Laboratory evaluation of the GreenSeeker™ hand-held optical sensor to variations in orientation and height above canopy

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Abstract: Handheld optical sensors recently have been introduced to the agricultural market. These handheld sensors are able to provide operators with Normalized Difference Vegetative Index (NDVI) data when cloud cover prevents acquisition of satellite or aerial images. This research addressed the sensitivity of the GreenSeeker hand-held optical sensor to changes in orientation and height above a ryegrass canopy. Planter boxes were oriented both parallel and perpendicular to the light beam from the sensor head and heights of 30.5 cm (12”), 61.0 cm (24”), 91.5 cm (36”), 122 cm (48”) and 152 cm (60”) were tested. Results indicated that the sensor was highly sensitive (P<0.0001) to both height above canopy and orientation of the sensor relative to the target. Operators should follow manufacturer’s recommendations on operating height range of 81 – 122 cm and orient the sensor head in-line with the target to obtain maximum signal response.

Keywords: remote sensing, NDVI, GreenSeeker, handheld optical sensor, spectral reflectance

DOI: 10.3965/j.ijabe.20120501.005

Citation: Daniel E Martin, Juan D López Jr., Yubin Lan. Laboratory evaluation of the GreenSeeker™ hand-held optical sensor to variations in orientation and height above canopy. Int J Agric & Biol Eng, 2012; 5(1): 43－47.

1 Introduction

Handheld optical sensors recently have been introduced to the agricultural market to simplify acquisition of spectral reflectance data. These handheld sensors are able to provide operators with Normalized Difference Vegetative Index (NDVI) data when cloud cover prevents acquisition of satellite or aerial images. The sensors can be operated independent of lighting conditions, and can be used at night[1]. This is achieved with a built-in light source.

The GreenSeeker™ is an active spectral radiometer that generates light centered at two wavelength bands. Overall, three bands (red, green and near-infrared (NIR)) are available for use in pairs. Reflectance of this light back to the sensor can be used to calculate a vegetative index, which gives a quantitative measure of lushness or plant health. The sensor was designed to be held 81 cm (32 inches) to 122 cm (48 inches) over the target canopy, and the width of the sensor is a constant 61 cm (24 inches), independent of height, according to the manufacturer.

Several portable, optical sensing technologies have been designed, developed and tested over the past decade. Optical sensors previously have been designed to detect weeds and distinguish the weeds from wheat and soil background[2]. Laboratory tests showed that these constituents could be classified with an accuracy of 70% or greater. A commercially available optical sensor, called the WeedSeeker, was used by Antuniassi et al.[3] to detect weeds in a field under a variety of soil surfaces, weed species and sensitivity levels. The investigators found that they could achieve 100% detection of weeds

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Received date:2011-04-08 **Accepted date:**2012-02-01

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when the leaf areas were larger than 9.92 cm^2. Turfgrass quality has also been assessed with a dual spectroradiometer covering a spectrum of 350-1050 nm[4]. It was determined that a dual-band system of red and NIR light could accurately assess turfgrass quality with an average Standard Error of Performance value of 0.70 or less depending on turf species. A GreenSeeker handheld optical sensor also was used to assess the effects of different levels of nitrogen fertilization on barley in two irrigation systems[5]. Two sensors were mounted on a custom-designed platform with high clearance and equipped with a computer and GPS. The researchers calculated a standard deviation of less than 0.051 in the sensor's NDVI responses for sunlight illumination effects during 26 h. Small standard deviations were found due to illumination changes between sunny and cloudy conditions. The GreenSeeker sensor also has been used to measure the reflectance from cotton and compare the NDVI values from the GreenSeeker to those from a spectraradiometer to determine which better estimated in-season plant N status[6]. Martin et al.[7,8] used a GreenSeeker sensor to collect NDVI data at multiple growth stages during the life cycle of corn and evaluated the relationship between NDVI and corn grain yields. Teal et al.[9] also evaluated the relationship between corn grain yield and early season NDVI readings using the GreenSeeker. Chlorophyll yield and concentration in spinach was estimated by using NDVI values from both a GreenSeeker sensor and a multispectral imaging system[10]. Freeman et al.[11] collected GreenSeeker NDVI values and plant height measurements on individual corn plants at various growth stages and related them to individual plant biomass, forage yield and N uptake. The GreenSeeker also was used to estimate in-season plant N status on three spring wheat cultivars[12]. Govaerts et al.[13] reported the great potential of the GreenSeeker sensor to detect spatial crop variability both within and between plots/treatments. These results suggest that the GreenSeeker might be useful in assessing general plant or crop health over a wide range of lighting conditions.

