FIELD TESTING OF MISSISSIPPI STATE UNIVERSITY COTTON YIELD MONITOR

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Abstract

A novel cotton-flow sensor was designed and fabricated at Mississippi State University (MSU) in 1999. Based on that sensor, a cotton yield monitor system has been developed. Three prototypes of the MSU cotton yield monitor system were constructed. Performance of these prototypes was field-tested in Texas, Georgia, and Mississippi in the year-2000 cotton-harvesting season. About 1310 acres of cotton with different varieties and large yield variations were harvested with this yield monitor system. Operating temperatures varied from about 50ºF to 100ºF. In the Texas test, average absolute errors for the two fields were 5.9% and 5.4%, while the total errors were 2.4% and 2.5%, respectively. Results from the test in Georgia showed that the average absolute error was 5.7% and the total error was 0.9%. System reliability was tested in Mississippi by harvesting more than 1100 acres of cotton. The test indicated that the system was reliable and easy to operate. Further efforts are being made to improve the MSU cotton yield monitor system.

Introduction

Crop yield maps play a key role in precision agriculture. They can be used as an important tool to adjust production inputs for optimizing farming profit and minimizing environmental impact. As precision-agriculture technologies have become more and more widely adopted in cotton production, accurate, tough, and inexpensive cotton yield monitor systems are greatly needed by cotton producers. Yield monitors will collect cotton yield information on small locations within a field to make a cotton yield map.

Literature Review

Several cotton yield monitor systems have been researched and tested in recent years. Wilkerson et al. (1994) developed a sensor to measure cotton flow. Each sensor unit had two parts, a light-emitter array and a light-detector array mounted opposite each other. The sensor measured light attenuation caused by particles passing through a cotton picker duct, and then the light attenuation measurement was converted to the amount of cotton passing the sensor cross-section in a given time. The sensor performed well in preliminary laboratory tests. However, when tested in field, sensor performance was affected by dynamically changing ambient light. This system was significantly modified since Wilkerson et al. reported it in 1994. Moody et al. (2000) presented the resulting design and accuracy tests of the modified system. The test results were promising. The modified system has recently been marketed as the AgLeader Cotton Yield Monitor.

Thomasson et al. (1999) reported the design and fabrication of two experimental devices (device A and device B) for measuring the flow of pneumatically conveyed cotton. Both devices worked on the principle of optical attenuation and consisted of a light-sensing bar and a light source in Device A, and an LED array and light-sensors in Device B. Device A was tested in both a cotton picker duct and cotton gin duct, while device B was tested only in a cotton gin duct. High correlations between sensor output and the weight of passing cotton were reported for both device A and device B.

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Micro-Trak Systems, Inc. and Zycom Corporation commercialized optical cotton yield monitors in 1997. Both Micro-Trak and Zycom cotton yield monitors have been evaluated under field conditions (Durrence et. al., 1998; Gvili, 1998; Roades et. al., 2000; Sassenrath-Cole et. al., 1999; Searcy and Roades; 1998; Wolak et. al. 1999). These yield monitors have provided some useful data, but they have had some problems. One of the primary problems with optical yield monitors to date is that they are greatly affected by the buildup of dirt and dust on sensor surfaces. Khalilian et al. (1999) developed an air-box, pressurized by the picker fan, to help keep the sensors clean. The air-box completely encloses the sensor, effectively sealing it from environmental contamination. This method was able to keep the sensor clean over several harvested loads. In general, test results have shown that the commercial cotton yield monitors performed with a reasonable accuracy when their sensor windows were clean and the systems were properly calibrated on a regular basis. These conditions are very difficult to maintain in a commercial production situation, so most commercial interests are working to improve their systems.

Thomasson and Sui (2000) designed, fabricated, and field-tested a novel optical cotton-flow sensor as a yield monitor at Mississippi State University (MSU). Test results showed that sensor output was very strongly correlated with the passing seed cotton weight (R^2 = 0.97). Their sensor was also designed for estimating trash content in the passing cotton. The sensor was tested in 2000 with a laboratory device that simulated a cotton picker. A very strong correlation (R^2 = 0.99) was observed between seed cotton weight passing through the duct and the output signal of the sensor (Sui et. al., 2000).

Objectives

Three prototypes of the MSU cotton yield monitor were made in 2000 based on slight experience-based improvements to the previous work (Thomasson and Sui ,2000; Sui et. al., 2000). The objectives of the work reported here were (1) to evaluate the MSU cotton yield monitor in terms of accuracy, and (2) to evaluate its ease of use and long-term reliability.

Materials and Methods

Sensor Description

The MSU cotton yield monitor consists of two sensors and a data box. Sensors detect the cotton flow through a picker duct and provide an output signal to the data box. The data box records and processes sensor outputs in real time based on preset algorithms. Yield information was displayed on a screen and stored in a PCMCIA memory card. A Trimble AgGPS 132 receiver was employed for use with the monitors. The GSA sentence and RMC sentence from the receiver were selected to provide PDOP, location, and speed data. Location data were differentially-corrected with the signal from the nearest U.S. Coast Guard beacon station. The system's data box directly read those data from the DGPS receiver. Because of patent considerations, further detail about the sensor and data process of the system will be reserved for a later manuscript.

