DEVELOPMENT OF A GROUND-BASED PLATFORM FOR PLANT PHENOTYPING AND CROP MANAGEMENT DECISIONS

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Abstract

The objective of this effort was to evaluate current commercially-available sensor technology for use in a ground-based platform for plant phenotyping and crop management decisions. Field experiments showed that the Global Positioning System (GPS) receiver from Trimble provided a high level of accuracy during our tests, and Normalized Difference Vegetation Index (NDVI) data collected using the GreenSeeker sensors were more consistent when compared to the Decagon SRS sensor. Our tests also indicated that although sonic ranging sensor technology may be employed to obtain average plant height estimates, the technology is still a limiting factor for high-accuracy measurements at the plant level. To address limitations of the sonic ranging sensor, we propose the development of a Light Detection and Ranging (LiDAR) system for accurate plant-level height measurements.

Introduction

Advanced sensor technology has become fairly affordable over the past few years. When properly equipped, both manned and unmanned platforms have great potential to help improve the decision-making process for crop management as well as for high-throughput phenotyping of various crops. The possible applications for such technology at this point, are almost endless. These applications range from plant growth analysis and canopy cover development, to seasonal changes in overall plant health and response to different sources of biotic and abiotic stress, and possibly final yield estimates. The main objective of this effort is to evaluate different commercially available sensors for their suitability in providing accurate measurements for spatial positioning (GPS), plant height, and Normalized Difference Vegetation Index (NDVI) to be used in the ground-based platform.

Materials and Methods

Our proposed phenotyping system is based on a modified ground crop sprayer tractor (Spider, Lee Co. Inc., Idalou, TX). Sensors were mounted on a front support bar (boom) attached to the front end of the platform spaced at 0.96 m. One hydraulic cylinder was installed vertically on the center of the tractor boom to allow for changes in sensor height throughout the growing season. The sensors evaluated for the platform includes GPS receivers (AgGPS 162, Trimble Navigation Limited, Sunnyvale, CA; GPS16X-HVS, Garmin International Inc., Olathe, KS), multi-spectral sensors (GreenSeeker, Trimble Navigation Limited, Sunnyvale, CA; SRS, Decagon Devices Inc., Pullman, WA), a measurement and control system (CR1000, Campbell Scientific, Inc., Logan, UT), a precision infrared radiometer (SI-111, Campbell Scientific, Inc., Logan, UT), sonic ranging sensors (SR50A, Campbell Scientific, Inc., Logan, UT; TS14, Senix Co., Hinesburg, VT; MB7092, MaxBotix Inc., Brainerd, MN), a temperature and relative humidity probe (HC2S3, Campbell Scientific, Inc., Logan, UT). There were two independent data collection systems running simultaneously (Fig. 1). Data collected was matched using GPS time for posterior analysis (Fig. 1).

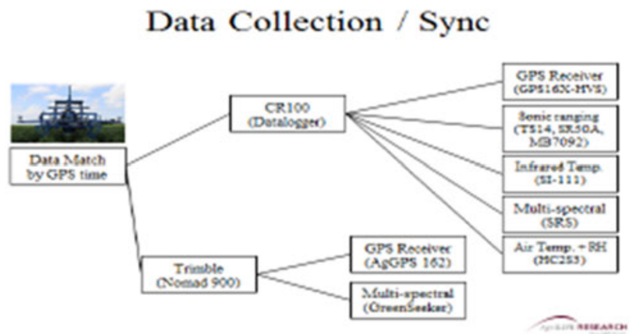

Figure 1. Ground based data collection system design

Results and Discussion

Data were collected in two different crops, cotton (*Gossypium hirsutum* L.) and peppers planted at the Texas A&M AgriLife Research and Extension Centers at Corpus Christi and Weslaco, TX, respectively. As shown on Fig. 2, there were significant differences in GPS accuracy between the Trimble and Garmin receivers. Images show raw data from the Trimble system (Fig. 2, left) and processed (filler plots removed) Garmin receiver (Fig. 2, right).

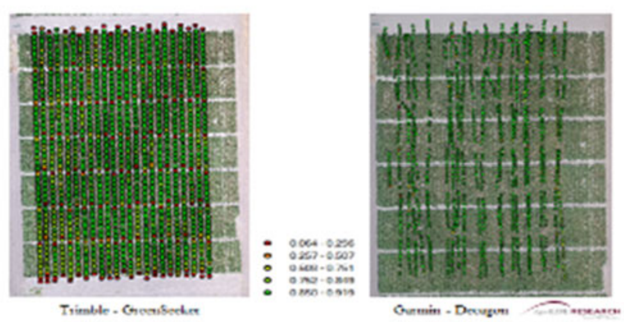

Figure 2. Differences in GPS receiver accuracy. Data points shown in the figure are Normalized Difference Vegetation Index (NDVI) values collected on 6/26/2015 at the Texas A&M AgriLife Research and Extension Center, Corpus Christi, TX.

Figure 3 shows a comparison between the GreenSeeker and Decagon SRS NDVI sensors. Overall, the GreenSeeker sensors produced the most consistent results. The Decagon SRS had several missing (or bad readings). This may be explained by the fact that the GreenSeeker uses active radiation to acquire reflectance data independent of solar radiation.

