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Precision Agriculture
Best Management Practices for Collecting Accurate Yield Data and Avoiding Errors During Harvest

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Yield monitoring technology has been in use since the mid-1990s in the United States. These systems have not changed a great deal over time. Many users focus on the in-cab display as the "yield monitor." However, it is important to remember that a yield monitoring system is made up of several sensors that provide the data to the in-cab display for yield estimation and map generation. The impact plate mass flow sensor located at the top of the clean grain elevator (*Figure 1*) is the most widely used sensor for monitoring grain flow on combines.

In some cases, operational errors may be unavoidable, but often combine operators can minimize the impact that errors will have on yield estimates. Therefore, the best management practices (BMPs) discussed in this publication will focus on minimizing errors for yield monitoring systems that use an impact plate mass flow sensor and provide a basic set of BMPs for combine operators to collect accurate yield data during harvest.

Figure 1. Impact plate mass flow sensor located at the top of the clean grain elevator.

After explaining how yield values are estimated, the primary areas for collecting quality yield data that will be discussed are:

- mass flow sensor calibration;
- moisture sensor operation;
- lag time settings;
- header position settings;
- distance traveled measurements; and
- header cut width settings.

How Are Instantaneous Yield Values Estimated?

To better understand how sensor measurements during harvesting can affect crop yield estimates, it is important to understand how yield is calculated. In most cases, the in-cab display is recording output every second from the combine sensors, along with GPS coordinates (generally recorded as longitude and latitude). All of the sensor information is used to generate an instantaneous estimate of grain yield in bushels per acre (bu/ac) at each GPS point logged in the field. The generic formula for crop yield in bu/ac has been well-documented and is shown in *Equation 1*.

Equation 1 provides an estimate of the instantaneous yield measurement at a GPS point logged within the field. The main parameters measured with combine sensors to compute instantaneous yield are mass flow rate

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$$Yield\left(\frac{bu}{ac}\right) = (43{,}560)\left(\frac{m * t}{d * w * p}\right)\left(\frac{100 - MC_{harvest}}{100 - MC_{market}}\right)$$

Equation 1

m = mass flow rate estimated from the impact plate sensor (lb/sec)

t = logging interval of the yield monitoring system (sec)

d = distance traveled between logged data points (ft)

w = header cut width setting (ft)

p = grain density or test weight (lb/bu)

$MC_{harvest}$ = moisture content measurement from the yield monitor moisture sensor (%)

MC_{market} = marketable moisture content (%)

43,560 = conversion from ft^2 to acres

(m), distance traveled (d), and harvested moisture content of the grain ($MC_{harvest}$). Distance traveled between logged yield data points is computed based on ground speed typically provided by the GPS receiver. Accurate mass flow rate values are highly dependent on the yield monitor calibration. Calibration procedures outlined in the operator's manual must be followed. The remaining parameters for *Equation 1* are constants that must be entered into the in-cab display by the operator.

As an operator, it is important to understand which parameters in *Equation 1* are being estimated using a sensor and which are constants that the operator must enter. All parameters are needed to compute an accurate yield data point. For example, as header cut width changes, the operator will need to manually change the value within the in-cab display to make sure the area representation of a point is accurate. However, in some newer systems, cut width may be automatically modified by the in-cab monitor based on field coverage logged during harvest. Operators should be clear on whether manual cut width entry is required.

Mass Flow Sensor Calibration

The mass flow sensor is the most critical component of the yield monitoring system. The calibration procedure for the mass flow sensor is time-consuming, but absolutely vital for accurate yield measurements. Since mass flow sensor readings may be affected by crop type, moisture content, and test weight, operators should consider performing separate calibrations under these differing circumstances. A separate calibration procedure should always be performed — and stored in the in-cab display — for different crops such as corn, soybeans, or wheat.

In some cases, mass flow sensor data can be improved by performing separate calibrations for high and low moisture corn. A good rule of thumb is to have a different calibration for corn over and under 20 percent moisture content. For example, consider a calibration procedure for high moisture corn at the beginning of the harvest season.

The mass flow sensor calibration process involves harvesting small loads of grain (around 3000 pounds), depending on manufacturer specifications, and measuring the scale weight of each load (*Figure 2*). Most yield monitoring systems allow the operator to collect multiple loads (two to six) per calibration procedure. This is to compensate for varying yields expected across a field during harvest. Remember that the mass flow sensor is measuring grain flow (lb/sec) through the clean grain elevator; multi-point calibrations allow the system to provide accurate estimates through the combine over a range, from low to high flow.

