EVALUATING TEMPORAL VARIATION IN ACTIVE-LIGHT PLANT SENSORS

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Abstract

Significant variability in cotton reflectance, specifically the Normalized Difference Vegetation Index (NDVI), was observed over the course of a day for three cotton varieties at the University of Tennessee Research and Education Center at Milan (Milan, TN) on July 18, 2008. The objective of this research was to investigate potential impacts of ambient radiation on NDVI measurements made with active-light plant sensors. Both of the commercially available active-light plant sensors showed a response to changes in ambient radiation intensity. NDVI measured with the GreenSeeker system and NDVI measured with the CropCircle were strongly related to ambient radiation intensity. The CropCircle showed the same magnitude of variation during testing but the relationship appears as a mirror image of the GreenSeeker. The strong relationships will allow for simple correction of NDVI data from these systems if additional testing finds the same trend in induced variability outside the published range of error for the sensor. The significant relationship between NDVI and ambient radiation signifies the need for further testing during the peak growing season when solar intensity and angle are greater.

Introduction

Close-proximity remote sensing has developed a significant body of research over the past decade as a non-destructive method for evaluating crop and soil characteristics. Sensors in close proximity to the crop target have several benefits over sensors mounted on satellites or aircraft. Sensing resolution can be much higher and timing of data collection can be more precise. However, ground-based remote sensing takes more time to collect data over large areas.

Active-light sensors use a modulated light source to remove ambient light dependence and interference. Intensity of the emitted light is constant and data can be collected irrespective of time of day or weather conditions. For this reason, active-light sensors have come to the forefront of ground-based remote sensing research. Because these sensors are either handheld or vehicle mounted, covering large areas takes a significant period of time. Significant variability in cotton reflectance, specifically the Normalized Difference Vegetation Index (NDVI), was observed over the course of a day for three cotton varieties at the University of Tennessee Research and Education Center at Milan (Milan, TN) on July 18, 2008 (Figure 1). NDVI data was averaged for one 0.5 mile long row of cotton from each of three varieties nine times over the course of a day. The first observation began at 8:21 (CST) and the last observation began at 15:58 (CST).

This diurnal NDVI variability can likely be attributed to environmental and physiological variables such as moisture on the leaves, change in leaf angle due to plant water stress, heliotropism, etc. The objective of the following research was to investigate potential impacts of ambient radiation on NDVI measurements made with active-light plant sensors.

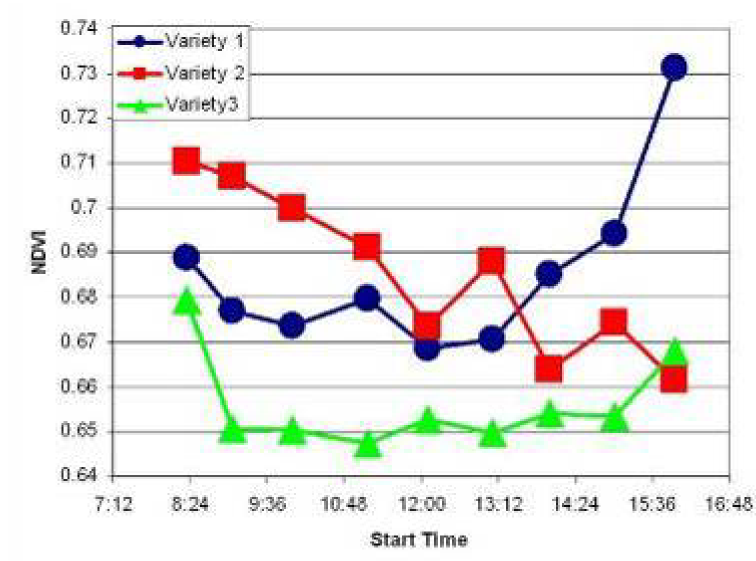

Figure 1. Average NDVI from one 0.5 mile long row of each variety sampled nine times over the course of a day.

Methods

To investigate the impacts of ambient radiation on NDVI measurements, active-light sensors were positioned over static targets and NDVI data was logged for extended time periods. Intensity of ambient radiation was logged in conjunction with NDVI measurements using a pyranometer. Data was collected from each of the two dominant commercially available active-light sensors, the GreenSeeker (NTech Industries, Ukiah, CA) and the CropCircle (Holland Scientific, Lincoln, NE). This data set was collected on 12/12/08.

