EVALUATION OF COTTON YIELD MAPPING

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Abstract

An evaluation was conducted of the Zycom AGRIplan 600 cotton yield mapping system. The system was installed on producer's cotton pickers and used by the picker operators. The yield map data was compared to hand sampled yield estimates. The hand samples were gathered as two samples of 0.001 acre in order to provide a comparison of the variability of the sample estimates as well as the yield map data. The Zycom yield mapping system did show general trends in yield across the fields, but there was considerable scatter in the data. Comparing the average of yield points within an area of 10 m radius improved the yield estimates. The 95 percent confidence interval for the area averages ranged from 35-50 percent of the yield.

Introduction

Yield mapping is expected to play an important role in the precision management of cotton. In 1997, commercial cotton yield mapping systems for cotton pickers were offered for the first time. Zycom, Inc. agreed to cooperate with the Texas Agricultural Experiment Station to evaluate the AGRIplan 600 system. The objective of this study was to evaluate the accuracy of the Zycom system in measuring the yield at specific points within the fields. The intended use of yield maps is to document the yield in all parts of the field, not just to estimate the total mass harvested. For this reason, no attempt was made to compare the Zycom system's measurement of accumulated mass.

System Description

The Zycom AGRIplan 600 cotton yield mapping system consisted of an integral GPS receiver, operator display and data entry boxes, and two optical sensors for mounting on the air ducts of the picker. The GPS differential correction signal was supplied by mounting an OmniStar 7000 DGPS receiver on the cab, and using the available RTCM 104 output. The optical sensors use a through beam arrangement, so that cotton that passing through the duct will break the light beams. The cotton yield is estimated from the changes in light beam signals. Since the Deere 9965 pickers pass all cotton harvested by a row unit through a single duct, each sensor measured the entire amount of cotton harvested on that row. With the two sensors, one half of the cotton harvested was sensed.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 1:636-639 (1998)
National Cotton Council, Memphis TN

A yield mapping system was installed on a John Deere 9965 cotton picker at the King Ranch, Kingsville, Texas with the assistance of Zycom factory personnel. This picker was used for recording yield data during harvest in Texas during August and again in Arizona in November. A second unit was made available for installation on a cooperating producer's John Deere 9965 cotton picker near Temple, TX. Due to a shortage of sensors at that time, the system at Temple was installed with only one row sensor. A Zycom representative indicated that this would result in a decrease in accuracy of approximately 1.5 percent, compared to a two row system. Both systems recorded yield and position data at a two second rate.

Calibrations were attempted after both yield mapping systems were installed.At the King Ranch picker, a weighting boll buggy was used to correct the calibration coefficients. However, at the time of the calibration, problems were experienced with the system. The factory representative had to replace system components, and by the time the system was working properly, the weighing boll buggy was no longer available. In the judgement of the Zycom factory representative, the calibration factor entered was reasonable. No attempt was made to recalibrate the system when it was used in Arizona. The Temple system was calibrated by pulling a cotton trailer to a truck scale. Subsequent testing showed that the yield mapping system was measuring total mass harvested with approximately 3 percent accuracy. During harvest, the machine operators were instructed to clean the sensors daily in order to maintain system accuracy.

Evaluation Procedures

The evaluation of the Zycom system was focused on the accuracy of yield estimates at points within the field, rather than accumulated mass measurements. This approach required that a manual yield estimates at the same points be obtained for comparison. For the manual samples to be most accurate, large areas should be harvested. Unfortunately, obtaining those additional yield estimates requires destructive sampling and affects the resulting yield maps.

The sampling procedure used for most of this study was to harvest 0.002 acre areas at selected locations within several fields. The sample locations were determined by walking into the fields and selecting areas which visually appeared to be uniform over the local region. Each sample position was geo-referenced using a DGPS receiver. The 0.002 acre sample area was selected to approximate the area covered by the picker for each data point. The sample was taken as two 0.001 acre samples in different rows, and later averaged. Taking two samples enabled a comparison of the variability between those samples, and provided a statistical basis for evaluating the Zycom system. In Kingsville, 12 manual samples of 0.002 acre were taken as single samples. In all other fields, the manual estimates were taken as two samples. The individual 0.001 acre samples were used only to evaluate the variable of the manual samples. For all comparison to Zycom generated data, yield for the 0.002 acre area was used.