Objectives

- To determine if the height of the optical sensor above the target canopy or the orientation of the target relative to the sensor head affects reflectance values.
- To determine if the orientation of the target relative to the sensor head affects reflectance values.

2 Materials and methods

2.1 Study setup

A GreenSeeker hand-held optical sensor (Model 505, NTech Industries, Inc., Ukiah, California) was suspended at five different heights (30.5 cm (12"), 61.0 cm (24"), 91.5 cm (36"), 121.9 cm (48"), 152.4 cm (60")) above 45.7 cm×19.1 cm (18"×7.5") window boxes (Model DCB18 TC, Duraco Products Inc., Streamwood, Illinois) planted with fourteen day old ryegrass (Figure 1). Six different window boxes planted with ryegrass were used for this study. Kraft paper was placed beneath the window boxes to provide a uniform background for the scans. The sensor was passed over each window box, parallel to the ryegrass canopy, five times at each of two orientations (Figure 2) and at a speed of 15 cm per second (6" per second). The resulting NDVI values were calculated from the red (660 nm) and NIR (770 nm) bands and automatically recorded to a personal digital assistant (PDA). All scans for the study were conducted within a 60 minute timeframe, thus ensuring minimal variation in ambient conditions. Since individual window boxes were situated over a uniform background and the light beam extended beyond the extents of the

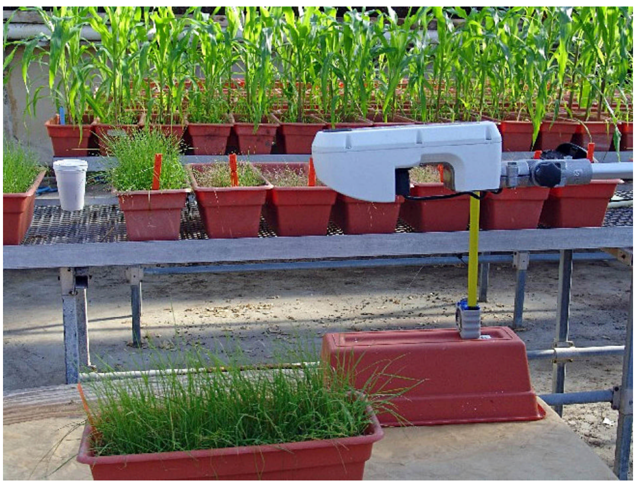

Figure 1 GreenSeeker optical sensor scanned over window boxes planted with ryegrass at various heights and orientations. The resulting NDVI values were automatically recorded to a PDA connected to the optical sensor.

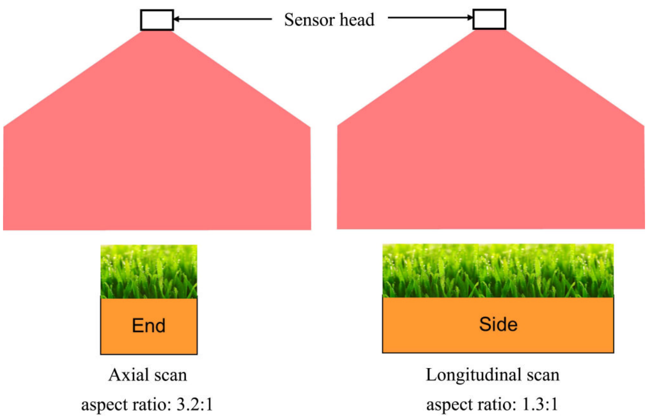

Figure 2 GreenSeeker hand-held optical sensor passed at two different angles relative to window boxes planted with ryegrass to determine the effect of orientation on NDVI. Aspect Ratio was calculated as the ratio between the GreenSeeker light beam width (61 cm) and the traversed width of the planter box (19.1 cm for axial scan and 45.7 cm for longitudinal scan). Shape of light pattern is author's conceptual depiction based on available information

window boxes, only the maximum NDVI values for each pass were used in analysis of results. This method was recommended by the manufacturer and ensured a consistent measure of reflectance from the ryegrass canopy, minimizing the influence of the background.

2.2 Statistical analyses

All the statistical analyses were performed using SAS 9.3[14]. The Least Square Means for different heights and orientations and their interactions were separated with the Tukey adjustment using the Proc GLM.

3 Results and discussion

3.1 Overall statistical results

Heights, orientations, and their interactions were all highly significant (P<0.0001). The mean NDVI for all the interactions is shown in Figure 3. It shows that NDVI was greatest (0.9211) at 31 cm when scanned longitudinally, and then reached a minimum at 152 cm when scanned axially. The effects of height (P<0.0001, F=490.04) and orientation (P<0.0001, F=1618.14) on NDVI were highly significant.

