COTTON YIELD MAPPING: TEXAS EXPERIENCES IN 1999

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Abstract

A commercially available cotton yield mapping system from Micro-Trak and an experimental cotton yield mapping system developed by the Texas Agricultural Experiment Station were evaluated in 1999 on cotton strippers in the Southern High Plains. The systems were evaluated for ease of use, maintenance requirements and accuracy of yield measurements. 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 the 95 percent confidence interval for the yield estimates was established to be 110 lbs lint/ac. For both the Micro-Trak and the TAES systems, the sample and mapped estimates were equivalent on only about half of the sample sites.

Introduction

As interest in precision agriculture increases, the need for an accurate cotton yield mapping system becomes greater. 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. The two most widely marketed commercial yield mapping systems, Micro-Trak® and Agri-Plan®, both use optical sensors on the air ducts. These systems relate the portion time the light beams are blocked to the rate of cotton flowing through the ducts. Since cotton is harvested by both picking and stripping, yield mapping techniques compatible with both harvesting machines are needed. Both Agri-Plan and Micro-Trak are interested in marketing their systems for cotton strippers. Evaluations of the accuracy of the systems in the cotton stripping conditions in the Southern High Plains of Texas were needed.

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 advantage of not requiring frequent calibrations. A disadvantage is the requirement of accumulating a mass of cotton over a harvest distance, instead of taking instantaneous flow measurements as the optical systems do. The accuracy of the yield maps created and the user friendliness of the TAES system needed to be evaluated.

The objectives of this study were to

1. evaluate commercially available yield mapping systems on cotton strippers, and
2. modify and evaluate the TAES cotton yield mapping system for use on pickers and strippers.

Yield Mapping Systems Evaluated

To evaluate the Micro-Trak, Agri-Plan and TAES yield mapping systems in 1999, the systems were to be installed on two cotton strippers located near Lubbock, Texas. A John Deere 7745 operated by the TAES research center had both Micro-Trak and TAES systems installed. A John Deere 7755 stripper owned by the USDA-ARS Cotton Mechanization Laboratory had a TAES system and an Agri-Plan system installed. The Agri-Plan system was purchased in 1998 by the USDA, and installed by factory personnel. The operator interface module was sent to Agri-Plan for upgrading in 1999. After it was returned and installed, the system did not work properly, and no data was successfully recorded. As a result, the Agri-Plan system could not be evaluated for mapping accuracy in 1999. All performance analyses were limited to the Micro-Trak and TAES yield mapping systems.

The Micro-Trak cotton yield mapping system was provided for evaluation under a cooperative agreement between Micro-Trak and TAES. The system was installed by factory personnel, with two locations for the optical sensors. At each location, the sensor set included two sensors connected in a daisy-chain manner. Each sensor consisted of a transmitter module and a receiver module that had to be aligned across the area where the cotton was to be sensed. 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. The sensors mounted on the air duct were detecting the burr cotton and trash being conveyed from the stripper units. The sensors on the outlet side of the field cleaner were measuring the seed cotton after it was doffed from the saw cylinder. For each sensor, a series of holes were precisely drilled in the sheet metal so that the receiver and transmitter of each optical beam was properly aligned. The cables for each sensor location were routed so that research personnel could select the sensor location to be tested by changing the cable attached to the junction module. Figure 1 shows one of the sensor modules mounted inside the field cleaner. The individual holes for each optical beam are part of the design of the module. 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

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stripper operator and the research personnel received training in the operation and calibration of the Micro-Trak system. Data was recorded on an SRAM card provided with the system, and downloaded using the Grain-Trak software utilities.

Figure 1. Sensor module mounted inside field cleaner. Module is opened for cleaning.

A previous version of the TAES yield mapping system had been installed on both the 7445 and 7455 strippers. Significant modifications were made to the system hardware and software in 1999. For initial testing of those modifications, the system was installed on a Case 2055 cotton picker and operated in the Brazos River Valley near College Station in August and early September. Adjustment and optimization of the software occurred during that period. Research personnel installed identical systems on both strippers in late September. Modified basket supports incorporated load cells to provide continuous weighing of the basket and cotton. The operator interface and data recording was accomplished with a PC-104 format, DOS computer mounted in the cab, with a Flash Rom Card for storing data. The DGPS receivers used for the TAES and USDA strippers were the Omnistar 7000 and Omnistar 7000L, respectively. A software package named YMAP-Pro was developed for archiving and processing data files.