Figure 2. A grain cart equipped with scales or a weigh wagon is often used to quickly weigh loads for the mass flow sensor calibration procedure.

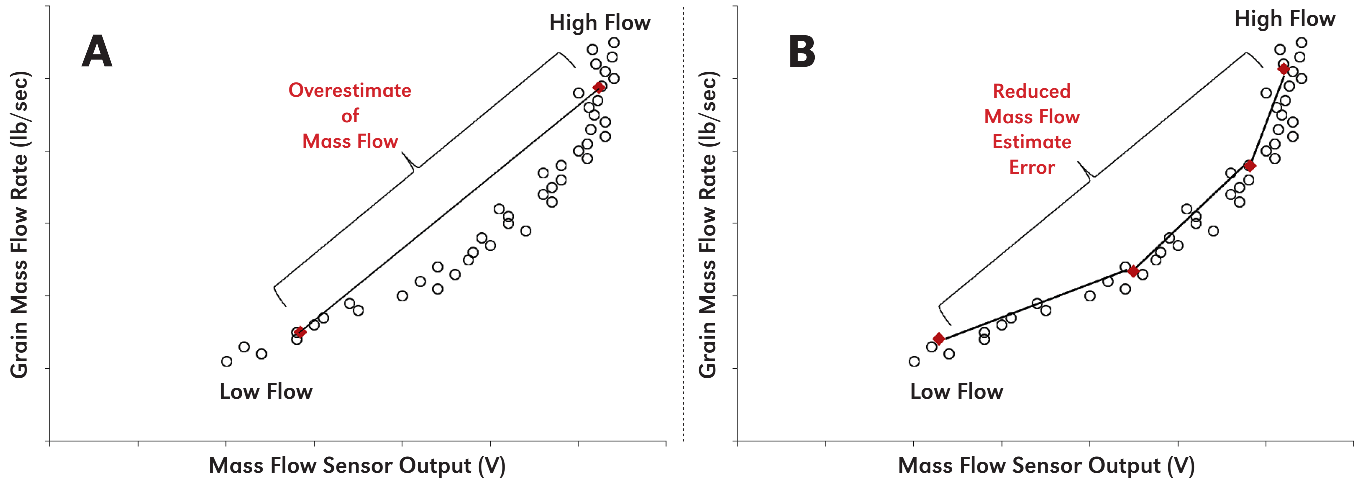

Figure 3. Potential error when using a two-point calibration (A) versus additional point (B). Calibration load points are shown in red.

During the yield monitor calibration process, the load weights are entered into the in-cab display automatically or by the operator. The in-cab display then creates an equation to estimate a physical value in pounds of grain flow based on sensor output, which was actually measured in millivolts.

One problem associated with mass flow sensors is that the response is nonlinear. This nonlinearity becomes an issue when only one or two loads are used during the calibration process. An example of this is shown in *Figure 3* where sensor output is plotted versus mass flow rate through the clean grain elevator. When a two-point calibration is used (one point for high flow and one for low flow), a discrepancy occurs between the calibration equation and the actual values. In this case, between the two calibration points, mass flow rates — and thus, yield — will be overestimated.

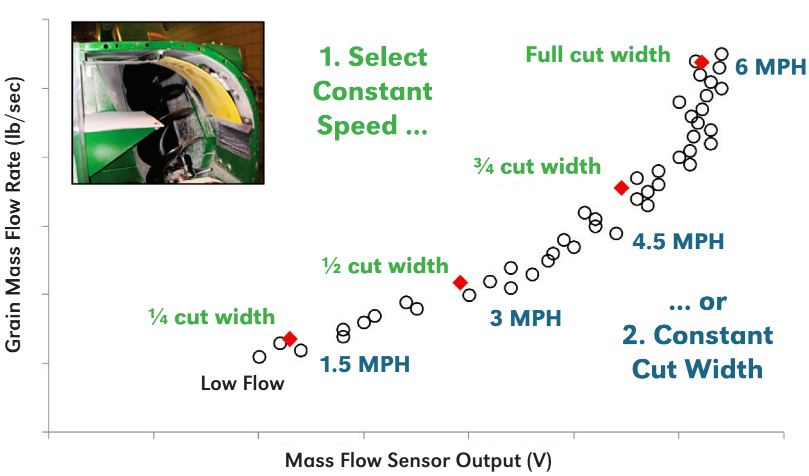

Figure 4. Two methods for varying clean grain elevator flow for mass flow sensor calibration: method 1, constant speed in green; method 2, constant cut width in blue. Calibration loads shown by points in red.

