INTEGRATION OF SATELLITE AND UAV IMAGERY FOR ASSESSING CORN NITROGEN UPTAKE AT EARLY VEGETATIVE GROWTH STAGES

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ABSTRACT

Post-emergence sidedress applications of nitrogen (N) fertilizer can reduce N loss and improve plant uptake, so efficient and practical ways to identify corn N status at early corn growth stages is key to assessing plant N needs. The objectives of this study were to 1) compare metrics from aerial imagery for predicting biomass, 2) compare vegetation indices (VI) from satellite and unmanned aerial vehicle (UAV) imagery for estimating N uptake and concentration, and 3) identify if integration of canopy cover fraction (CC) from UAV imagery integrated with VI from satellite imagery can improve N uptake prediction at early growth stages. To accomplish this, two large scale field trials during the 2019 crop growing season in Indiana were used for the study. Multispectral UAV (MicaSense Altum on DJI Matrice 200, 2-in resolution) and satellite imagery (Planet, 118-in) was acquired at early corn growth stages (ranging V3 to V5) prior to the sidedress application of fertilizer treatments. Imagery was post-processed in Pix4D and ArcGIS to calculate multiple VI and extract CC. Biomass samples were collected from pre-determined sampling areas to obtain plant height, dry matter weight, and calculate N uptake. Regression analysis determined the relationship between biomass, nitrogen uptake, plant height, and metrics derived from UAV and satellite imagery. The results suggest that the integration of satellite and UAV imagery derived metrics can be used to assess corn N status and identify N needs in a time efficient way.

MATERIALS AND METHODS

Field experiments were conducted in 2019 at the Pinney-Purdue Agricultural Center (“PPAC”, 50 acres), near La Crosse, IN, and at an on-farm location (“Simpson”, 60 acres), near Morristown, IN. Starter fertilizer was applied 2 inches below and 2 inches to the side of the seed at planting at a rate of 40 lb acre^{-1} N as 28-0-0 urea-ammonium-nitrate (UAN) at PPAC. Starter fertilizer was not used at Simpson, but 18 lb acre^{-1} N as 28-0-0 UAN was broadcast applied prior to planting.

Establishment of ground-truth sampling locations was determined based on multi-year NDVI zones to take into consideration the spatial variability of each field. A total of 96 and 54 sampling locations were randomly established at PPAC and Simpson respectively. Individual sampling locations were defined as two corn rows wide (60 inches) by 6.5 feet long.

Image acquisition, plant height measurements, and biomass harvest were conducted on the same date within each field, June 14 (growth stage V3-V4) at PPAC and June 26 (V4-V5) at Simpson. Biomass samples were sent to a commercial laboratory to be analyzed for N concentration. Nitrogen uptake was calculated as the product of biomass dry weight and N concentration. Multiple VI were calculated from both UAV and satellite imagery (Table 1), and canopy cover (CC) from UAV imagery only. Regression analysis determined the relationship between biomass, nitrogen uptake, plant height, and metrics derived from UAV and satellite imagery.

For this study, plant height was evaluated as a predictor variable for biomass and nitrogen uptake. Even though plant height was collected manually, it is also a metric that can be derived from UAV aerial imagery.

Table 1. Vegetation indices (VI), their formulas, and the researchers who first developed each VI evaluated.

VI	Index full name	Formula
VDVI	Visible-band Difference Vegetation Index	[(2G-B-R)/(2G+B+R)]
VIG	Vegetation Index Green	[(G-R)/(G+R)]
NDVI	Normalized Difference Vegetation Index	[(NIR-R)/(NIR+R)]
GNDVI	Green Normalized Difference Vegetation Index	[(NIR-G)/(NIR+G)]
OSAVI	Optimized Soil-Adjusted Vegetation Index	[(NIR-R)/(NIR+R+0.16)]

RESULTS

Tables 2 to 4 summarize the coefficient of determination (R^2) results from the linear regression analysis. The column name indicates the predictor variable(s) used to predict biomass (Table 1), N concentration and uptake (Table 2), and N uptake (Table 3). The higher the R^2 value, the better the regression formula predicted the variable. No data shown (-) indicates that regression model was not significant ($P<0.10$).

Table 2. Coefficient of determination (R^2) results derived from linear regression analysis between biomass dry weight and plant height, canopy cover fraction, and vegetation indices (VI).

Height	Canopy	VI		
			UAV	Satellite
PPAC				
0.71	0.53	VDVI	0.07	-
		VIG	0.11	-
		NDVI	0.54	0.05
		GNDVI	0.57	0.06
		OSAVI	0.49	0.05
Simpson				
0.92	0.88	VDVI	0.48	0.26
		VIG	0.67	0.33
		NDVI	0.73	0.52
		GNDVI	0.71	0.40
		OSAVI	0.79	0.52

Table 3. Coefficient of determination (R^2) results derived from linear regression analysis between N (concentration and uptake) and canopy and vegetation indices (VI).

	N concentration		N uptake	
	VI		VI	
	UAV	Satellite	UAV	Satellite
PPAC				
VDVI	0.17	-	0.25	-
VIG	0.19	-	0.22	0.13
NDVI	-	-	0.38	-
GNDVI	-	-	0.31	0.14
OSAVI	-	-	0.29	-
Simpson				
VDVI	0.02	-	0.23	0.28
VIG	0.17	-	0.64	0.38
NDVI	0.46	-	0.74	0.48
GNDVI	0.60	-	0.69	0.31
OSAVI	0.37	-	0.81	0.48

Table 4. Coefficient of determination (R^2) results derived from linear regression analysis between N uptake, canopy cover fraction, and vegetation indices (VI).

Canopy		VI + canopy	
		UAV	Satellite
PPAC			
0.57	VDVI	0.58	0.57
	VIG	0.60	0.59
	NDVI	0.58	0.59
	GNDVI	0.62	0.61
	OSAVI	0.60	0.59
Simpson			
0.87	VDVI	0.89	0.87
	VIG	0.87	0.88
	NDVI	0.90	0.88
	GNDVI	0.92	0.88
	OSAVI	0.92	0.88

CONCLUSIONS

- Differences among locations were likely related to differences in growth stage, with Simpson (V4-V5) resulting in models with greater R^2 values than PPAC (V3-V4).
- Although metrics derived from UAV (canopy cover and VI) at early vegetative growth stages were better indicators of biomass and N, satellite imagery may be a viable alternative at later growth stages when the crop canopy is more complete
- **Objective 1.** Plant height and canopy cover were the best predictors of biomass, followed by VI derived from UAV and satellite.
- **Objective 2:** VI are better indicators of N uptake than N concentration, with models based on VI from UAV resulting in greater R^2 values.
- **Objective 3:** Integration of canopy cover (from UAV imagery) and VI (from satellite imagery) into the N uptake regression model resulted in greater R^2 values than using only canopy cover. However, increase in R^2 was small, ranging from 0.01 up to 0.05.