Yield Mapping Evaluation Methods

Both the Micro-Trak 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 Deere 7455 stripper operated by USDA personnel. The performance of each system was evaluated separately.

The evaluation of the Micro-Trak system had four objectives. These were to

1. determine preferred sensor location (prior to or after the field cleaner),
2. determine the consistency of calibration and the optimum conditions for calibration of the flow sensors,
3. determine the level of sensor maintenance required under Southern High Plains conditions and
4. determine the accuracy of the yield estimates on both a basket total and a site basis.

The Micro-Trak system was calibrated for distance traveled and harvested mass according to the operator's manual. To determine the initial mass calibration factor, two baskets were harvested and an approximate average of the two calculated values was used. Weighing boll buggies were available for most dumps of the two strippers. Initial plans were to evaluate the performance of the Micro-Trak system with the optical sensors located in the main air duct prior to the field cleaner and on the outlet side of the field cleaner. The intention was to alternate the sensor location used on a daily basis. However, the first few baskets showed that the sensors mounted on the field cleaner outlet rapidly plugged up with lint. As a result, all the yield mapping was done with the sensors on the main duct. The sensors were cleaned daily with a foam-type glass cleaner. After cleaning, the sensors were wiped down with anti-static material normally used in clothes dryers. During harvest, each basket load weight indicated on the Micro-Trak display was recorded manually. Actual basket weights were determined with the weighing boll buggy. After each dump, the load buffer was zeroed.

The TAES system was evaluated in a similar manner. The emphasis for that evaluation was on the accuracy of yield estimates, user-friendliness and system robustness, as the sensor position was previously determined and no calibration of the system was necessary. 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 Micro-Trak 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 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.

Because manual sampling is a destructive process, it is not possible to make direct comparisons of yield estimates. Instead, comparisons were made between the sampled areas and adjacent mapped areas. The sampling procedures varied, depending on the work crew available. The intended sampling procedure was to manually strip or pick the cotton in 0.001 acre of the two rows adjacent to both sides of a machine pass. This procedure provided four estimates of the yield at a point. These estimates could then be analyzed individually or combined for larger area estimates. In several instances, labor limitations forced modifications of this sampling procedure. In some cases, four sample of 0.0005 acre were taken. In other cases, two samples of 0.001 acre were taken.

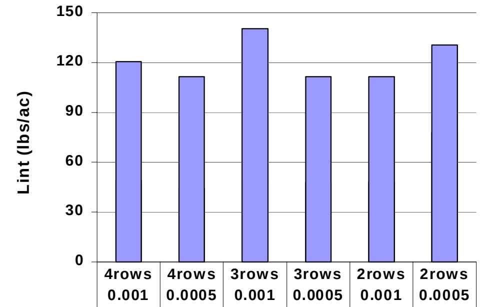
The manual samples at a point are yield estimates, just as are yield map values. A statistical analysis of the multiple manual samples was used to determine the inherent variability in those estimates. At each sample point, regardless of the number or area of the samples, a 95 percent confidence interval for the mean was calculated. The average confidence interval for the mean was calculated for all the points in each sampling method. A comparison of these average confidence intervals provided a basis for evaluating the accuracy of the mapped yield estimates. Mapped and sampled yield estimates that differed by less than the average confidence interval were considered to be in agreement for predicting yield.

Results

Hand Sample Yield Estimates

The hand yield sample estimates showed considerable variability at each sample site. Figure 2 shows the mean 95% confidence interval for all sample yield estimates taken with a given sampling method. The confidence interval means for three sample estimates were calculated by selecting the first three estimates as a subset of a four sample site. The exceptions were a few sites where labels were lost, and one of the bags could not be attributed to a specific site.

The resulting mean confidence intervals did not vary greatly with the sampling method. This was a surprise, as more and larger samples were expected to give a small confidence interval. It was generally true that the range of individual confidence intervals was smaller with more samples, but these values were highly variable. As a result of comparing the confidence intervals for the estimated lint yield, a value of 110 lbs/ac was selected as the value against which to compare the manual and mapped yield estimates. Any mapped estimates that were within 110 lbs lint/ac were considered equivalent.