Test Sites

Two fields near Weslaco, Texas, were harvested with a four-row cotton picker (John Deere Model 9940) on July 4and 5, 2000. Each field is about 35 acres, although only about a third of the second field was included in the yield monitor study. The maximum ambient temperature there was approximately 100ºF.

About 1100 acres in 12 fields located near Vance, Mississippi, were harvested with a four-row picker (John Deere Model 9970) over the period from September 18 to October 17, 2000.

About 165 acres in five fields in South Georgia were harvested with a four-row picker (John Deere Model 9965) in November 2000. The minimum operating temperature there was about 50ºF.

Installation

The two sensors of the system were installed on the two outside ducts of the picker. One 2.0- x 4.6-inch hole was cut at the bottom of the duct for sensor installation. In Texas and Mississippi, the sensor was mounted on the lowest section of the duct, but in South Georgia, it was mounted on the middle section.

Test Operation

Sensors were cleaned only once per day during the picker's routine maintenance, usually in early morning before picking.

Since the primary objective for the tests in Texas and Georgia was to investigate the accuracy of the system (objective 1), the yield monitor performance there was tested on a per-basket-load basis. In Texas, a weigh wagon (a boll buggy with a load cell weighing system) was used to determine actual cotton weight in the picker's basket. In Georgia, cotton weight in the basket was measured with five truck scales (Model PT300, Intercomp) on which a boll buggy was placed. After the cotton in the picker's basket was dumped into the boll buggy, weight values shown on the five scales were recorded and summed to obtain a total weight for the basket. After emptying the basket, the scales were set to zero.

The main purpose for the test in Mississippi was to evaluate ease of use and long-term reliability of the system (objective 2), so performance there was tested on a per–field basis. In Mississippi, for system calibration only, the picker basket was emptied into a cotton wagon that had been placed on a set of four scales (Model PT300DW, Intercomp).

To calculate a coefficient for calibration, the actual cotton weight was divided by the corresponding integrated sensor output. Four consecutive loads harvested in the middle of the day were used for calibration in the Texas and Georgia tests, while four consecutive loads harvested on the first day of the harvesting season were used for calibration in the Mississippi test.

Twenty-nine loads of cotton in two fields were harvested in Texas during two days of harvesting. Due to extremely heavy weeds and very low yield in the first part of field 1, data from the first two loads were not included in the analysis. So data from 27 loads were analyzed for the Texas test. Because data analysis for all fields has not been completed yet, results from only the first (Perry Field-1) of five fields harvested in Georgia are presented in this paper. Perry Field-1 was about 35 acres. Nineteen loads were harvested over two days (Nov. 1 and 2, 2000). The only cotton loads weighed in the Mississippi test were the four weighed for system calibration.

Results

Results of the field test conducted in Texas are shown in Tables 1 and 2. Average absolute error of the system was 5.9% in the first harvesting day. It was 5.4% in the second day. When the sum of scale weights and the sum of system predicted weights were used to calculate a "total error", the values were 2.4% and 2.5% for the first and second harvesting days, respectively. The highest error occurred in the first two loads of the first day. This could be related with the weed levels in the corresponding location and a possible temperature effect (cool morning, hot afternoon) on system performance. In that particular area, a large amount of extraneous material associated with high weed levels was harvested along with the cotton. Any optical yield monitoring system will be affected by extraneous material. The effect of the error was that the predicted cotton weight was higher than the actual weight. Figure 1 is the cotton yield map of the Texas fields. The map was created in Arcview with the data collected by the MSU yield monitor system. The harvested land area for these two fields is 46.5 acres. Average yield was 1,460 lbs per acre (seed cotton). The map related well to cotton yield variations across the field, and the information shown on the map matched visual observation.

Table 3 involves the results obtained in South Georgia. Average absolute error over two days of harvesting was 5.7%, and total error was 0.9%. It was again noticed that the first load of the first harvesting day had the greatest error among all loads. In this field, it is possible that this effect is mainly due to the temperature effects on the sensor and the cleanness of the sensor window. Once again, the predicted cotton weight was much higher than the actual weight of the first load.

Figure 2 is one of the cotton yield maps created with data from the Mississippi test. During a one-month harvesting season with the MSU cotton yield monitor system, more than 1100 acres of cotton were harvested. Cotton yield maps of all fields harvested were created with the data from the yield monitor system. All maps realistically exhibited the yield variations within the field. The producer has drawn useful information from the yield maps for guiding future production. The yield monitor system worked continuously at least 8 hours per working day, and the entire system performed well. The system's reliability was observed to be very high. The only problem, which developed when a portion of the last field was being picked, was that some noise was introduced into the system, apparently because of abnormal performance of the alternator in the cotton picker, which served as the power supply for the yield monitor.

