Site-Specific Yield Monitoring of Sugarbeets

Thomas Hall, Vern Hofman, Les Backer[1], Larry Smith[2]
[1]Agricultural and Biosystems Engineering, Box 5626, North Dakota State Univ., Fargo, ND 58105
[2]NW Experiment Station, 108 Ag. Research Center, Univ. of Minnesota, Crookston, MN 56716

ABSTRACT

Site-specific yield monitoring, a technology which allows a crop producer to identify areas of yield variation within a field, has become relatively well developed for small grain applications. However, due to limited research efforts and non-readily available equipment, development of this technology has lagged for bulk crops such as sugarbeets. HarvestMaster, Inc. commercially markets a yield monitor for bulk crops, but it is still undergoing development. The HarvestMaster HM-500 Yield Monitor was evaluated for accuracy and precision using three different chain support systems (a double tandem idler, a single idler, and a slide bar) on two different beet harvesters. Additionally, yield maps were developed for the 400 acres monitored.

The load percent error was determined by comparing the amount of sugarbeets loaded on each truck as recorded by the yield monitor to the actual amount of sugarbeets on each truck as given by the scale tickets from the piling station. This data was then plotted against the truck load number, and the mean and standard deviation were calculated. The standard deviation was used primarily for the evaluation since it is a measure of consistency and precision.

All three chain support systems were used on a 4-Row WIC harvester covering about 250 acres. The double tandem idler and the slide bar gave similar results with the standard deviation equal to 11.31% and 13.93%, respectively. The single idler gave significantly better results with the standard deviation equal to 3.80%.

The single idler system was also used on a 6-Row Arts-Way harvester, however a 6-in. diameter idler was used instead of a 5-in. diameter idler to compensate for a larger pitch conveyor chain. This system had a standard deviation of only 2.23%, however a statistical analysis showed it was not significantly better than the single idler on the 4-row WIC harvester.

OBJECTIVES

The objectives of this project were:

1. To evaluate the accuracy and precision of the HarvestMaster HM-500 yield monitor using different chain support systems on several harvester designs
2. To make changes to the yield monitor during the harvest season to improve its operation
3. To produce yield maps from the data gathered by the yield monitor
4. To validate the yield maps by comparing them to satellite images and aerial photographs.

BACKGROUND

Site-specific or precision farming technology is a tool used by farmers to manage and reduce yield variability within a field. Yield variability within a field can be caused by factors such as soil nutrient deficiency, poor water drainage, soil types, plant populations, weed, insect, or disease infestations, etc.

Yield monitors, such as the HarvestMaster HM-500, are used to identify and quantify the yield variability within a field. They can help identify crop responses to different applied or existing factors such as fertilization and/or chemical rates, water drainage, plant populations, etc.

Variable fertilizer and chemical application rates can be used to increase production of the low yield areas.

Yield monitors for small grain combines have been readily available and are becoming popular. However, yield monitors for bulk crops such as sugarbeets are still in the early stages of development. The high value of sugarbeets and their sensitivity to management practices make them an ideal candidate for site-specific technology.

EQUIPMENT

The HarvestMaster HM-500 yield monitor system consists of four basic components--the Signal Conditioner and Conversion Unit (SCCU), the Pro-2000 Hand-held Computer, two speed sensors, and two load cells. This system was used in conjunction with a differentially corrected Global Positioning System (DGPS) for position data.

Signal Conditioner and Conversion Unit (SCCU)

The SCCU is basically the heart and soul of the yield monitor. Figure 1 shows how it was connected to all the components of the yield monitor. Its function is to collect and process signals from each system component and send them to the Pro-2000 computer located in the tractor. Unwanted noise from the load cells was eliminated using high frequency filters.