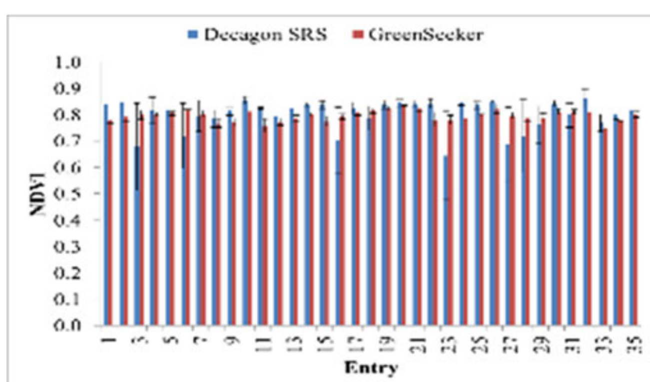

Figure 3. Differences in Normalized Difference Vegetation Index (NDVI) values collected on 7/17/2015. Values are presented as the average value for each of the 35 entries included in the trial. Black error bars in the figure represent ± one standard deviation.

Stationary plant height measurements using the SR50A sonic ranging sensor showed that it was capable of producing fairly accurate cotton plant height measurements, with an average difference between manually measured and sensor of about 2 cm (Table 1). It was evident, however, that when the platform was moving at approximately 0.44 m s^{-1}, sensor readings became unreliable (i.e. SR50A) or missed some plants completely (TS14 and MB7092) (Fig. 4). All three sonic ranging sensors seemed to be able to accurately detect the flat surface of the soil (at 20 cm), for measurements on pepper plants.

Table 1. Stationary measured plant height differences between manual measurements and sonic ranging (SR50A)

	Left row (cm)			Right row (cm)		
	Tape	Sensor	Diff.	Tape	Sensor	Diff.
Avg.	89.9	91.8	-1.9	90.5	92.8	-2.3
Stdev.	7.6	6.8		8.2	7.0	

Avg. = Average, Stdev. = Standard deviation, Diff. = Difference

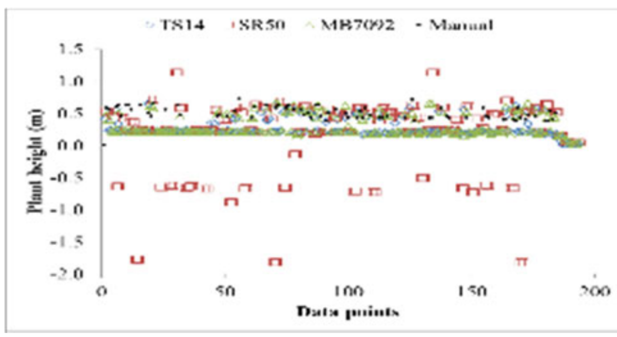

Figure 4. Variability in plant height (Pepper plants) measurements from three different sonic ranging sensors collected at the Texas A&M AgriLife Research and Extension Center, Weslaco, TX with a ground speed of approximately 0.44 m sec^{-1}. Plants were planted in a 20 cm bed.

Although sonic ranging sensors may be effectively used for "average" plant height estimates, we believe the limiting factor for high accuracy measurements at the plant level is the technology. Sonic ranging sensors may be programmed to collect data (i.e. refresh rate) up to 50 Hz, although at this point the distance between sensor and target may be limited. Further, due to the relatively low refresh rates accurate plant-level height measurements are unlikely (Fig. 5, left). To overcome this issue, we plan to develop and deploy our own Light Detection and Ranging (LiDAR) sensor. LiDAR technology should allow a much higher level of accuracy (Fig. 5, right).

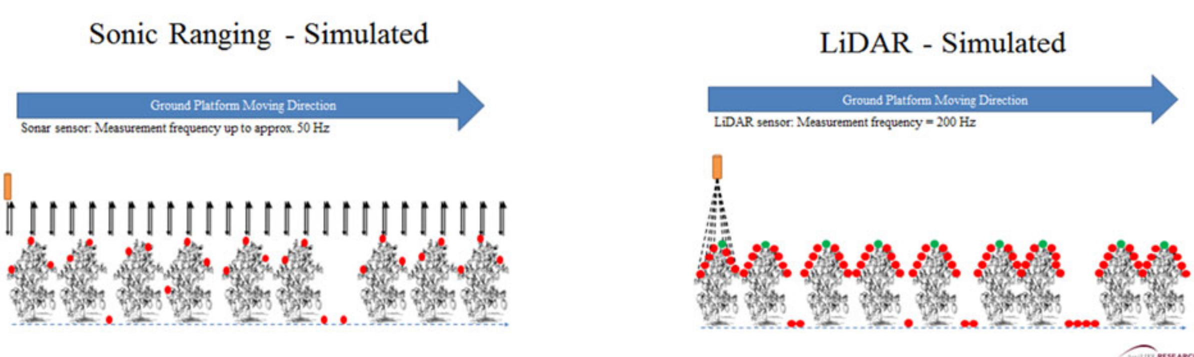

Figure 5. Example of simulated sonic ranging and LiDAR measurements.

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