Assessing the Performance of Spectral Reflectance Sensors for Detecting N Stress in Corn

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Introduction

A series of corn N rate experiments were conducted from 2004 to 2007 at two diverse locations in Maryland to evaluate active and passive remote sensing instruments for detecting N stress in corn. Remote sensing instrumentation included a Holland Scientific Crop Circle ACS-210 and a Cropscan, Inc. MSR16R. Biophysical parameters were measured including leaf area index (LAI), leaf chlorophyll content, vegetative stage, and plant height in conjunction with the acquisition of remotely sensed data at approximately weekly intervals, with growth stages ranging from V6 to R1. This enabled an examination of the relationship of growth stage with the expression of N stress in the corn and the sensors ability to detect the stress. Multiple years of data were examined to help account for variations in the temporal exhibition of stress due to residual soil N, meteorological variables, and other factors. Correlation coefficients between remote sensing instrument derived vegetation indices, leaf chlorophyll content, LAI, and crop yield were calculated.

Objectives

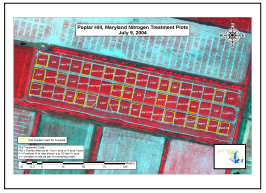
- Evaluate several active and passive multispectral sensors for assessing corn N status and predicting final yields.
- Correlate spectral vegetation indices to leaf chlorophyll content and plant biomass.
- Assess whether the addition of a 720 nm band to the Cropscan and Crop Circle instruments improved their ability to detect crop stress in corn.

Figure 1. Collecting leaf area index data with the LAI-2000

Instrumentation

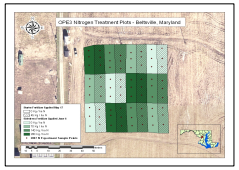
- SPAD-502 Chlorophyll Meter. Konica Minolta, Hong Kong.
- LAI-2000 Plant Canopy Analyzer. LI-COR, Lincoln, NE (Fig. 1).
- "Amber" Crop Circle ACS-210, emission bands = 590, 880 nm. Holland Scientific, Lincoln, NE.
- Prototype 3 band Crop Circle ACS-210, emission bands = 590, 720, and 880 nm. (2007) Holland Scientific, Lincoln, NE.
- Cropscan MSR16R multispectral radiometer, bands = 530, 550, 560, 570, 580, 620, 670, 700, 740, 780, 840, and 880 nm. 720 nm band added 2007. Cropscan, Inc, Rochester, MN.

Site Descriptions



Poplar Hill Site

- Located on the Eastern Shore region of Maryland at the University of Maryland's Poplar Hill Research Farm. 75º46' 33" W 38º 21' 22" N
- The soil is a Mattapex silt loam (Aquic Hapludult) with a textural analysis of 19% sand, 67% silt and 14% clay.
- Corn was planted May 18, 2004.
- Randomized complete block with 3 reps.
- Treatments were rates of fertilizer N (NH_4NO_3) from 0 to 280 kg N/ha in increments of 56 kg N/ha, a P-based rate of poultry litter (2240 kg/ha) with fertilizer rates of 0 to 225 kg N/ha, and a N-based rate of poultry litter (6720 kg/ha) with fertilizer rates of 0 to 112 kg N/ha.



OPE3 site

- Located near Washington D. C. on the USDA Agricultural Research Services Beltsville Area Research Center. 76º 50' 39" W 39º 01' 51" N
- The soil is a Matawan sandy loam (Typic Hapludult) with a textural analysis of 72% sand, 14% silt and 14% clay (surface layer).
- Corn was planted April 29, 2006 and May 4, 2007.
- Randomized complete block with 3 reps.
- Treatments were rates of fertilizer of 280, 140, 70, and 0 kg N / ha. In 2007 plots were split in two with the Eastern half of each plot receiving an application of starter fertilizer at a rate of 45 kg N / ha on May 17.
- Sidedress N application June 9, 2006 and June 6, 2007.

Methods

Poplar Hill, 2004

- Leaf Chlorophyll (SPAD) readings collected from 20 plants per plot on uppermost fully expanded leaf (Fig. 2).
- Cropscan data collected from a handheld pole with instrument at a height of approximately 1.5 m above canopy (Fig. 3). Pairs of scans were collected at nadir at each location with one scan taken with instrument centered above the row and the second with the instrument centered between rows. Reflectance data were averaged by plot.
- Images were collected with a digital camera mounted next to the MSR16R in conjunction with each scan and analyzed for percent vegetative cover.
- LAI readings were collected in sets of 2 repetitions per location in adjacent rows, each repetition consisting of one above canopy reading and 4 below canopy readings located next to the row, at ¼, ½ and ¾ toward the next row.
- Yield data was collected with a combine mounted yield monitor by plot.