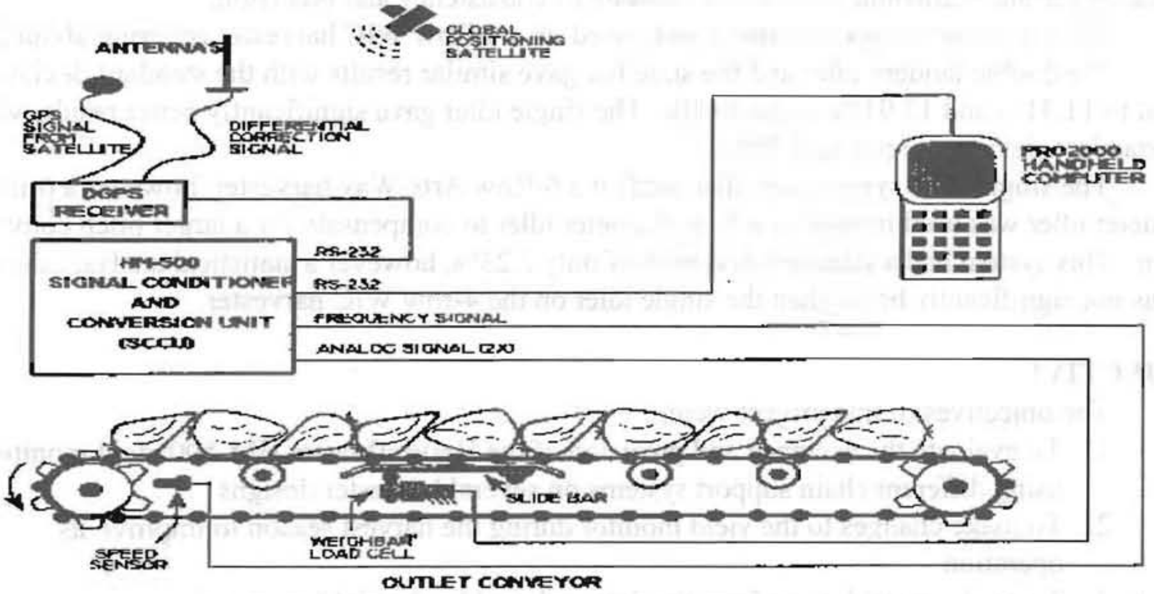

Figure 1: HarvestMaster HM-500

Pro-2000 Hand-held Computer

The Pro-2000 is a 286 DOS-based computer mounted in the tractor. It calculates the yield and ground speed values and stores the date, time, position, yield, ground speed, and weight data. Approximately 2 to 3 days of information can be stored on the Pro-2000's two megabytes of internal memory before downloading is required. The software used on the Pro-2000 allows calibration factors and other variables for the weight, speed, harvester width, lag time, and recording time interval to be set by the operator.

Speed Sensors

Speed sensors were used to determine the outlet conveyor and ground speeds. Magnets were mounted on a rotating surface, such as the conveyor shaft or the ground wheel rim. By sensing the presence of a magnetic field, the sensor's output was the rotational frequency of the shaft or wheel. Using the radius of the sprocket and the radius of the wheel, the conveyor and ground speeds were calculated.

Load Cells

Two 500 pound load cells were mounted under the outlet conveyor to determine the weight of the sugarbeets as they were loaded into a truck. With a chain support system attached, the load cells were mounted directly across from each other under the conveyor. Mounting them close to the outlet allowed for as much dirt to be removed from the sugarbeets as possible.

Concord BR6-183 DGPS Receiver

The DGPS used in this project was a Concord BR6-183 DGPS receiver which gave latitude and longitude coordinates accurate to approximately 10 feet. An FM signal from DCI provided the differential correction.

EXPERIMENTAL METHODS AND PROCEDURE

Chain Support Systems

Three different chain support systems on two different harvesters were mounted on the load cells for the 1996 harvest season. The first system used was a double idler system mounted on the load cell in a tandem configuration (Figure 2) and was used on a 4-Row WIC harvester. The idlers were spaced so that one idler was directly below a chain link when the other idler was between links. This arrangement was to help filter spikes in the data caused by a chain link contacting an idler. The idler bracket was not allowed to rotate with respect to the load cell, since it gave better results than a walking assembly in preliminary laboratory testing.

Figure 2: Double Idler Chain Support System

The second chain support system used was a single idler (Figure 3) mounted on the load cell. A 5-in. diameter idler was used on the 4-row WIC harvester and a 6-in. diameter idler was used on the 6-row Arts-Way harvester. Six inch idlers were used on the Arts-Way harvester to compensate for the larger pitch conveyor chain.

