COTTON YIELD MAPPING: TEXAS EXPERIENCES IN 2000

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Abstract

Precision agriculture techniques have limited adoption in Texas cotton production, and a contributing factor is the lack of a reliable yield mapping system. Most of the commercial efforts for cotton yield mapping have been focused on cotton pickers. A yield mapping system that will work on cotton strippers is needed for Texas conditions. A commercially available cotton yield mapping system from MicroTrak and an experimental cotton yield mapping system based on load cells were evaluated in 2000 on cotton strippers in the Southern High Plains. Both systems had been modified compared to designs evaluated in 1999. They were evaluated for accuracy of yield estimates at points within the fields being mapped. The yield estimate accuracy was determined by comparing hand-sampled estimates from those of the yield map. Multiple hand samples were obtained at each site, and a 95 percent confidence interval of 110 lbs lint/ac was used for comparing the hand sample and map yield estimates. If the difference between the two estimates was less than the confidence interval for the hand samples, the two estimates were considered to be equivalent. For the MicroTrak and the TAES systems, the sample and mapped estimates were equivalent at 80 and 60 percent of the comparisons, respectively.

Introduction

For interest in precision agriculture to increase in the south, an accurate, reliable cotton yield mapping system is needed. Like many other crops, cotton yield can vary significantly within a field. The ability to measure the yield in each location of the field could provide cotton producers with the opportunity to optimize their management practices.

Commercial yield mapping systems have been offered for cotton pickers since 1997, with new systems coming on the market recently. The commercial yield mapping systems use optical sensors on the air ducts to estimate the mass of seed cotton accumulated in the basket. These systems relate the time and/or pattern of beam blockage to the rate of cotton flowing through the ducts. Since both cotton pickers and strippers convey the harvested material by air, it seems reasonable that the optical sensor could function on both machine types. However, the differences in the duct sizes, the exposure to ambient light and the option of using or bypassing the field cleaner have made yield mapping with strippers a more difficult problem. The work described here has had twin strategies of working with manufacturers to adapt existing optical systems for strippers and to develop an alternative approach.

The Agricultural Engineering Department of the Texas Agricultural Experiment Station (TAES) has been working for several years to develop and improve a cotton yield mapping system based on weighing the mass of cotton contained in the basket. A weighing approach to yield mapping can be applied to either pickers or strippers, and has the significant advantage of not requiring field calibration. Disadvantages of the weighing approach are the need to accumulate a mass of cotton over a harvested distance to determine the change in weight (instead of instantaneous flow as the optical systems measure), and the need to modify the basket supports to insert the load cells.

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The objectives of this study were to:

1. improve the performance of the TAES and MicroTrak cotton yield mapping systems on cotton strippers, and
2. evaluate both systems for accuracy of yield estimates at selected points and basket dump weights.

Yield Mapping Systems Evaluated

The TAES and MicroTrak systems were evaluated on two cotton strippers operated near Lubbock, Texas. A John Deere 7745 operated by the TAES research center had both MicroTrak and TAES systems installed. A John Deere 7755 stripper owned by the USDA-ARS Cotton Mechanization Laboratory had a second TAES system installed. These same two strippers were used for yield mapping evaluations in 1999 (Roades, et al., 2000). The same operators worked with the systems in both years.

In 1999, MicroTrak Inc. provided their cotton yield mapping system for evaluation by TAES. Factory personnel installed the system, with the optical sensors installed in two locations. One sensing location was on the air duct leading into the field cleaner, and the other set on the output side of the field cleaner. Evaluation in 1999 showed that the installation in the field cleaner (originally expected to be the superior location) did not work because of rapid blockage of the light beams by loose cotton fibers. Although the location in the inlet air duct was not plagued with blockage problems, the resulting yield estimates were not judged sufficiently accurate. For 2000, the decision was made to concentrate on the field cleaner location, but with a modified sensor mounting that would eliminate the problem of loose fibers accumulating and blocking the beams. The previous installation method had drilled holes in the duct sheet metal, matching the locations of the beam emitters and receivers on the sensor units. The alternative design was to cut a larger slot for mounting of the sensor unit and use clear plastic to prevent fiber accumulation (Fig. 1). In 2000, all yield map data was recorded with the sensors mounted on the field cleaner. While this location had the disadvantage of not recording data when the field cleaner was bypassed, it did have the advantages of a low ambient light condition and a cleaner material to sense. The operator interface module was mounted in the cab and an Omnistar 7000 DGPS receiver was mounted on top of the cab to provide position information.