	4rows 0.001	4rows 0.0005	3rows 0.001	3rows 0.0005	2rows 0.001	2rows 0.0005
Number	49	44	49	48	48	78
Mean 95 % Conf. Int.	121	112	140	112	112	131

Sampling Method

Figure 2. 95 percent confidence intervals for the mean yield as determined for the various sampling techniques used.

Micro-Trak Results

As the Micro-Trak system could not be operated using the sensors located at the outlet of the field cleaner, the only viable sensor location was the main air duct. This location was used for all testing. In order to determine the stability of calibration for the Micro-Trak using the main duct sensor location, indicated and actual basket weights were recorded for nearly 120 loads. Since the initial loads tested showed varying calibration factor, a single value that seemed reasonable was selected and used for the entire season. Availability of both the indicated and actual weights allowed the calculation of the calibration factor for each load. Figure 3 shows the value used for the season, the calibration factor for each individual load and the mean value for all loads. Figure 4 contains a plot of the indicated and actual basket weights. The season long mean value was 63.9 and had a standard deviation of 18.4. The mean value did not vary significantly if the extreme outlying basket values were omitted. The calibration factor of 63.9 was used to recalculate the yield estimates for all data files. These recalculated yield maps were used for comparison of map estimate accuracy.

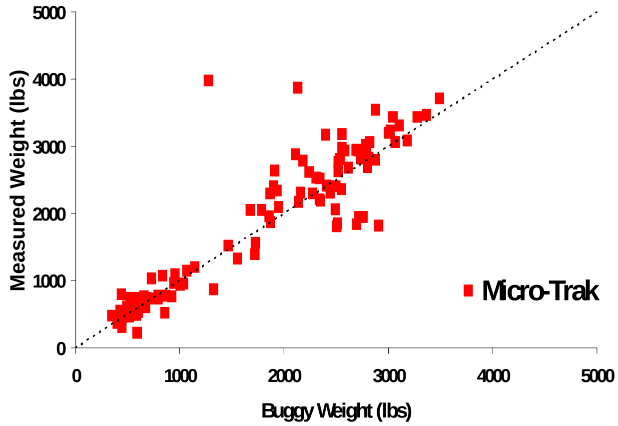


Figure 3. Actual versus measured basket dump weights.

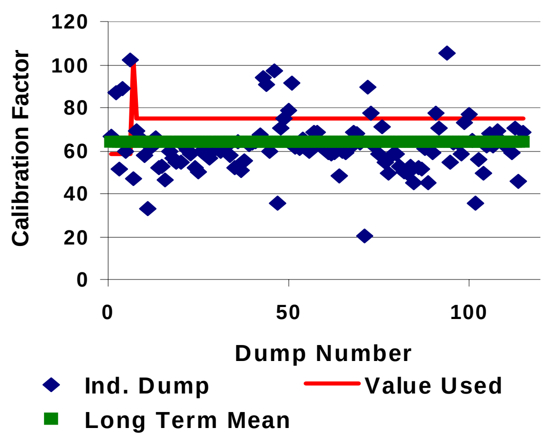


Figure 4. Micro-Trak Calibration factors calculated for each basket dumped.

The Micro-Trak cotton yield mapping system records the mass of seed cotton harvested. It should be remembered that at the sensor location before the field cleaner, the harvested mass includes burrs, sticks and other trash. The manual yield estimates were hand stripped, and 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 5 shows the comparison of the manual and mapped yield estimates 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 40 meters from the sample point. The correlation between the estimates generally increased as the radius, and the number of points included in the mean, increased. For the comparison shown here, a radius of 30 m was used. A radius of that size generally included 70 or more data points. The correlation coefficient between the manual and 30 m estimates was 0.71. If the radius were reduced to 10 m, the number of points included was reduced to 12-18, and the correlation coefficient to 0.48. For the 30 m estimates, 16 of the 29 points were within the confidence interval.

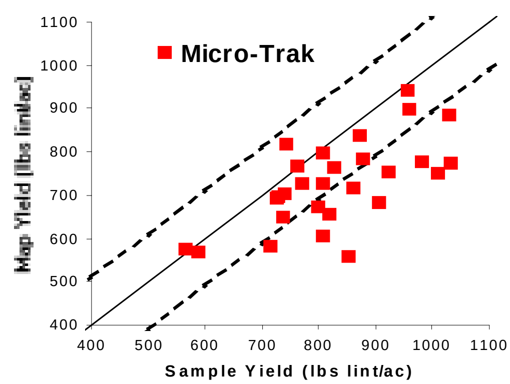


Figure 5. Comparison of sample and map yield estimates. Points falling between the dotted lines are considered to be equivalent.