To reduce the potential error, some yield monitor manufacturers provide the operator with the ability to enter additional calibration loads over a range of flow rates. This additional calibration data can help reduce the error from mass flow sensor estimates, such as those shown in *Figure 3*, by improving the sensor output equation or curve. In this particular case of using multiple calibration points, the nonlinearity of the sensor is better estimated by the internal yield equation of the system (as reported by Arslan and Colvin, 1999). Typically, the operator can choose from two methods for varying the flow rates for proper mass flow sensor calibration: (1) constant speed with varying cut width, or (2) varying speed with constant cut width. Both options can achieve the same result of varying flow through the clean grain elevator (*Figure 4*).

Calibration of the mass flow sensor is critical for collecting accurate yield data. Remember to check manufacturer guides to determine how to best collect calibration loads for the yield monitoring system. Plan to conduct a new calibration each year unless yield monitor weights are being checked against scale weights, and errors are less than 3 percent. A separate calibration procedure must be conducted for different grains. Large variations in moisture content or test weight may justify additional calibrations for a particular grain. Always check throughout the growing season to make sure that debris or other materials are not building up on or around the mass flow sensor. It should be free to deflect normally during operation.

Another issue that affects many mass flow sensors is field slopes encountered during harvesting. Traveling up and down or across side slopes may affect the amount of grain that

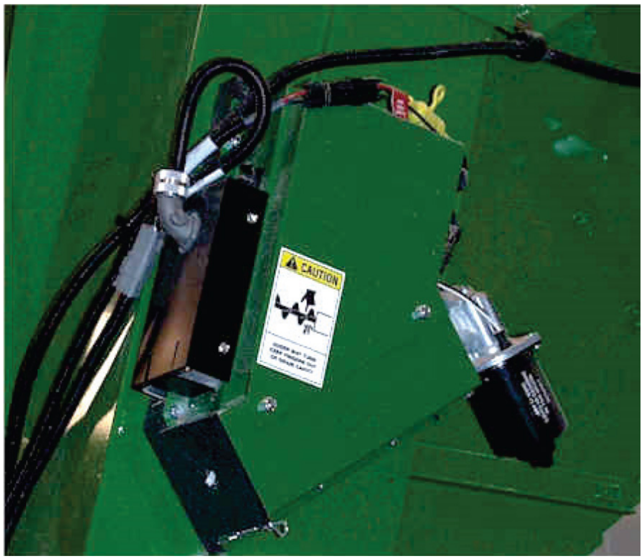

Figure 5. Moisture sensor located on the side of the clean grain elevator.

impacts the mass flow sensor and should be considered if pass-to-pass comparisons are being made (as discussed by Grisso et al., 2002). This issue is difficult to address during typical field harvest operations. In the case of in-field plots that are harvested and evaluated using a yield monitoring system, special considerations must be taken to ensure data accuracy among comparisons.

Moisture Sensor Operation

While most moisture sensors do not require much service and maintenance throughout the harvest season, operators should check, when possible, that the sensors are clean and functioning normally. *Figure 5* shows the location of the moisture sensor. Manufacturer specifications should be followed for calibration of the moisture sensor as well as the embedded temperature sensor. This calibration can be easily completed by comparing sensor output with any grain that has been tested during trips to the elevator.

In general, moisture sensors provide adequate estimates of grain moisture ranging from 10 percent to 33 percent. Values that fall outside of that range may be suspect to error and may not be suitable for data analysis. The harvest moisture content is an important measurement. It helps correct back to the desired yield value set by the market, or the moisture content at which the operator sells grain locally. Crop moisture content across the field may vary and could affect marketable yield values. Nominal values for grain test weight and MC_{market} are shown in *Table 1*.

Table 1. Nominal market moisture content and test weight by grain type used within yield monitors.

Grain	Market Moisture Content (%)	Test Weight (lb/bu)
Corn	15.5	56
Soybeans	13.0	60
Wheat	13.5	60

Lag Time Settings

It takes some time for the grain to travel through the combine once it's cut at the header. As such, mapping programs use a delay or lag time to locate when and where the grain impacting the mass flow sensor was cut. Having an appropriate lag time setting for the in-cab display is necessary to compensate for grain flow delays through the machine.

