Site-Specific Management Guidelines

T.S. Colvin and S. Arslan

SSMG-9

Yield Monitor Accuracy

Summary

Field and laboratory experiments were done to investigate the performance of an impact-based yield sensor. Laboratory tests showed that the accuracy of the yield sensor was affected by sudden grain flow changes. The yield sensor had a quick response to flow variations; however, it did not provide consistent readings when grain flow variations were abrupt. In field tests, the yield monitor showed yield trends quite reasonably. The yield monitor accuracy was higher at a constant combine ground speed compared to varying speeds based on weights from individual strips. Yield monitor calibration plays a key role in obtaining the best possible accuracy from the yield monitor.

Introduction

In order to use yield maps in precision agriculture effectively, one needs to understand how grain flow (lb/s) is measured by a yield sensor and how this measured quantity is related to yield (bu/A) at a specific location. When addressing "yield monitor accuracy", we should be aware of the interactions between yield sensors and combines and how they relate to the accuracy of a yield map. This is important to avoid misinterpretations when yield maps are analyzed.

This guide presents some of the results of laboratory and field tests conducted to understand the behavior of an impact-based yield sensor under different operating conditions. In laboratory tests, the objective was to determine how calibration and grain flow variations affect sensor accuracy in flow measurements. In field tests, the goal was to determine whether a yield monitor could show known yield variations. The effect of changing combine ground speed on accuracy was also investigated.

After evaluating the results of these studies, you will have a better idea of how the measurement accuracy at the yield sensor that is installed somewhere on the clean grain path of the combine differs from the accuracy of the estimated yield that is based on a combine flow model.

Methodogy, Results, and Discussion

Effect of combine dynamics on yield map accuracy

When you use a differential global positioning system (DGPS) with your grain yield monitor, you probably think you are building a map of yields for specific locations. In reality, you are measuring the output of the combine harvester system, which is a smoothed version of the crop input to the combine. **Figure 1** illustrates this point and shows us the length of time for colored grain to flow through a combine at a 3-mph ground speed. In this experiment, corn kernels between 60 and 70 ft. from the edge of the field were painted blue. As you can see, it took 20 ft. before blue kernels were measured, 50 ft. to reach a peak, and 100 ft. to get the majority through the machine. Two important observations can be made about the yield signal shown in **Figure 1**. First, the yield is not measured as soon as the crop enters the combine, which results in a delay in the measured outcome. Second, the colored corn kernels do not move as a bulk through the combine, but are diffused, which makes the colored corn signal spread over time.

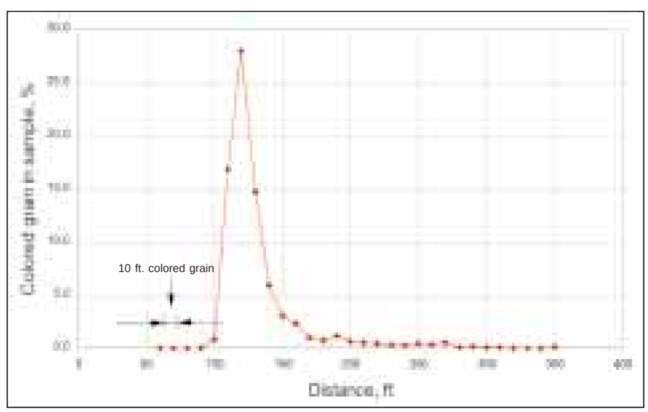

Figure 1. Colored grain flow through combine.

Why is the estimated yield only a simulation of the actual yield, when yield monitors can be 95 to 100 percent accurate? Let's begin with the header. As you picture the

The Site-Specific Management Guidelines series is published by the Potash & Phosphate Institute (PPI) · Coordinated by South Dakota State University (SDSU)
Sponsored by the United Soybean Board (USB) and the Foundation for Agronomic Research (FAR). For more information, call (605) 692-6280.www.ppi-far.org/ssmg

combine at work, it is easy to see that the grain in the middle of the header will reach the combine before the grain at the ends of the header. Then, looking inside, there are many paths for grain in the combine. At one extreme, the grain may drop out of the thresher at the beginning, miss the separation area, and be conveyed to the cleaning sieves, drop through immediately, and be conveyed directly to the grain tank. Other grain, however, may move the full length of the thresher, move the full length of the separation area, be conveyed to the cleaning sieve, and move across the entire length of the sieves before dropping down to be conveyed to the grain tank. This does not take into account the possibility that the grain is not completely threshed the first time and is sent back to the front of the combine via the return elevator. The multiple paths through the combine account for the differences between grain that entered the header at the same time.