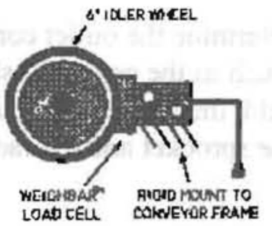

Figure 3: Single Idler Chain Support System

The third chain support system used was a slide bar assembly (Figure 4), which was used only on the 4-row WIC harvester. One end of the slide bar was fixed to a pivot assembly while the other end exerted a vertical force on the load cell. The slide bar was covered with 3/8" thick ultra high molecular weight (UHMW) plastic to reduce wear.

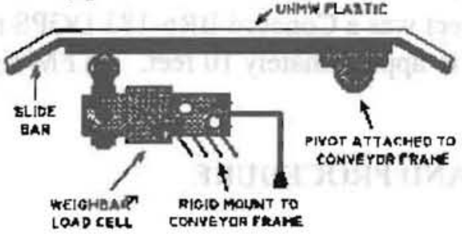

Figure 4: Slide Bar Chain Support System

Evaluation

The effect of each chain support system on the accuracy and consistency of the yield monitor was determined by comparing the measured weight to the actual weight of sugarbeets in a truckload. The yield monitor kept track of the amount of sugarbeets accumulated in each truckload as measured by the load cells. The actual weight of the sugarbeets in that truckload was determined using piling station scale tickets. However, the weight of the tare dirt had to be considered, since it was also being measured by the yield monitor. Therefore, the empty truck weight, without the tare dirt, was used. Since a scale was not readily available to weigh each truck without the tare dirt after each load, an empty weight was obtained at the beginning of each day and 20 pounds of fuel was assumed to be used every load. For simplicity, all the data from the Arts-Way harvester is based on an assumed 1.5% tare dirt per truckload.

The load percent error was calculated according to the following equation:

$$\%error = \left[\frac{actual\_weight - measured\_weight}{actual\_weight}\right] x100\%$$

The load percent error was graphed vs. the truckload number, and the mean, standard deviation, maximum, and minimum values were determined. The standard deviation was used as an indicator of yield monitor consistency. A lower standard deviation indicates more consistency and higher precision.

Statistical Analysis

The goal of the statistical analysis was to identify differences between the standard deviations of the data from each chain support system. To accomplish this, the data for each system was divided into groups of ten truckloads. The standard deviation for each group was then calculated, providing replicated values for the standard deviation of each chain support system. An ANOVA was then performed to compare the means of the standard deviations. The process was then repeated with the data set divided into groups of five and fifteen truckloads.

Yield Maps

Since high load percent errors were encountered in certain fields, the yield data had to be corrected. The assumption that the error was constant for each truckload was made, meaning that the error for any particular truckload was not due to spikes in the weight readings. A correction factor was calculated by subtracting the measured weight from the actual weight of each truckload and dividing the difference by the number of acres harvested while loading that truck. The correction factor was added to each yield value recorded by the monitor for that truckload. This process was then repeated for each truckload.

Erroneous yield values were also deleted from the data file. Any values over 50 tons/acre and any values recorded when the ground speed was zero were deleted. The corrected yield data were then imported into the Surfer computer software package to create yield maps.

RESULTS

Double Tandem Idler Chain Support System (WIC Harvester)

A total of 108 truckloads were measured over four days using the double idler system on the 4-Row WIC harvester. Figure 5 is a graph of the percent error vs. the truckload number. Note that the calibration factor is the solid line toward the top of the graph.