The operator needs an accurate entry of lag time into the in-cab display to ensure that mass flow sensor readings are offset properly to match up with logged GPS points and other sensor data. The lag time setting should reflect the amount of time from when the crop is cut until the threshed grain impacts the mass flow sensor, not as it enters the grain tank.

For most harvesters, the lag time should be between 10 and 15 seconds, but operators may want to confirm this by double-checking the lag time. This can be accomplished by measuring the amount of time from when the crop is first cut until it enters the bin, keeping in mind one or two seconds should be subtracted from this value since the mass flow sensor is ahead of that point.

The lag time is used by the in-cab display to shift mass flow sensor readings to better reflect when and where that grain was harvested, improving yield map quality. The actual lag time may be somewhat dependent on the grain flow through the machine and is affected by crop yield and travel speeds during harvest, according to Hemming and Chaplin (2005). Viewing yield maps after data has been downloaded should allow the operator/producer to verify that an accurate estimate of lag time was entered.

Header Position Sensor

The header position sensor setting also can contribute to errors in the field harvested area if not properly used. The header position sensor should be installed correctly, and the operator should be sure to raise and lower

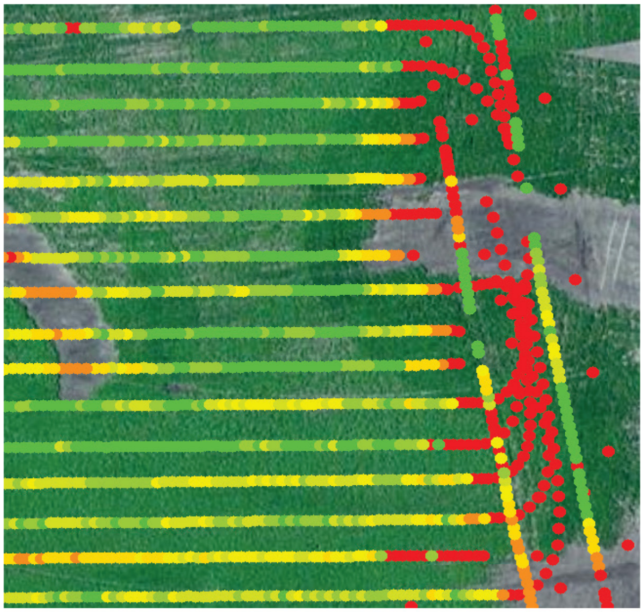

Figure 6. Yield data points collected during turning in the headlands; points (in red) collected in the turn contribute to errors in overall yield estimates and representation within yield maps.

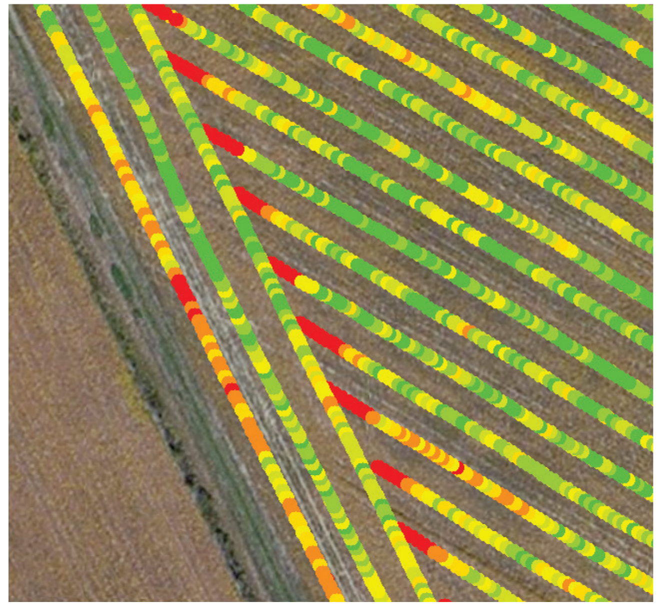

Figure 7. Cut width errors contributed to lower yield data estimates within point row locations.

the header only when exiting or entering the uncut crop. This will ensure that yield data points are logged properly, and data are shifted according to the lag time setting. The setting for this sensor represents the height of the header below which data will be logged while harvesting.