Yield measurement accuracy

To explore the issue of yield monitor accuracy, we tried to compare the performance of yield monitors by combining parallel strips of crop with two combines. One combine was equipped with scales and the other with a yield monitor. We soon learned that spatial yield differences in adjacent strips can affect the reliability of the comparisons between yield monitors and scales. The only way to make a comparison was to measure the same stream of grain passing through both measuring devices so that spatial differences in yield did not get in the way.

We have looked at yield monitors on a laboratory test stand and in the field. In the lab, we used a test stand to remove problems associated with the combine systems and vibration. For field tests, a scale was mounted in the clean grain tank of the combine. The scale weighed the grain at 1-second intervals and provided a total weight for strips up to 400 ft. long.

With the test stand, we were able to show that the yield monitor responded as quickly as the scale to flow rate changes (**Figure 2**).

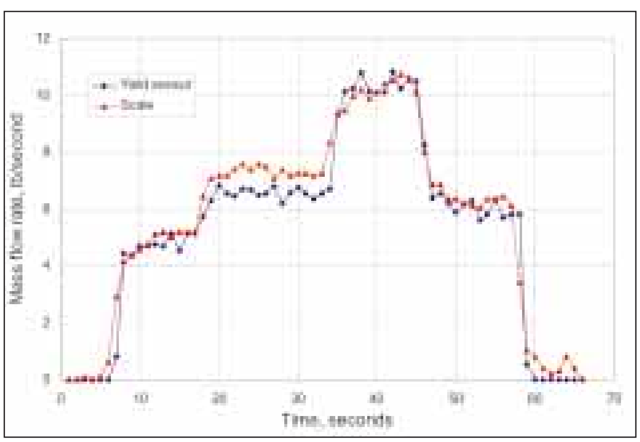

Figure 2. Response to simulated yield variation.

However, it took slightly less time for the yield monitor to register zero flow when the flow was cut off abruptly (**Figure 3**).

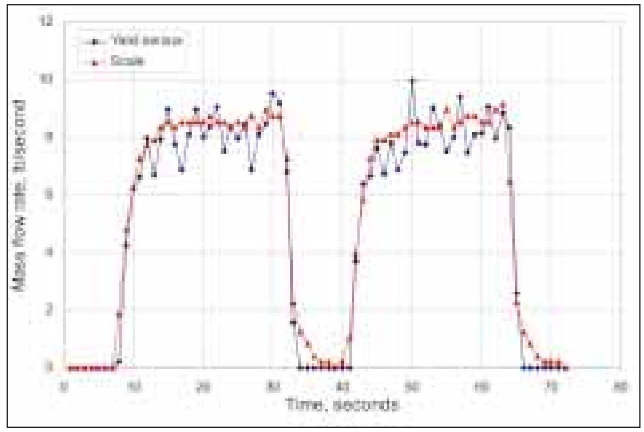

Figure 3. Response to simulated low yield areas.

The threshold of the yield monitor may have caused this because at very low flows, the yield monitor did not register flow (**Figure 4a**).

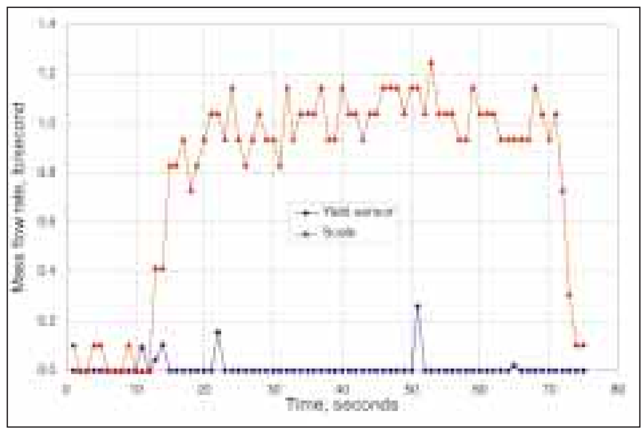

Figure 4a. Threshold flow rate determination for the yield sensor.

As the flow rate increased, the yield monitor started to reflect flow rate accurately (**Figure 4b**).

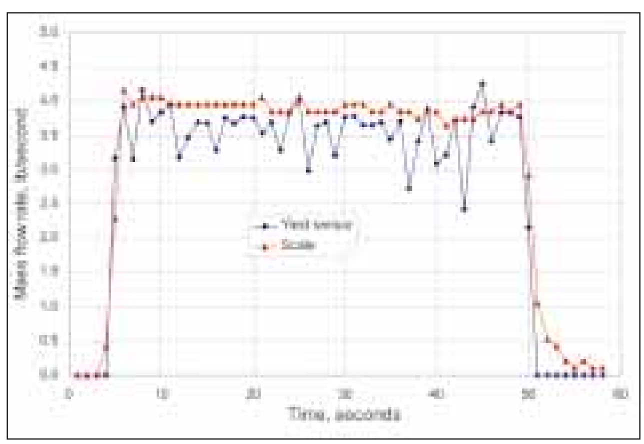

Figure 4b. Threshold flow rate determination for the yield sensor.