The TAES yield mapping system was previously installed on both the 7445 and 7455 strippers. The system consists of four load cells mounted under the corners of the basket, a microprocessor-based data acquisition module for each load cell and a computer in the cab to provide operator display and to record the data. In 1999, significant changes were made in the data acquisition modules that digitized the load cell output. After the 1999 results showed that only about half of the yield estimates were within the desired level of accuracy, additional testing was performed while recording all data observations. Because of the machine vibrations, data smoothing is required, and the individual load cell readings are not saved to extend the data storage life. While trying to determine the cause of the inaccuracies, it was determined that the analog to digital circuitry was generating erroneous values. The data collection software was designed to eliminate load cell values that deviated significantly from the moving average, but it was the erroneous values affected the mapped yields. For 2000, the data acquisition modules were reprogrammed in an attempt to eliminate the erroneous readings. In addition, the data collection software on the cab computer was modified to improve the identification of erroneous data values. The DGPS receivers used for the TAES and USDA strippers were the John Deere Starfire and Omnistar 7000L, respectively.

Yield Mapping Evaluation Methods

Both the MicroTrak and TAES systems were evaluated simultaneously on the Deere 7445 stripper. Since the sensing principles were completely different, there was no interference or conflict between the two systems. Additional data on the performance of the TAES system was obtained from the USDA-operated stripper. The performance of each system was evaluated separately.

The MicroTrak system was calibrated for distance traveled and harvested mass according to the operator's manual. To determine the initial mass calibration factor, a basket was harvested and calibration factor determined by comparing the indicated and boll buggy weights. This single calibration factor was used in all subsequent harvesting. During harvest, most basket load weights indicated on the MicroTrak display were recorded manually, along with the actual basket weights determined with the weighing boll buggy. After each dump, the load buffer was zeroed. No cleaning of the modified sensors was done during the harvest season.

The TAES system was evaluated in a similar manner. The only daily maintenance necessary was to ensure that cotton did not build up between the engine cover and the bottom of the basket. A build up in this area could affect the measured basket weight. The basket dump weights were manually recorded at the same time as the MicroTrak data.

The emphasis of the evaluation for both systems was on point yield estimates rather than basket totals. The accuracy of the yield estimates was determined by comparing the map data to manual yield samples taken at locations scattered across the fields being harvested. The location of the manual samples was recorded with a DGPS receiver. The hand samples and mapped yields were obtained from two fields in the Southern High Plains, a research field near Lamesa, TX and a producer's field near Ropesville, TX. The TAES stripper harvested the Lamesa site and the USDA stripper harvested the Ropesville site. The comparisons were made for lint yield between the total hand sample and the mean mapped yield estimate for a region surrounding the sample location. The mapped yield estimate points were obtained by including all yield points that fell within a circle of fixed radius centered at the location of the hand sample.

Yield estimate comparisons were made between the manual samples and adjacent mapped areas. The sampling procedures varied, depending on the site. The sampling procedure in 2000 was to manually strip the cotton in 0.001 acre in each of two adjacent rows, or 0.0005 acre in four adjacent rows. This procedure provided either two or four estimates of the yield at a point. These estimates could then be analyzed individually or combined for larger area estimates. The latitude and longitude of each sampled location was recorded and later used to identify mapped points in that same region for comparison.