GreenSeeker

Static sensor stability testing was conducted using a six-sensor GreenSeeker RT220 system (NTech Industries, Ukiah, CA). The system was mounted on the boom of a high-clearance sprayer located at the West Tennessee Research and Education Center in Jackson, TN. Sensor software configuration and mounting positions were left at the system owner's settings. NDVI data was output two times per second. Sensors were spaced a minimum distance of 76 inches apart with a maximum spacing of 118 inches (between the center two sensors). The center two sensor positions (noted below as s77 and s78) resulted in a sprayer tire in the field of view of the sensor.

Pieces of green fabric were secured to plywood backing and served as individual targets for each sensor (Figure 2). The boom height was set so that the average height of the sensors was 36 inches above the targets. The maximum distance from sensor to target was 38 inches (s80) and the minimum distance was 30 inches (s78). Fabric pieces were 42 inches wide, to ensure no edge effect over the sensor's effective width, and at least 24 inches long. The sprayer was positioned so that the boom faced south to minimize shadows on the target cast by the boom and sensors.

CropCircle

A single CropCircle (ACS-210, Holland Scientific, Lincoln, NE) was positioned 38 inches over a green fabric target (described above) (Figure 2). Sensor software configuration was left at the system owner's settings. NDVI data was output ten times per second. The sensor was positioned facing south to minimize shadows on the target cast by the mounting platform.

Pyranometer

An LI200X silicon pyranometer (Campbell Scientific, Logan, UT) was mounted on the highest point of the boom-lift structure and leveled to measure incoming ambient radiation. Readings from the pyranometer were recorded ten times per second using a CR23X data logger (Campbell Scientific, Logan, UT).

Data Logging

The raw ASCII serial stream from the GreenSeeker system was logged on a PC laptop for six hours, beginning at ~9:40AM and ending at ~3:30PM (CST). A time stamp from the laptop clock was logged with each reading from the RT200. Prior to beginning the test, the clock on the CR23X was synchronized with the clock on the laptop.

Data from the CropCircle was logged separately from the GreenSeekers using a GeoSCOUT 400 data logger (Holland Scientific, Lincoln, NE) because of its RS-485 interface. Start and end times for the CropCircle data logging were recorded from the PC laptop clock.

Figure 2. GreenSeeker (left) and CropCircle (right) sensors positioned over green fabric targets.

Results

GreenSeeker sensor s80 began reporting incorrect data about half way through the test period and was omitted from data analysis (Figure 3). This was a hardware problem and was known about prior to this testing. NDVI values from sensors s77 and s78 appeared to be influenced by the sensor proximity to the sprayer tire and were also excluded during data analysis (Figure 3).

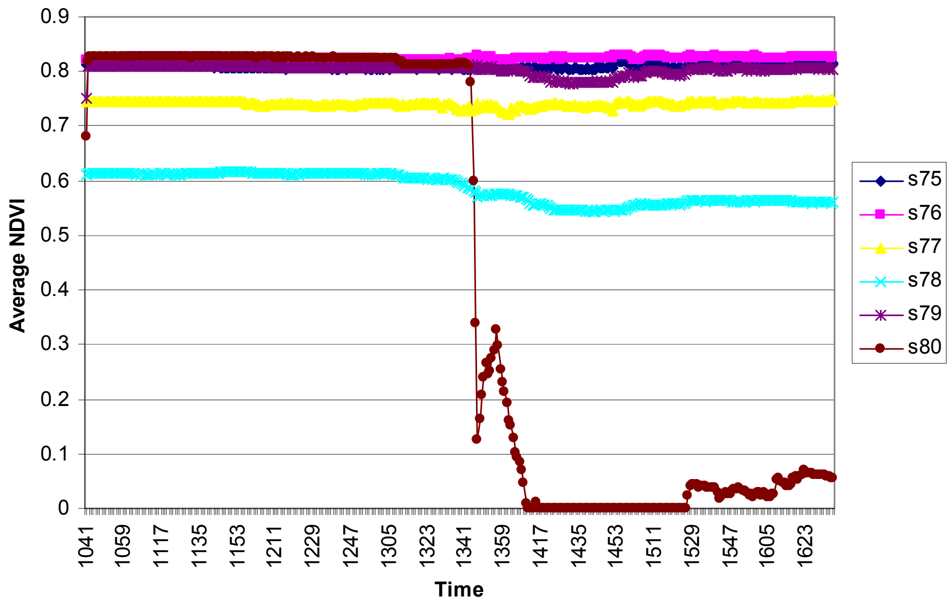

Figure 3. Average NDVI by minute for each sensor over the course of the test period.