Results

The manual yield data clearly illustrates the problems associated with sampling to estimate yield. Although the samples were taken in areas that appeared to be relatively uniform and no more than four rows apart, there were significant differences between the yield estimates. At some sites, the differences were 50 percent or greater. Figure 1 shows the scatter of the paired sample yield estimates. Since these samples were to be used as yield estimates, excessive deviation between the samples caused both of the estimates to be in question. For this reason, any sample pairs that differed by more than 25 percent from their mean were eliminated. Table 1 shows the correlation coefficients between the remaining sample pairs for four fields where split sampling was done. The correlation for all sites is better than the individual sites because of the extended range of yield. Any single field had a smaller range of yield estimates.

For comparison with the yield map data, both sample estimates were averaged. This gave a sample yield estimate for a 0.002 acre area. Since the yield mapping system recorded data on a two second interval, the area harvested was variable depending on the forward travel speed and the row spacings. For the operating conditions in the test fields, each yield data point would represent between 0.0013 and 0.0025 acres. Based on these data, it would be unreasonable to expect a correlation of 0.7 or better between the manual samples and the mapped yield estimates.

Table 1. Correlation between paired yield samples.

Field Name	Corr. Coef.	No. of Sample Points
Coufal	0.68	9
King Ranch 640B	0.54	14
King Ranch 506B	0.84	15
Lamesa	0.72	26
All Sites	0.88	64

Figure 2 is an example of raw yield data from the Zycom system. Each data point represents the yield integrated over the distance traveled in two seconds. Figure 2 represents a worst case situation, as the yield was rather low. The high degree of change in the yield estimate from point to point is unrealistic, and indicates the probability of error associated with each estimate. The curve is a moving average of five consecutive points (10 sec period). This smoothing removes some of the variability, and appears to give a more realistic estimate of yield. For all of the following comparisons, averaging will be used to determine the yield estimates at a point.

For point comparisons of the mapped yield, four different values were generated. These included the single map value closest to the manually sampled area and the average of mapped yield estimates for three different radii (5, 7.5 and 10 meters). Table 2 gives the correlation coefficients for each comparison and each field. The values for the individual fields are relatively low. The comparisons are worse for the King Ranch and Coufal fields where yields were low (90-1500 seed cotton lbs/ac). The correlation coefficient for all sites is much higher because of the greatly expanded range of yields. These coefficients indicate a better agreement with manual yield estimates for higher yielding fields. The comparison between the mapped value and the combined sample estimate is lower than that of the two 0.001 acre manual yield estimates.

Table 2. Correlation between manual yield estimates and Zycom data.

Field	Sample Point	5 m Radius	7.5 m Radius	10 m Radius
King Ranch	0.36	0.36	0.24	0.09
Coufal	0.24	0.47	0.06	-0.02
KR 640	0.46	0.48	0.42	0.42
All Sites	0.84	0.90	0.90	0.90

Figure 3 shows yield estimates for a set of three passes of the cotton picker in a field near Temple, TX. The sampled yield estimates are shown as individual points. Overall yield in this field was relatively low, approximately 3/4-1 bale per acre. The adjacent passes indicate that the yield was varying significantly over very short distances. There is considerable variation in the yield magnitude between the individual passes. Figure 4 shows a similar situation for a field in Arizona. This was a much higher yielding field (3-4 bales). In this situation, the yield mapping system was more consistent in estimating yields on adjacent passes of the picker.

Regression equations were calculated for the sample yield estimates compared to the nearest map yield estimate and the 5, 7.5 and 10 m map averages. Averaging proved to have better agreement than the single point estimates, but there was no improvement with change in radius. Therefore only the 10 m average will be discussed. Figure 5 illustrates the individual data points, the linear regression line and 95 percent confidence lines. The 95 percent confidence lines represent the confidence intervals on the intercept and slope terms of the linear regression. Figure 6 shows the deviation between the regression and 95 percent confidence interval, expressed as a percentage of the yield. The greatest deviations in yield estimates came for the lowest yields, regardless of the type of comparison. With the exception of the very lowest yield, the single point vs. sample yield estimates were slightly worse than the manual sample comparisons. The averaged map yield comparisons were considerably less variable. This indicates that averaging over a 10 m region would improve the accuracy of the yield maps. Regardless of the comparison or the level of yield, the uncertainty is still greater than producers would desire. This points out the limitations of verifying yield map accuracy. It is desirable to validate the accuracy of a yield mapping system over small areas, but the verifying yield estimates require destructive sampling, making a direct comparison difficult.