Another aspect of the evaluation of the Micro-Trak system was the ease of use and maintenance. A single operator used the system for the entire season, and found the system to be easy to use. The documentation and technical support provided information and assistance as necessary. The cotton yield mapping system used the same console and utility software as Grain-Trak, the grain yield mapping system. As a result, some of the terminology was not appropriate for cotton. While this situation was workable, it did cause some confusion. Daily cleaning of the sensors on the air duct was adequate to keep the system operating properly.

<u>TAES Yield Mapping System Results</u>

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. The two operators found the system to be generally reliable and easy to use. However, the performance of the system was different on the two strippers. The system operated by the TAES personnel did not perform as well as the ARS system in measuring the mass of cotton harvested. Reasons for this are uncertain. Differences may be partially due to operating practices, and partially to differences in the machines. It was observed that starting data logging before the stripper units and the fan were fully up to speed resulted in incorrect weigh data. Software modifications are needed to accommodate a wider range of operating practices.

The yield maps created were considered to be accurate representations of the variability observed in the fields. However, the comparison of hand to mapped yield estimates resulted in a large number of locations that did not agree. Figure 6 shows the comparisons for both the 7445 and the 7455 strippers. Although the 7455 was more accurate in predicting the total dumped cotton weights, it was not superior in estimating the point yields. The data shown is for a 20 m region around the sample points. The yield accuracy was compared for a range of distances from 5 to 40 m (Table I). The radius used for determining the mapped yield estimate did not affect the accuracy of those estimates. In general, slightly less than half of the estimates could be considered equivalent to the hand samples. It is interesting to note that for both strippers, the erroneous estimates were primarily below the 1:1 line. Reasons for this bias are unknown. One potential source of error was the use of a field average lint percentage to adjust the measured seed cotton weights to lint weights.

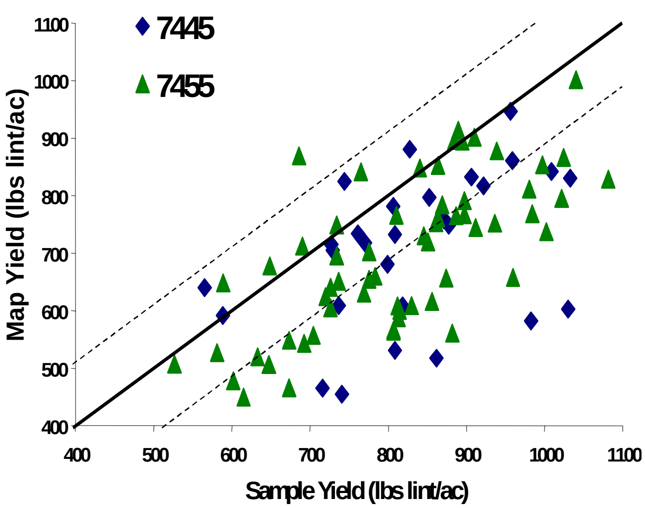


Figure 6. Comparisons of mapped and sampled yield estimates. Mapped estimates were determined from a 20 m radius area around the sample points.

Table 1. Number of map yield estimates equivalent to sample yield estimates.

Radius (m)	7445 Equivalent/Total	7455 Equivalent/Total
5	10/29	13/31
7.5		8/31
10	15/29	14/31
12.5	15/29	12/31
15	15/29	
20	16/29	12/31
30	11/29	12/31
40	12/29	14/31

Conclusions

Neither the Micro-Trak or the TAES cotton yield mapping systems showed the level of accuracy desired for site-specific management. Although both systems showed general trends of yield variability across the fields, the resulting patterns were not identical. For the Micro-Trak system to operate with the sensors located on the output of the field cleaner, design changes will be needed to prevent the sensor from being clogged with lint and trash. The calibration factor for the sensors located on the main air duct was highly variable, and several loads needed to be averaged to obtain a stable value. The differences in performance of the TAES system on the two strippers indicated the need for improvements to reduce the effects of operator practices on yield accuracy.

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