The manual samples at a point are yield estimates, just as are yield map values. A statistical analysis of the multiple manual samples at each point was used to determine the inherent variability in those estimates. At each sample point, regardless of the number or area of the samples, a 95 percent confidence interval for the mean was calculated. The average confidence interval for the mean was calculated for all the points in each sampling method. Mapped and sampled yield estimates that differed by less than the average confidence interval were considered to be in agreement for predicting yield. In 1999, the confidence interval used for comparison was 110 lbs lint/ac. In 2000, the overall yields were lower, and the mean 95% confidence interval was also somewhat lower. The mean CI calculated for two, three and four samples per location was 89, 107 and 81 lbs lint/ac. The 110 lb value was used in the rest of this study to evaluate map accuracy.

Results

MicroTrak

The stability of the calibration factor was initially examined. Availability of both the indicated and actual weights allowed the calculation of the calibration factor for each load. In 1999 conditions, the calibration factor changed drastically from load to load. Figure 2 shows the comparison of the actual weights (as indicated by the boll buggy) and the dumped mass estimates using the initial single load for calibration, or an average of the calibration factors for three loads. The average provided better accuracy for both total dumped mass and the local estimates (shown below). As a result, the average calibration coefficient from three loads was used for subsequent mapping, and would be recommended as a calibration procedure. However, even with the three load calibration, several basket weight predictions were more than 10 percent different than the boll buggy weights. Under the conditions tested, the MicroTrak unit with the modified sensors did not achieve the reliable, accurate prediction of load weights that farmers desire.

The MicroTrak cotton yield mapping system recorded the mass of seed cotton passing through the field cleaner. The manual yield estimates were hand stripped, and as a result, the two estimates could not be directly compared. In order to make the comparison, the lint yield was used. Each manual sample was ginned and the lint yield determined. Lint yield for the mapped yield estimates was determined by using the average gin turnout ratio for the field. While it is recognized that the percentage of lint may vary across the field, this limitation is inherent in all cotton yield mapping systems. The mapped lint yield estimates are quite sensitive to the lint percentage, and the relative agreement of the two manual and mapped estimates can be affected by a few percentage points change.

Figure 3 shows the comparison of the manual and mapped yield estimates for the MicroTrak data using an 8 m radius with the 110 lbs lint/ac confidence interval lines shown. Any points that fall between the two dotted lines are considered to be equivalent. Mapped yield estimates were calculated for radius distance of between 5 and 15 meters from the sample point. Table 1 shows the portion of the comparisons that the two estimates were considered equivalent. The best results were obtained when using an 8 or 10 m radius, with over 80 percent of the points equivalent. This high level of agreement with the sampled yield estimates indicates that the mapping system is nearly as accurate (under the conditions tested) as hand sampling. Examination of the resulting yield maps showed that the system was able to document features present in the field. Producers would likely be pleased with the resulting maps.

TAES Yield Mapping System

Since the TAES system used load cells to weigh the cotton as it is harvested, no calibration was necessary. Maintenance was limited to occasional cleaning of debris off the stripper to prevent a buildup that might affect the weights. However, several difficulties were experienced with the TAES systems in 2000. The system on the USDA stripper received damage to one of the load cells mounted in the basket pivot bracket, and as a result, inaccurate weights were recorded. With the TAES stripper, intermittent recording problems were experienced, causing some of the recorded data to be in error. Since some of the data from that machine was known to be erroneous, sections of the data were manually removed. This resulted in some of the sampled data points not being included in the comparisons. While analyzing the data, an attempt was made to estimate the yield using only the two load cells on the basket support bar. Examination of previous data showed that the bar carried approximately 63 percent of the basket weight. Summing the two load cell force readings and dividing by 0.63 estimated total basket weight.

Table 2 shows the results of comparing the TAES mapped and hand sampled yield estimates. Several interesting observations can be made from the data. On the TAES stripper mounted system, there was no loss of accuracy when estimating yield from two load cells compared to four. The weighing system had improved accuracy when averaging over a wider radius. This increasing accuracy with more points included may be a result of the distance that the system must travel to accumulate enough mass for an accurate measurement. For this study a 25 m travel distance was used to obtain starting and ending weights. The system did not perform quite as well on the ARS stripper. Reasons for this difference are unknown.