Figure 4 illustrates the relationship between ambient radiation and the three representative GreenSeekers (s75, s76, s79). The magnitude of NDVI response has been magnified in the figure for clarity and all variability seen is within the 0.03 error published by NTech. There is, however, a strong linear relationship (R2 = 0.8956) between NDVI and ambient radiation intensity (Figure 5).

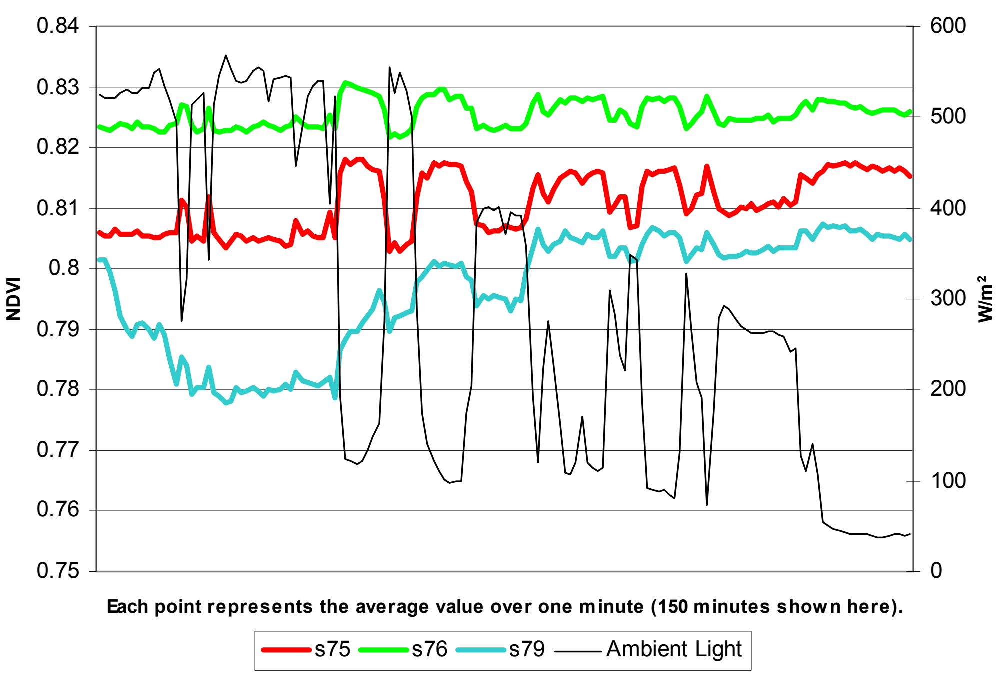

Figure 4. A strong relationship between NDVI from three GreenSeeker sensors and ambient radiation intensity.