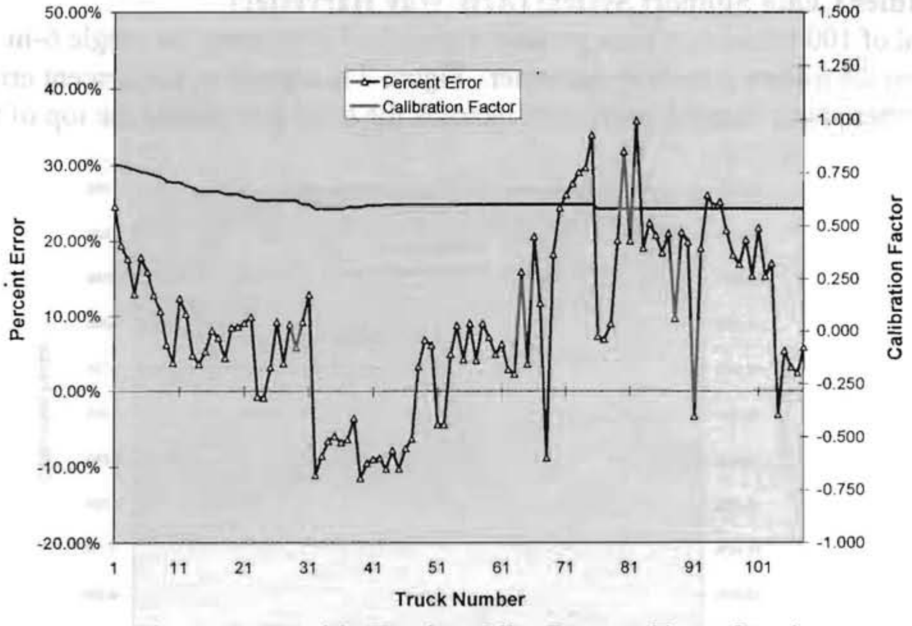

Figure 5: Double Tandem Idler Percent Error Graph

The mean of the percent error was 9.21% with a standard deviation of 11.31%. The range of the percent error was from 35.86% to -11.46%.

Single 5-in. Idler Chain Support System (WIC Harvester)

A total of 43 truckloads were measured over two days using the single 5-in. idler system on the 4-Row WIC harvester. Figure 6 is a graph of the percent error vs. the truckload number. Note that the calibration factor is the solid line toward the top of the graph, which was held constant in this case.

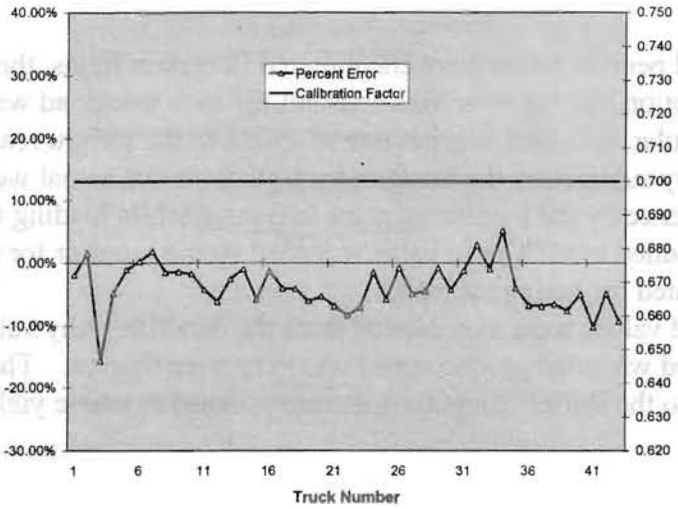

Figure 6: Single 5-in. Diameter Idler Percent Error Graph

The mean of the percent error was -3.85% with a standard deviation of 3.80%. The range of the percent error was from 5.26% to -15.58%.

Single 6-in. Idler Chain Support System (Arts-Way Harvester)

A total of 100 truckloads were measured over four days using the single 6-in. diameter idler system on the 6-Row Arts-Way harvester. Figure 7 is a graph of the percent error vs. the truckload number. Note that the calibration factor is the solid line toward the top of the graph.