A common problem for many operators is that they do not raise the header above this height when turning in the headlands. As a result, several points generally are logged with little or no yield estimates, as no grain passed across the mass flow sensor, as shown in *Figure 6*. This also results in logging a field area larger than that actually harvested, which lowers the total field estimated yield.

Logging of yield data points is controlled by the header position sensor. Many operators will notice that the accumulated yield values continue to increase after the combine has exited the crop, while turning in headland areas, for instance. The yield monitoring system continually logs impact plate mass flow readings throughout the field to calculate this accumulated yield value. After field harvest operations are finished, this accumulated yield value should be closest to scale weights from the entire field.

Distance Traveled

On most yield monitoring systems, GPS is used to calculate travel speed and distance. While the travel distance estimate is generally adequate, abrupt changes in travel speed can lead to errors in yield data estimates. These errors most commonly occur when the combine stops very quickly.

Even with a proper lag time setting, a very small travel distance is usually logged and then coupled with normal mass flow readings. The result is an inflated yield estimate that can exceed 1000 bu/ac. While quick stops may be unavoidable, operators should realize the impact that changes in travel speed may have on yield estimates and be cautious in making abrupt changes.

Header Cut Width

Header cut width has been one of the toughest problems to solve with regard to accurate yield estimates. It is a problem that has most often been corrected during post-processing of yield data files. Manual input of cut width is still common practice, and operators need to enter a good estimate for cut width for the in-cab display. When cut widths are overestimated, yield will be estimated lower than actual. Underestimating cut width will end up artificially inflating yield estimates. If the combine is operated in point rows or passes at less than the set cut width, the operator must make the necessary in-cab display changes.

Some recent yield monitors offer automated cut width settings using swath control or section control technologies, which reduce the cut width entry based on field coverage logged during harvesting. As the header passes over previously harvested areas, the cut width is automatically decreased. The opposite occurs as the header encounters increasing crop widths; for example, when entering point rows, but the combine operator does not need to adjust the cut width within the in-cab display when taking less than the full header width. Cut width can significantly influence the resulting yield estimates, especially in fields with point rows (*Figure 7*). When manual mode is used for cut width, the operator should take care to ensure that the proper units are entered in either inches, feet, or rows.

Summary

This publication discusses some critical issues involved with collected quality yield data during harvest operations. Georeferenced yield data, collected using yield monitoring systems on combines, is without doubt one of the most useful data sets available to the agricultural industry. To collect yield data while minimizing errors, operators should focus on the following.

- **Mass flow sensor calibration:** Perform calibration procedures outlined by the manufacturer for different crops during the harvest season. If large variations are expected in moisture content, perform a separate calibration for high and low moisture contents for a specific crop.

- **Moisture sensor operation:** The moisture sensor should be checked periodically to ensure proper calibration. Readings above 33 percent or below 10 percent are likely errors and should be omitted.

- **Lag time settings:** The operator needs an accurate entry of lag time into the in-cab display to ensure that mass flow sensor readings are offset properly to match up with logged GPS points and other sensor data.

- **Header position settings:** The header position sensor should be installed correctly, and the operator should be sure to raise and lower the header only when exiting or entering the uncut crop. This will ensure that yield data points are logged properly and data are shifted according to the lag time setting.

- **Distance traveled measurements:** While logged automatically by the GPS system, sudden starts and stops should be avoided by the operator, if possible, as they will contribute to errors in yield estimation.

- **Header cut width settings:** Some automated cut width functions are now available from Ag Leader® and Deere & Company® that simplify this setting. However, care must be taken by the operator when adjusting this value manually within the in-cab monitor.

Even a well-calibrated harvester will generate errors in yield data due to uncontrollable circumstances. If yield data are to be used in any further analysis (hybrid trials, nitrogen recommendations, etc.), some form of software should be used to remove these errors prior to any analysis. When setting expectations about accuracy, remember that if properly calibrated, a yield monitoring system estimate of accumulated yield should be within 1 percent to 3 percent of total field grain scale weights. The important step is to ensure that the farm data manager is aware of these issues and makes every attempt to produce quality yield maps with as few errors as possible. BMPs for creating more accurate yield maps are discussed in EC2005, *Improving Yield Map Quality by Reducing Errors Through Yield Data File Post-Processing.*

Resources

For more information about precision agriculture research, education, and demonstration programs at the University of Nebraska–Lincoln, visit the website at *http://precisionagriculture.unl.edu/*

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