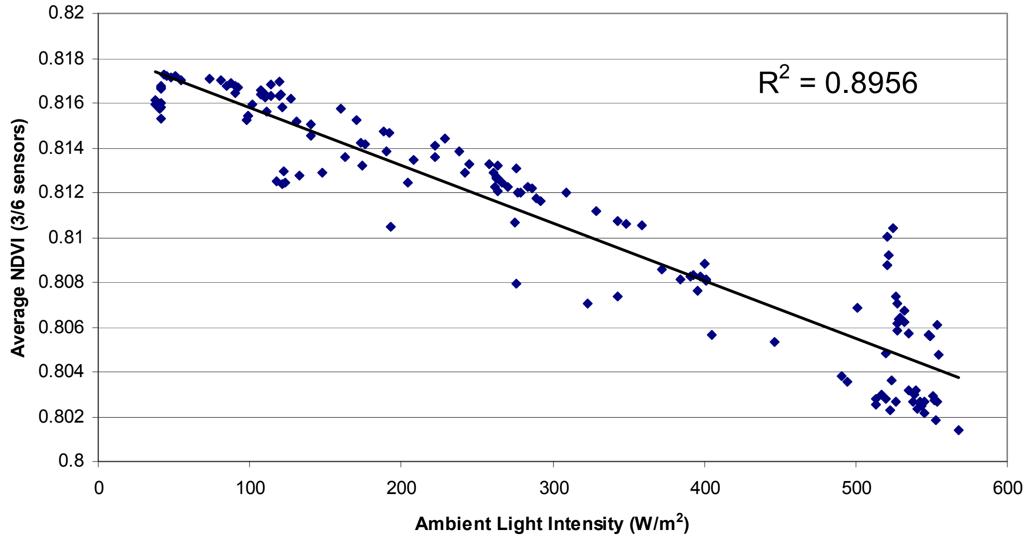

Figure 5. GreenSeeker NDVI shows an inverse linear correlation with ambient radiation intensity.

The CropCircle data shows the same amount of variability with changes in ambient radiation, but the response appears to be a mirror image of the GreenSeeker (Figure 6). The relationship between the CropCircle NDVI and ambient radiation is best described with a polynomial relationship (R2 = 0.8926), maintaining the mirrored response to that of the GreenSeeker (Figure 7).

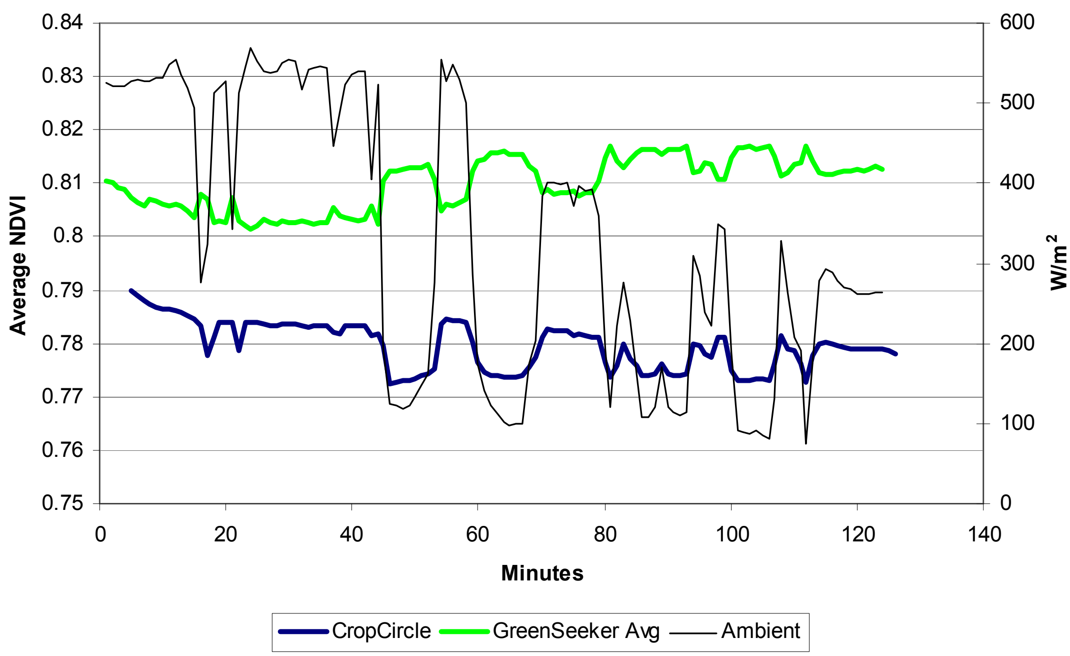

Figure 6. CropCircle response to changes in ambient radiation appears to be a mirror image of the GreenSeeker.

