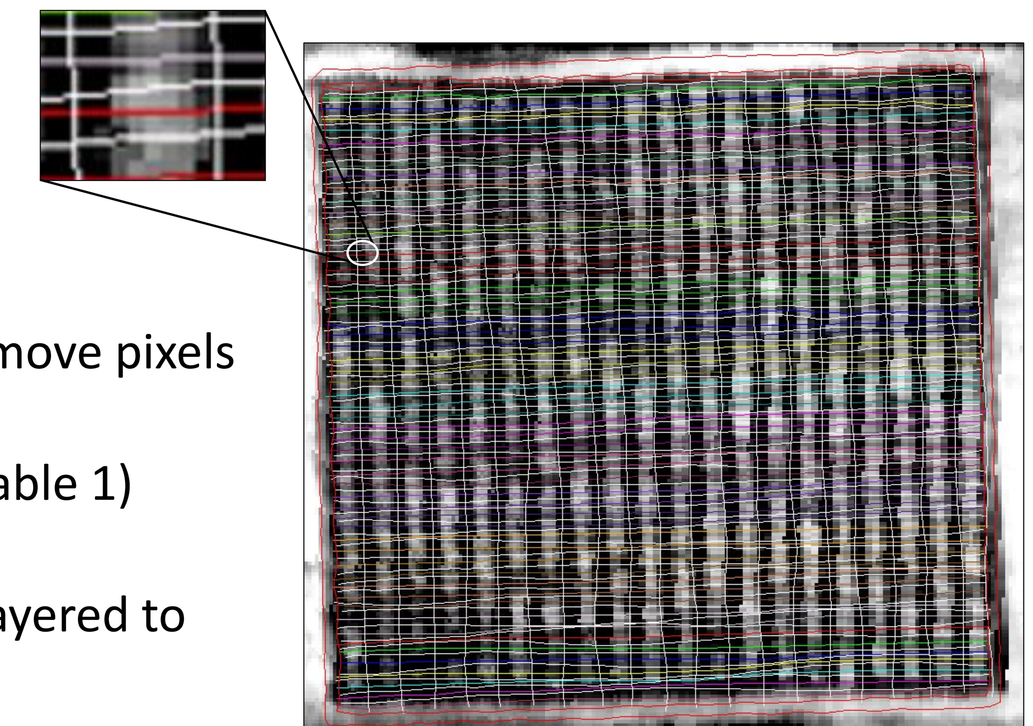

Figure 3: ROI polylines on layerstack image

RESULTS

Table 2. Correlation† of proximal and airborne (AB) indices of check plots

	Date	AB_NDVI	AB_NDVIg	AB_EVI	AB_CI
PROX_NDVI	131	0.329***			
	142	0.487 ***			
PROX_NDVIg	131		0.368 ***		
	142		0..453 ***		
PROX_EVI	131			0.332 ***	
	142			0.441 ***	
PROX_CI	131				0.510 ***
	142				0.471 ***

†Pearson *r*, *** = *p*< 0.001

Table 3: Correlations of airborne (AB) and proximal sensed indices at day= 131 with plant productivity parameters of check plots

	N	Anthesis Biomass	Maturity Biomass	GrainN Yield	Grain Yield
AB_NDVI†	120	0.306***	0.540***	0.497***	0.477***
AB_NDVIg	120	0.344***	0.550 ***	0.521***	0.490***
AB_EVI	120	0.267**	0.488***	0.447 ***	0.436***
AB_CI	120	0.357***	0.556***	0.528***	0.486 ***
PROX_NDVI	60	0.607***	0.658***	0.643***	0.691***
PROX_NDVIg	60	0.493***	0.604***	0.588***	0.612***
PROX_EVI	60	0.684***	0.717***	0.674***	0.770***
PROX_CI	60	0.485***	0.649***	0.619***	0.614***

†Pearson *r*; **, *** = *p*< 0.01, 0.001

Table 4: Mean airborne (AB) sensed indices at day=131 and plant productivity parameters of checks

	Jagger	Settler	*SE(diff)*	*p(diff)*
AB_NDVI†	0.679	0.712	0.012	0.006
AB_NDVIg	0.647	0.662	0.006	0.018
AB_EVI	1.58	1.71	0.04	0.001
AB_CI	4.84	5.14	0.22	0.025
Plant productivity (g m^{-1} row)				
Biomass: Anthesis	124	175	5	<0.001
Biomass: Maturity	248	336	10	<0.001
Grain N Yield	2.79	3.62	0.11	<0.001
Grain Yield	96	143	6	<0.001

CONCLUSIONS

- Airborne CSR imaging can discriminate genotypes in small plots; therefore airborne CSR indices can be used as a high throughput tool to measure NUE traits.
- Improvements in data capture, analysis, and use of ground control points are expected to improve correlations with proximal indices and plant productivity parameters.

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STATISTICS: SAS Institute (2010). Cary, NC. SAS Version 9.3