3.2 Effect of height

The height of the sensor head above the canopy target had a significant effect (P<0.0001) on the resulting reflectance values (Figure 3). There was an inverse relationship between height above target and NDVI values. The closer the sensor head was to the target, the higher the NDVI values. Conversely, the greater the distance between the sensor head and the target vegetation, the lower the NDVI values. For the longitudinal orientation, there was a significant difference between the NDVI readings at each of the heights (P<0.0001) except between 93 cm and 122 cm (P=0.3046). This indicates that the readings stabilize between those two heights. In the axial orientation, NDVI readings are different between 31 cm and 93 cm (P<0.0001) but level out above that height (P=0.5285 and 0.9977). Since NDVI is based on a ratio of the near-infrared and red reflected light energy, a loss of reflected energy due to the increasing distance from the target alone would not be expected to explain this effect. If the width of the light beam was not constant, this could result in a greater contribution of the background at greater heights, thus reducing the NDVI values as the sensor is moved away from the target. This effect was outside of the scope of this project and thus was not tested. The manufacturer recommends holding the sensor 81 – 122 cm (32 – 48") away from the intended target. While this recommendation provides the operator with usable guidelines, it can be difficult to maintain a steady height in the field. Lower heights are also more attractive to the user because less effort is required due to the smaller arm angles required to hold the instrument at 31 cm versus 93 cm. The results indicate that the sensor height above canopy has a direct effect on NDVI. Users should operate the instrument within the manufacturer's recommended height range of 81–122 cm for best results. Failure to remain consistent in the distance between the sensor and the target may lead to erratic results.

3.3 Effect of orientation

The orientation of the sensor head to the target also was a significant factor (P<0.0001 for all heights). When the largest dimension of the window boxes (longitudinal orientation) was in line with the light beam from the GreenSeeker, maximum reflectance values were obtained (Figure 3). Similarly, axially scanning the boxes resulted in the lowest reflectance readings at each height. One may presuppose this to be the case as a larger percentage of the light is reflected by the vegetative material when oriented in-line with the sensor head. The point that must be made here is that orientation matters and one must be consistent in their use of the optical sensor. Many of these sensors will be used for scanning row crops. When traversing through a field, the sensor may yield different results depending on whether the sensor is oriented parallel or perpendicular to the row. This would be especially true when the canopy is not fully closed. Soil and other background materials may greatly influence the sensor readings. In order to obtain maximum response from the sensor, the sensor head should be oriented in-line with the vegetative material (i.e. the rows).

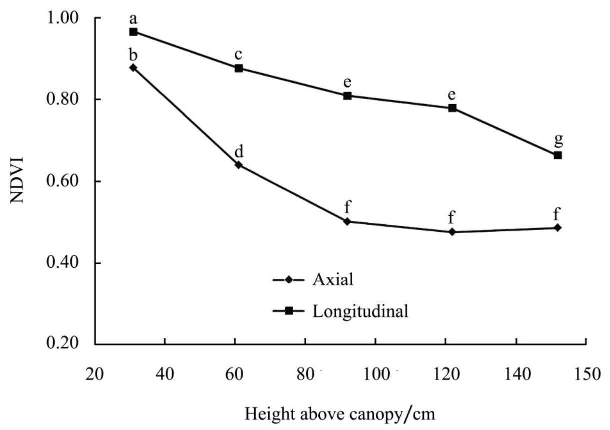

Figure 1 Response of reflectance values to height above target and orientation of the window boxes relative to the sensor head. Mean with the same lower-case letter are not significantly different ($P<0.05$)

4 Conclusions

1) The height of the sensor above the target had a significant effect on spectral reflectance values. NDVI decreased as height increased. Operating within the manufacturer's guidelines of 81 – 122 cm (32 – 48") for either orientation should provide the most consistent results.

2) The orientation of the window boxes had a significant effect on reflectance values. Orienting the target in-line with the light beam from the sensor head maximized NDVI values. Users conducting field studies in row crops need to be particularly aware of this aspect. If maximum reflectance values are desired or plants are very small, users should orient the sensor's light beam in-line with the rows. Orienting the light beam perpendicular to the rows is more likely to pick up background soil reflectance. This, however, is quite normal and acceptable, especially with larger plants and closed canopies.

3) Users need to remain consistent within the height range recommended by the manufacturer and orientation of the GreenSeeker optical sensor to the target.

Acknowledgments

The author would like to thank Mr. Curtis Hubbard for starting and maintaining the ryegrass samples and Mr. Chris Parker for his assistance in scanning the samples.

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