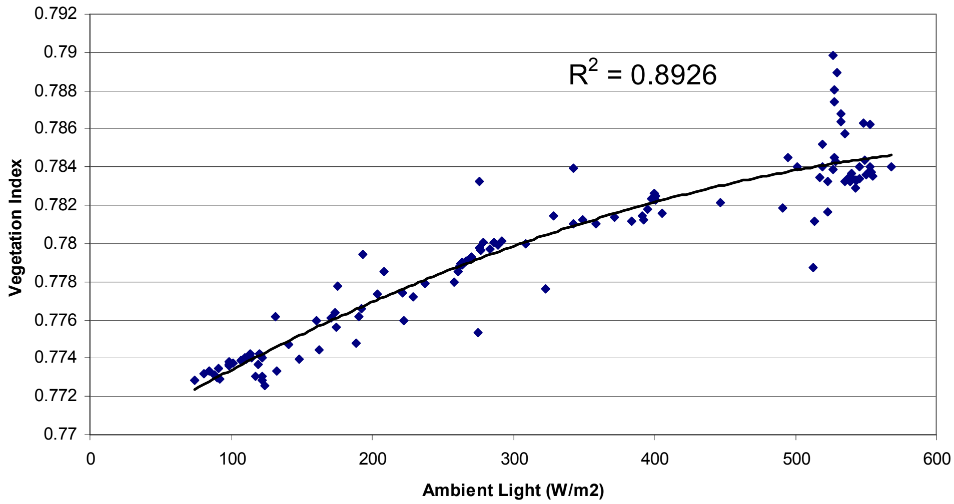

Figure 7. Significant positive relationship between CropCircle NDVI and ambient radiation intensity.

Observations from each sensor were normalized by dividing by the respective sensor's average NDVI for the day. Figure 8 shows the normalized values for comparing the two sensor systems. Variation is approximately the same magnitude for the two systems but appears as a mirror image.

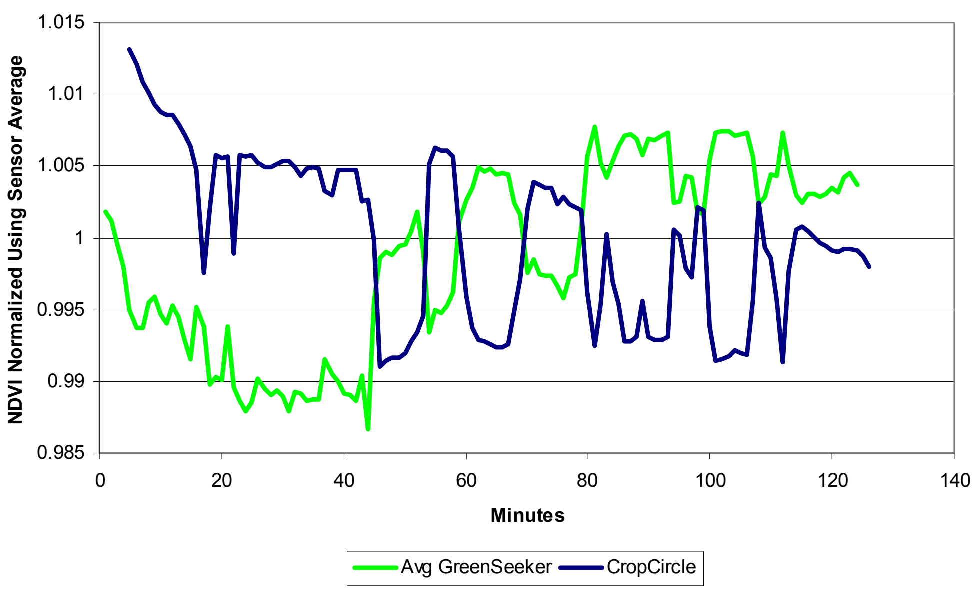

Figure 8. NDVI for each sensor was normalized using the average from each sensor.

Summary

Both of the commercially available active-light plant sensors showed a response to changes in ambient radiation intensity. Both NDVI measured with the GreenSeeker system and NDVI measured with the CropCircle were strongly related to ambient light intensity. The strong relationships will allow for simple correction of NDVI data from these systems if additional testing finds the same trend in induced variability outside the published range of error for the sensor. The apparent opposite response of the two systems to ambient radiation can not be explained at this time. Future testing will include measurement of solar angle, spectral distribution of incoming radiation, and temperature of the sensor housing. The significant relationship between NDVI and ambient radiation, while within the published error when tested during the winter, signifies the need for further testing during the peak growing season when solar intensity and angle are greater.