Operational Evaluation

In addition to accuracy of yield estimates, the Zycom system was evaluated for ease of use. The system as configured for these tests used a display box that was mounted o the steering column. This is an advantage over grain yield mapping system where the monitor is located out of the operator's normal line of sight. A set of toggle switches allowed the operator to enter setup data. The system was easy to operate after setup, as the only requirement was to turn on the system and wait for the GPS differential correction signal to be established. The system did not require (or allow) the entry of field identifiers. This made the field operation simple, but represented a problem when generating the yield maps. The data files were labeled by the date and time. In order to later assign the data to a particular field, the computer operator had to know when the machine was operating in each field. When this information was unavailable, matching data with field names could only be done by comparison to field boundaries in the GIS software.

Several operational problems were experienced during the testing. Initial installation at the King Ranch took several days work by the factory representative to get the system operational. During testing, it was discovered that the software for downloading data would not work on all computers. As a result, data was lost. At Temple, TX, the picker operator complained that the system had frequent interruptions that were only solved by powering the system off and back on. Although Zycom did make modifications to their system during the 1997 harvest season, these were not implemented on the systems evaluated in this study. Many of the operational problems experienced, while frustrating at the time, were not caused by insurmountable flaws in the system. Future improvements should minimize these difficulties.

Summary

A Zycom AGRIplan 600 cotton yield mapping system was evaluated for accuracy of yield measurements at specific points within a cotton field. Multiple estimates of seed cotton yield were made in five different cotton fields. These included two manual samples of 0.001 acres each, a summed manual sample of 0.002 acres, individual point yield estimates from yield maps and regional averages of 5, 7.5 and 10 m radius from the yield maps. For all paired comparisons of the yield estimates, the correlations were 0.8 or better when all sites were considered. When examining the correlation for the narrower yield ranges experienced in any one field, the correlation coefficients were reduced to 0.5 or less. The Zycom AGRIplan 600 cotton yield mapping system exhibited high variability, both for adjacent points along a pass through the field and between adjacent passes. This variability was more pronounced in low yielding fields. The variability measured between paired samples taken manually indicated that Zycom's strategy of sensing the yield on only a portion of the row units is questionable. The design of the operator interface and the system reliability in 1997 did not meet the standard of the grain yield mapping systems on the market. However, the system tested was relatively early in the development cycle, and improvements are expected. Further improvement is needed in order to achieve wide spread adoption by cotton producers.

Acknowledgements

The authors would like to acknowledge the support and cooperation of the Texas Agricultural Experiment Station, the King Ranch, Coufal Farms, and Zycom, Inc.

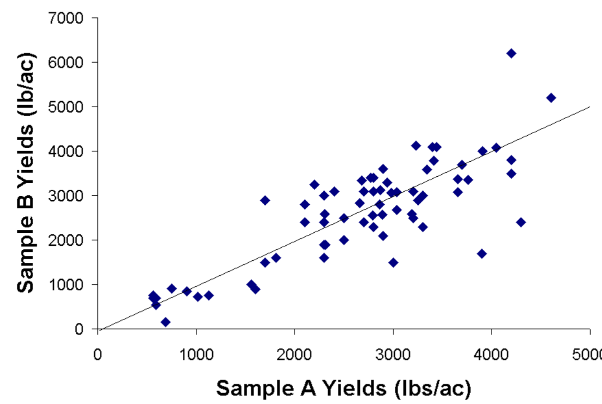

Figure 1. Paired estimates of seed cotton yield from manual samples of 0.001 acre. The line would indicate a perfect correlation between the samples.

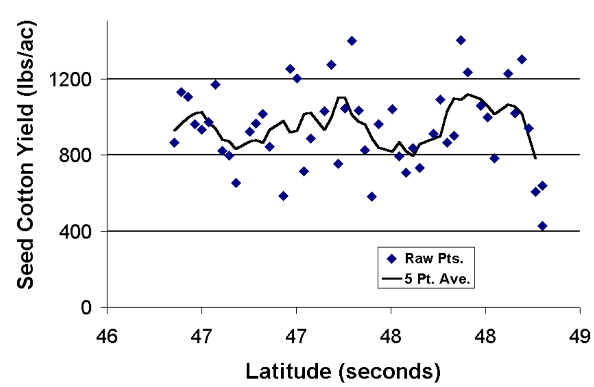

Figure 2. Raw yield estimates (points) and a five point moving average (curve) for a selected harvest pass in a field near Temple, TX.