Figure 2. Collecting Leaf chlorophyll data with a SPAD meter

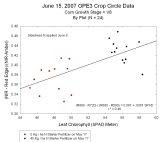
Figure 3. Collecting Cropscan data at Poplar Hill June 22, 2004

Figure 4. Crop Circle ACS-210 OPE3 June 8, 2007

OPE3, 2006 and 2007

- Leaf Chlorophyll (SPAD) readings were collected with 3 samples per leaf on 6 representative plants at each location. The uppermost fully expanded leaf was sampled at mid-leaf on all days except for the last data collection of each year, when the ear leaf was sampled.
- Cropscan data was collected as at Poplar Hill.
- Crop Circle data was collected with instrument mounted viewing at nadir on a modified jogging stroller (Fig. 4). Height was adjusted to be approximately 1 meter above the canopy. A series of 3 sample locations on the center row of each plot was established and points in the row 1.5 m on either side of the sampling point flagged. The jogging stroller was pushed down marked rows and flagged points marked on data as each point was reached. Vegetation indices were calculated by sampling location and by plot.
- LAI data was collected as at Poplar Hill.
- Yield data was collected by hand harvesting 3 m of row centered on the sampling points, oven drying the ears at 50º C, hand shelling and weighing the grain.

Figure 5. OPE3 Corn June 15, 2007
Differentiation of plots due to application of starter N apparent



Results

- Remote Sensing instrument derived vegetation indices correlation coefficients were strongest with percent cover and LAI at early growth stages. Leaf chlorophyll content was not significantly correlated with any index before growth stage = V8, with more significant correlations developing at growth stage V9 and later (Figs. 6, 8).
- LAI and leaf chlorophyll content were found to be poorly correlated in all growth stages before V15.
- In 2004 and 2006, leaf chlorophyll content had a significant correlation with yield at all growth stages examined. While the 2007 yield samples are not yet processed, it appears unlikely that any significant correlation would exist between yield and leaf chlorophyll content due to a drought in Maryland which left many plants barren.
- LAI had a significant correlation with yield in 2004 and 2006 only at growth stage V15 and later.
- The addition of a 720 nm band to both the Crop Circle and Cropscan in 2007 produced vegetation indices that had a superior response to leaf chlorophyll than indices which did not include that band (Fig. 7).

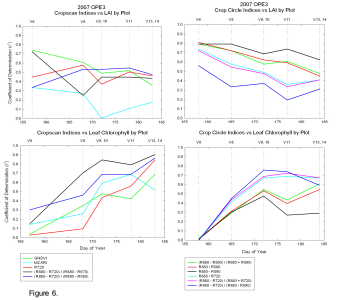


Figure 6.

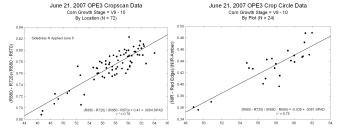


Figure 7.

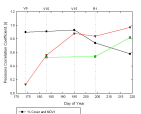


Figure 8. Relationship between RS indices and canopy parameters.

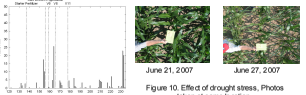
2004 Poplar Hill				
DATE	Veg Stage	LAI - Leaf Chlor	LAI - Yield	Leaf Chlor-Yield
		r²(obs)	r² (obs)	r² (obs)
July 1, 2004	V10-11	0.23 (20)	0.001 (24)	0.90 (10)
July 9, 2004	V13	ns	ns	0.49 (24)
July 21, 2004	V15	0.48 (24)	0.53 (24)	0.74 (24)
August 6, 2004 - late Milk		0.82 (14)	0.58 (25)	0.96 (5)
2006 OPE3				
June 8, 2006	V6	0.04 (12)	0.10 (12)	0.69 (12)
June 16, 2006	V8	0.02 (12)	0.05 (12)	0.58 (12)
June 22, 2006	V10	0.04 (12)	0.05 (12)	0.72 (12)
July 7, 2006	R1	ns	ns	0.45 (21)
2007 OPE3				
June 8, 2007	V6	0.02 (24)	ns	ns
June 15, 2007	V8	0.07 (24)	ns	ns
June 21, 2007	V8, 10	0.25 (24)	ns	ns
June 26, 2007	V11	0.25 (24)	ns	ns
July 3, 2007	V13, 14	0.22 (24)	ns	ns

ns= Not Available

Figure 9. Relationships between LAI, leaf chlorophyll content, and yield.

Discussion

Both the Cropscan MSR16R and the Crop Circle ACS-10 were able to begin to detect N stress as measured by leaf chlorophyll content in corn by growth stage V8, with coefficients of determination reaching 0.84 and 0.76 respectively by V9 – 10 in 2007 (Figs. 5, 6, 7). A growers utilization of remote sensing instrumentation to assess corn N status would benefit from the choice of indices that respond more to leaf chlorophyll content than to LAI, as leaf chlorophyll content appears to be a better indicator of potential yield. Postponing an assessment of a corn crops N status with these techniques until at least V8, and if feasible later, would also appear advisable due to the increasing influence of leaf color on VIs as the canopy fills in. The 720 nm band shows promise to improve assessment of leaf chlorophyll content, producing indices that outperformed MCARI and GNDVI in the 2007 Cropscan data (Fig. 6). The 2007 drought in Maryland and throughout much of the southeast illustrate a limitation on the ability of these techniques to successfully predict yield, as factors other than a crops N status such as water availability may have a stronger influence on the harvest (Fig. 10).



June 21, 2007

June 27, 2007

Figure 10. Effect of drought stress, Photos taken at same location.