The actual flow rate values used in the laboratory for this monitor are not as high as flow rates obtained from large combines. This yield monitor was equipped with a special low-flow chip that we use for harvesting plots with a small combine. The low-flow chip is supposed to increase the accuracy when yield monitors are used on small combines. High-flow chips on large combines should provide results as good as low-flow chips on small combines, if not better. According to the manufacturer, accuracy is better at high flow rates.

We found that we could achieve differences of about 2 percent compared to the scale with constant flow conditions in the laboratory based on total weights. When the flow varied, the yield data had considerable fluctuations resulting in larger errors. This required the data to be averaged over about 6-second intervals to keep the error about 3 percent. This means that individual points were not as accurate as yield values averaged over lengths of 30 to 75 ft.

Tests in the field showed that the yield monitor and the scales were in agreement when flow rates were incrementally changed by varying the number of rows harvested (**Figures 5a and 5b**). These figures suggest that yield trends (relative yields) in fields can be measured reasonably with a yield monitor. This, however, is a separate question from the relationship of the measurement to the actual change as shown in **Figure 1**.

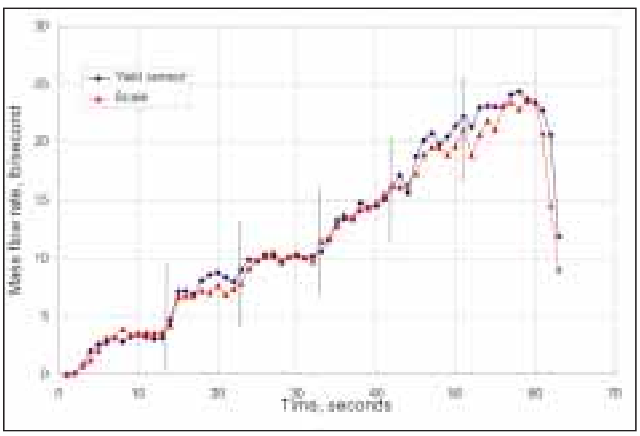

Figure 5a. Response to increasing yield at a constant ground speed in the field.

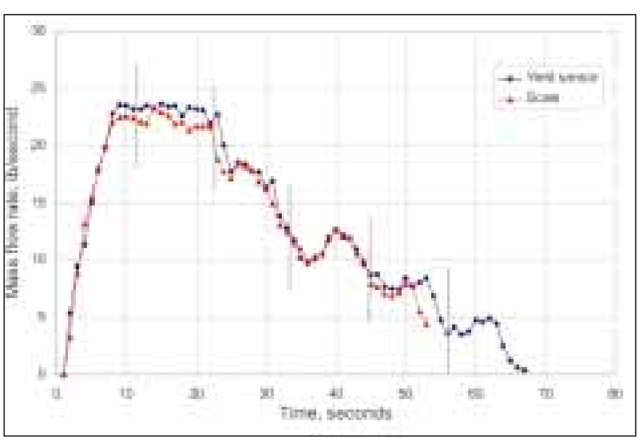

Figure 5b. Response to decreasing yield at a constant ground speed in the field.

Yield sensor calibration

The yield sensors that were used in our studies need at least six loads for calibration. Since yield levels vary in fields, the flow rate passing through the yield sensor will also vary during data collection. That is, during harvest, the yield sensor has to measure yield levels higher and lower than the average yield because of spatial yield variations.

During calibration, the flow levels that the yield sensor experiences and the combine speed should be varied in each load intentionally so that varying operating conditions are created if required by the manufacturer. For instance, when using a 6-row corn head, the first load can be obtained using all six rows while the second load can be harvested with using only five rows of the 6-row head at the same combine speed. Then another load can be determined using five rows, but by increasing the combine speed to keep the combine full of grain. Changing the number of rows (or cutting width for drilled crops) and harvesting at different speed levels will help simulate different yield levels and operating conditions for the yield sensor. This makes sure that a wide dynamic range is covered that should result in better accuracy for changing field and combine operating conditions.