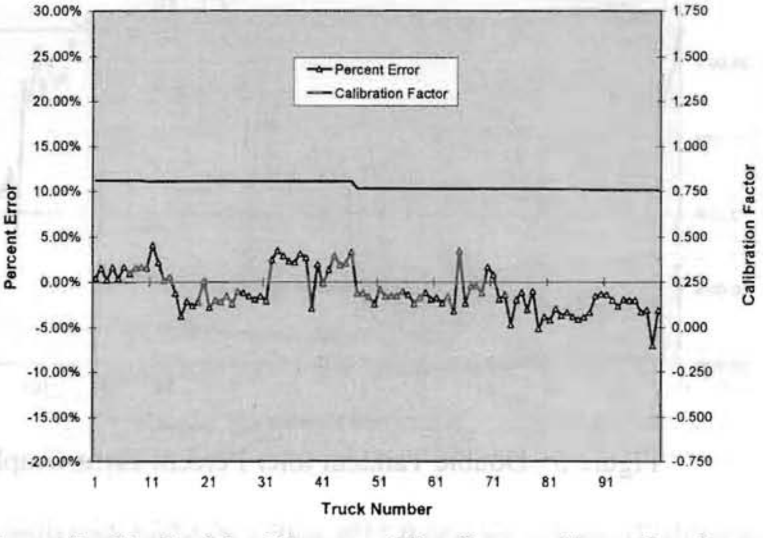

Figure 7: Single 6-in. Diameter Idler Percent Error Graph

The mean of the percent error was -0.97% with a standard deviation of 2.23%. The range of the percent error was from 4.07% to -6.99%.

Slide Bar Chain Support System (WIC Harvester)

A total of 121 truckloads were measured over four days using the slide bar system on the 4-Row WIC harvester. Figure 8 is a graph of the percent error vs. the truckload number. Note that the calibration factor is the solid line toward the top of the graph.

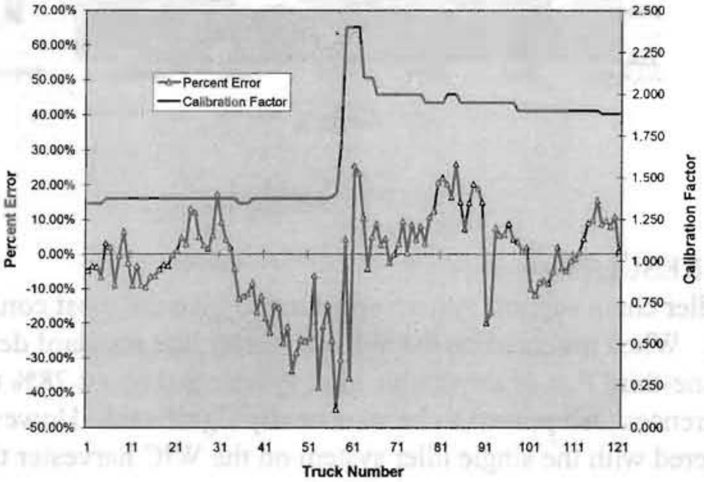

Figure 8: Slide Bar Percent Error Graph

The mean of the percent error was -1.50% with a standard deviation of 13.93%. The range of the percent error was from 26.01% to –44.77%.

Statistical Analysis

The statistical analysis showed that the single idler chain support system on the WIC harvester was significantly more consistent and precise than either the double idler system or the slide bar system. Comparing the data from the single idler systems on the WIC and Arts-Way harvesters showed no significant differences.

Yield Maps

A total of eight yield maps were created, one for each field harvested. Figure 9 is a yield map of Field 15 at the UMC NW Experiment Station.

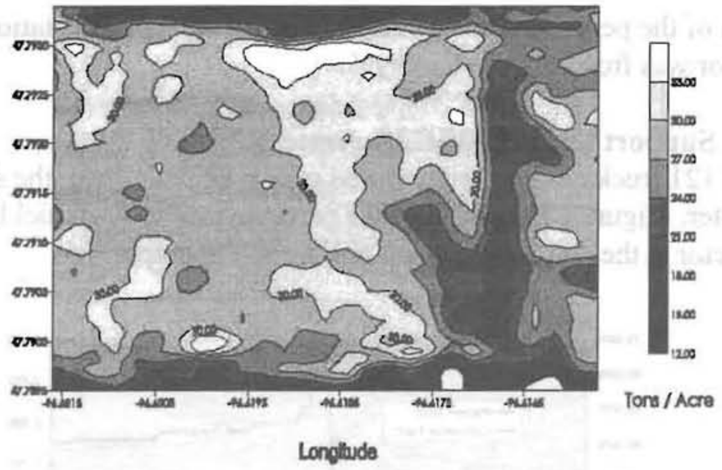

Figure 9: Yield Map

DISCUSSION OF RESULTS

The single idler chain support system appeared to give the most consistent results of the three systems tested. When mounted on the WIC harvester, the standard deviation of the load percent errors was one-third that of the double idler system and about 28% that of the slide bar system. These differences also proved to be statistically significant. However, about one-half as much data was gathered with the single idler system on the WIC harvester than with either of the other two systems.