Conclusions

The MicroTrak system with the modified sensor design performed well in limited testing on a cotton stripper in the Southern High Plains. The system required little attention from the machine operator, a necessity with the sensor units mounted on the field cleaner. Due to the inaccessibility of these locations, a design with will not require regular maintenance is needed. The accuracy in predicting the yield at local points within the field was quite good, with over 80 percent of the points statistically equivalent to the hand sampled yield estimates. While equivalence for all tested points should be the desired accuracy of the system, the configuration tested provided yield maps that were sufficiently accurate for management decisions by producers. The accuracy in estimating the mass of cotton dumped, did not achieve the level of accuracy generally expected with grain yield mapping systems, but this is secondary to describing yield variability.

The TAES yield mapping prototype system using load cells experienced a variety of problems, including hardware damage and software errors. The accuracy of point yield estimates was approximately 60 percent equivalent to sampled estimates. The necessity of accumulating mass over a travel distance before a yield estimate can be made results in data that is naturally smoothed. This system will likely not ever be able to achieve the level of detail that systems with instantaneous sensors (such as optical) can record. The balancing characteristic is the lack of calibration requirements. In previous years, the TAES system was highly accurate in predicting the mass of cotton in the basket. However, in 2000 problems with the filtering routines resulted in decreased accuracy of dump weights. Further development is necessary to bring this system to commercial viability.

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References

Roades, J. P., A. D. Beck and S. W. Searcy. 2000. Cotton yield mapping: Texas experiences in 1999. Proceedings of the Beltwide Cotton Conference. Pp. 404-407.

Table 1. MicroTrak mapped yield compared to sampled yield estimates.

Averaged Radius (m)	Single Load Calibration (% equivalent)	Three Load Calibration (% equivalent)
5	63	76
8	81	84
10	85	84
15	84	76

Table 2. TAES mapped yield compared to sampled yield estimates.

Radius (m)	TAES 4 Load Cells (% equivalent)	TAES 2 Load Cells (% equivalent)	ARS 2 Load Cells (% equivalent)
5	56	52	35
8	62	68	43
10	64	64	52
15	76	78	62

Figure 1. Modified MicroTrak cotton sensor. Both emitter and detector units had the same design.

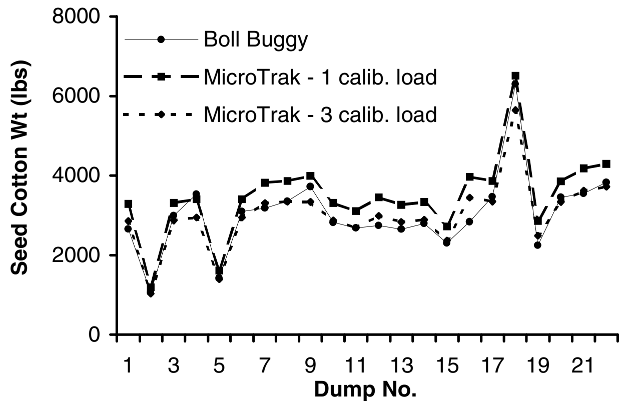

Figure 2. Comparison of dumped mass as indicated by the MicroTrak system with one or three load calibration and the boll buggy.

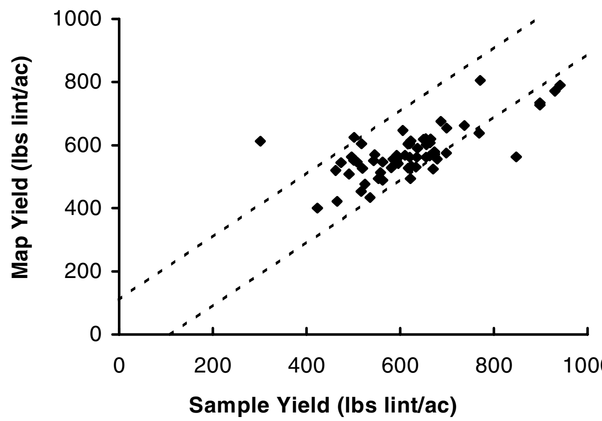

Figure 3. Comparison of hand sampled to MicroTrak map yield estimates. Map estimates are an average of points within an 8 m radius of the hand sample.