Summary

Three prototypes of the MSU cotton yield monitor system were field-tested with John Deere four-row cotton pickers in Texas, Georgia, and Mississippi. In the Texas test, average absolute errors for the two fields were 5.9% on day 1 and 5.4% on day 2, while the total errors were 2.4% and 2.5%, respectively. Early results from the test in Georgia showed that the average absolute error was 5.7% and the total error was 0.9%. A test of system reliability in Mississippi involving the harvest of more than 1100 acres indicated that the system was reliable and easy to operate. All yield maps created with the data from the MSU cotton yield monitor realistically exhibited yield variations within a field, and the map information well matched visual observation and estimation of experienced producers.

In general, the system performed well during the field tests. However, it appeared that system accuracy was possibly affected by operating temperature, build-up dirt on sensor windows, and by weed levels in the field. Further efforts are being made to improve the MSU cotton yield monitor system.

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Table 1. Results of the test of the first harvesting day in Weslaco, Texas in July 5, 2000.

Load No.	Scale (lb)	System (lbs)	Error (%)
1	2450	3100	26.6
2	2660	3094	16.3
3	2890	2984	3.3
4	2820	2808	-0.4
5	2730	2729	0.0
6*	2740	2597	-5.2
7*	2620	2640	0.8
8*	2490	2664	7.0
9*	2500	2456	-1.8
10	2370	2493	5.2
11	2470	2356	-4.6
12	2470	2319	-6.1
13	2750	2742	-0.3
14	2640	2502	-5.2
Total error: 2.4%; Average absolute error: 5.9%			

* loads used for calibration

Table 2. Results of the test of the second harvesting day in Weslaco, Texas in July 6, 2000.

Load No.	Scale (lb)	System (lbs)	Error (%)
1	3710	4052	9.2
2	2260	2423	7.2
3	2120	2352	10.9
4	1760	1819	3.3
5	2090	2081	-0.4
6*	1800	1759	-2.3
7*	2030	2049	0.9
8*	1780	1897	6.6
9*	1650	1575	-4.6
10	2550	2580	1.2
11	1930	2083	7.9
12	1780	1629	-8.5
13	2170	2028	-6.5
Total error: 2.5%; Average absolute error: 5.4%			

* loads used for calibration

Table 3. Results of the test in Perry Field-1, South Georgia.

Load No.	Scale (lb)	System (lbs)	Error (%)
1	6760	8382	24.0
2	4685	4983	6.4
3	4595	4651	1.2
4	3430	3510	2.3
5*	4580	4775	4.3
6*	4355	4522	3.8
7*	4375	4211	-3.8
8*	4325	4163	-3.7
9	6265	6036	-3.7
10	4165	3827	-8.1
11	6480	5765	-11.0
12	4065	4178	2.8
13	6125	5657	-7.6
14	6110	5690	-6.9
15	6070	5694	-6.2
16	5395	5070	-6.0
17	4680	4609	-1.5
18	4985	4777	-4.2

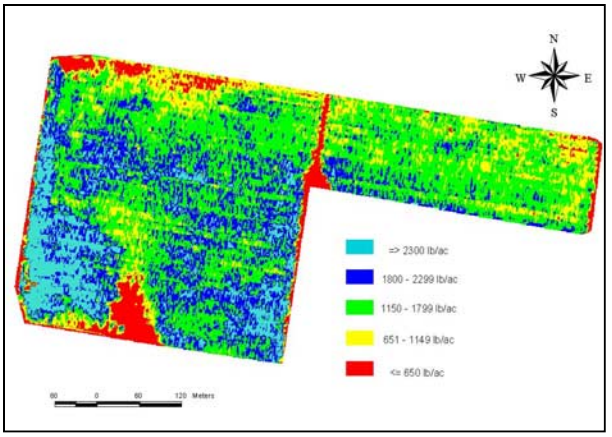

Figure 1. Cotton yield map of a 46.5-acre field near Weslaco, Texas. The map was created with the data collected by the MSU cotton yield monitor.

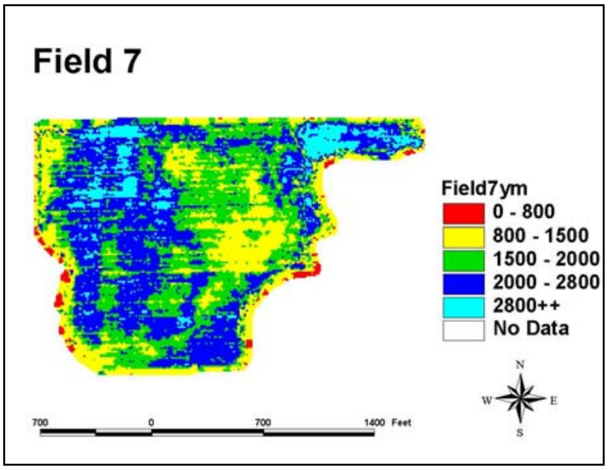

Figure 2. Cotton yield map of Field-7 near Vance, Mississippi. The map was created with the data collected by the MSU cotton yield monitor.