The calibration loads are measured by a scale or weigh-wagon and used as actual grain weights for those loads. After entering these actual weight values into the yield monitor, the yield monitor should be recalibrated by selecting the recalibration function as instructed in the user’s manual. After the calibration, the yield monitor will report an average error that is calculated based on the actual loads, say 2.4 percent. If the operator wants to reduce the error further or if the operator realizes that the error increased during harvest because of extreme changes in the field and operating conditions, then one or more loads can be added as the harvest continues. Recalibration using these additional loads should improve the accuracy. Some other sensors available in the market, however, may not provide an option for multiple calibrations.

The calibration needs to be done separately for each type of grain. Likewise, if field and crop conditions vary dramatically from one field to another for the same crop, the yield sensor should be recalibrated.

Practical Implications and Conclusions

We concluded that the most important factor in achieving good accuracy was good calibration. This can be achieved by following the yield monitor manual carefully.

Software allows users to create dot maps, grids, contours, and other types of yield maps. Because of grain mixing and smoothing inside the combine (as shown in field experiments) and the fluctuations in instantaneous flow rate measurements (as shown in laboratory experiments), individual dots should not be used for decision making. Each point on a dot map is an average of some mixed grain and does not perfectly indicate the yield that can be associated to a location in the field. Since grain in a 10 ft. long section is spread over about a 100 ft. long path, high accuracy cannot be achieved in spot measurements (**Figure 1**). In addition, a grid showing the average of 4 to 10 data points, for instance, would not show the exact yield variation, but would display yield trends as a smoothed version of the actual yield. That is why, even if the grain flow rate measurement can be done perfectly at the yield sensor, the accuracy of measurement does not translate directly to the same accuracy of yield measurement.

Operators should try to keep the combine ground speed constant. Even gradual speed changes from 5 to 7 mph, depending on yield changes in field, caused error to increase from about 3 percent to 5 percent in field tests. Sudden changes in combine speed should be expected to increase errors even more.

We concluded that yield monitors provide accuracy levels sufficient to determine yield trends for site-specific management. Care needs to be taken at the edges of fields or when yields vary dramatically to avoid inaccuracies related to the combine or yield monitor.

Future Research Needs

Some future research should focus more on developing better combine grain flow models to improve yield map accuracy. More research should also be done to determine the effects of field slope variations and combine ground speed changes on accuracy. Sensors that interact with grain and other materials may lose their sensitivities due to coating as a result of dust, moisture, and crop residue accumulation on the sensing element. Research on sensors that do not interact with materials and are not sensitive to grain moisture variations should be worth considering. ■

Acknowledgements

Thanks to J. Cook, K. Heikens, R. Hartwig, and R. Hennis of the NSTL for their help with this work. The support provided by the Case Corporation and the Iowa Soybean Promotion Board is also greatly appreciated.

Additional Reading

Arslan, S. and T.S. Colvin. 1999. Laboratory performance of a yield monitor. *Applied Engineering in Agriculture* 15(3): 189-195.

Doerge, T. 1997. Weigh wagon vs. yield monitor comparison. In *Crop Insights*, 7(17): 1-5.

Missotten, B., G. Strubbe and J. De Baerdemaeker. 1996. Accuracy of grain and straw yield mapping. pp713-722. In *Prec. Agriculture, Proc. 3rd Intn'l Conf. on Precision Agriculture*, ed: P.C. Robert, R.H. Rust, and W.E. Larson. ASA, CSSA, SSSA, Madison, WI.

Pierce et al. 1997. Yield mapping. In *Site-specific Management for Agricultural Systems*. pp211-243, ed: P.C. Robert et al. *ASA Misc. Publ., ASA, CSSA, and SSSA*, Madison, WI.

Vansichen, R. and J. De Baerdemaeker. 1992. Signal processing and system dynamics for continuous yield measurement on a combine. pp340-341. In *AgEng '92: Proceedings of an International Conference on agricultural Engineering*, ed: B. Sundell and O. Nored. Available from the editors, Uppsala, Sweden.

Whelan, B.M. and A.B. McBratney. 1997. Sorghum grain flow convolution within a conventional combine harvester. pp759-766. In *Precision Agriculture. 1st European Conference on Precision Agriculture*, ed: John V. Stafford. UK. BIOS Scientific Publishers Ltd. Oxford, UK.

This Site-Specific Management Guideline was prepared by:

Dr. Thomas S. Colvin
National Soil Tilth Laboratory
USDA-ARS
2150 Pammel Drive
Ames, IA 50011
Phone: (515) 294-5724
E-mail: colvin@nstl.gov

Mr. Selcuk Arslan
Iowa State University
Agricultural and Biosystems Eng.
Ames, IA 50011
E-mail: sarslan@iastate.edu