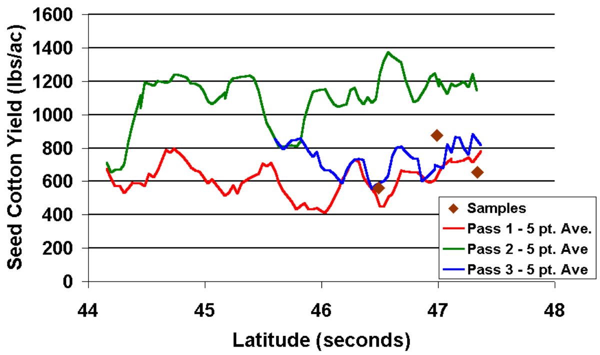

Figure 3. Adjacent passes of yield data from a field with a 3/4 - 1 bale per acre yield. Manual sample yield estimates are shown as individual diamonds.

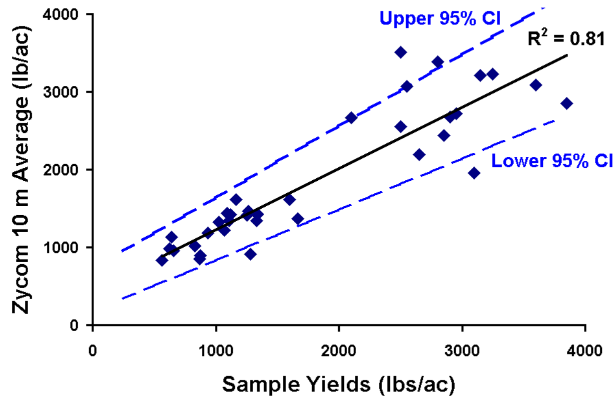

Figure 5. Paired comparisons between the sampled yield estimates and a 10 m radius average of the mapped yield data. The solid line indicate the best fit linear regression. The dotted lines show the 95 percent confidence interval values for the slope and intercept terms.

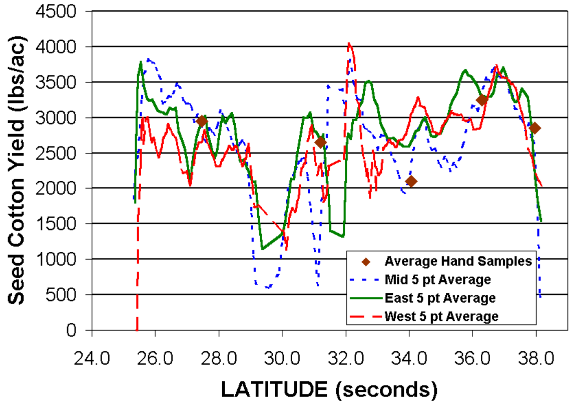

Figure 4. Adjacent passes of yield data from a field with a 3-4 bale per acre yield. Manual sample yield estimates are shown as individual diamonds.

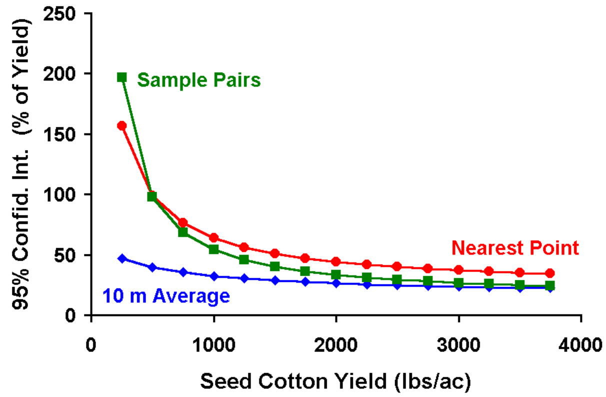

Figure 6. Ninty five percent confidence intervals for paired sample estimates, sample vs. single nearest map yield estimate and sample vs. 10 m averaged map yield estimate as a function of yield.