The yield monitor mounted on the Arts-Way harvester had better accuracy and precision than when mounted on the WIC harvester. The single idler system mounted on the Arts-Way harvester gave a standard deviation of only 2.23%; but when mounted on the WIC harvester, the standard deviation was 3.80%. However, the statistical analysis showed that these differences were not significant.

The statistics showing no differences between the two harvesters tested may be deceiving. The statistics merely show that there were no significant differences between these two particular configurations. If the slide bar and double idler systems would have been tested on the Arts-Way harvester, it is probable that those systems would have performed as well as the single idler system.

The short, horizontal portion of the outlet conveyor on the WIC harvester is the most probable cause for the poor results from the double idler and slide bar systems. The sugarbeets were never able to stop bouncing before reaching the load cells—possibly causing errors in the data. Since the double idler and slide bar systems weighed the sugarbeets over a larger area, these errors may have then been multiplied.

The long, horizontal outlet conveyor on the Arts-Way harvester is the most probable reason for the better results. Since the load cells were mounted near the end of the conveyor, the sugarbeets had stopped bouncing by the time they were weighed. Therefore, the double idler and slide bar systems may have performed just as well as the single idler system on this harvester. The larger diameter idler wheels used on the Arts-Way harvester and a faster conveyor chain speed may also have contributed to the better results.

Figures 5 through 8 show that a direct relationship between the percent error and the calibration factor did not always exist. One would expect to see a strong relationship between them, but Figure 5 shows that the truckload percent error increased while the calibration factor remained basically constant. Figure 8 shows that the truckload percent error decreased while the calibration factor remained basically constant. This data shows a tendency of the yield monitor to lose calibration, which is a very undesirable result. However, these trends are not as apparent for either of the single idler systems as shown in Figures 6 and 7.

The yield maps appear to be reasonable, since there are strong similarities between them and the satellite images and aerial photographs. Areas of low yield were shown as areas of low plant vigor on the satellite images and as areas of less dense crop canopy on the aerial photographs. However, since a relationship between satellite images or aerial photographs and yield maps has not been quantified, this method of verifying the yield maps is only subjective.

CONCLUSION

The HarvestMaster HM-500 Yield Monitor was evaluated for its accuracy and precision using three different chain support systems (a double tandem idler assembly, a single idler, and a slide bar assembly) on two different sugarbeet harvesters. The load percent error was determined by comparing the amount of sugarbeets loaded on each truck as recorded by the yield monitor to the actual amount of sugarbeets on each truck as given by the scale tickets from the piling station. This data was then plotted against the truckload number, and the mean and standard deviation were calculated. The standard deviation was used primarily for the evaluation since it is a measure of consistency and precision.

All three chain support systems were used on a 4-Row WIC harvester covering about 250 acres. The double tandem idler and the slide bar gave similar results with standard deviations equal to 11.31% and 13.93%, respectively. The single idler gave significantly better results with the standard deviation equal to 3.80%.

The single idler system was also used on a 6-Row Arts-Way harvester. However a 6-in. diameter idler was used instead of a 5-in. diameter idler to compensate for a larger pitch conveyor chain. This system had a standard deviation of only 2.23% which did not prove to be significantly different than the single idler system on the WIC harvester.

The design of the harvester may to be a factor in the accuracy and precision of the yield monitor. The single idler system mounted on the WIC harvester had a percent error standard deviation which was 1.5% higher than when mounted on the Arts-Way harvester. The load cells mounted on a long, horizontal outlet conveyor appeared to increase the accuracy and precision of the yield monitor.

Several areas of the sugarbeet yield monitoring system require further research.

1. The installation of the load cells should be modified and/or software should be updated to allow for the use of an onboard storage tank and to eliminate end effects.
2. The software used in the Pro-2000 Hand-held computer should be made more user friendly.
3. The weight sensing system should be modified so that accurate and precise data can be gathered regardless of the harvester design.

ACKNOWLEDGEMENTS

Special thanks to Larry Smith and Dale Kopecky of the UMC NW Experiment Station and Gus Johansen of G&G Farms, Inc. for providing the sugarbeet harvesters, assisting in the field installation and testing of the yield monitor, and enduring the inconveniences associated with the research. Funding for the project was provided by the North Dakota Power Use Council.