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Precision Farming Tools:
Yield Monitor

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Introduction

Using yield monitors is the first step many producers take in precision farming (*Precision Farming: A Comprehensive Approach*, Virginia Cooperative Extension (VCE) publication 442-500). A yield monitor, combined with Global Positioning System (GPS) technology, is an electronic tool that collects data on crop performance for a given year. The yield monitor for grain measures and records information such as grain flow, grain moisture, area covered, and location. Yields are automatically calculated. Yield monitors also are available for commodities such as peanuts, cotton, forage silage, and sugar beets. These monitors have some elements in common with grain-yield monitors. While the cost of a yield monitor is reasonable, the commitment of time and resources required to effectively use this technology can be significant.

Yield monitors come with various technical designs and features; however, yield monitors alone do not generate yield maps. A yield monitor is most useful with a Differentially-corrected Global Positioning System (DGPS) receiver (*Precision Farming Tools: Global Positioning System—GPS*, VCE publication 442-503). The goal of properly interpreting yield data (*Interpreting Yield Maps—I gotta a yield map, now what?*, VCE publication 442-509) is to answer the question: "How can I increase profits on this field?" To have accurate data for yield map interpretation, the yield monitor must be properly operated and calibrated.

Yield Monitor Systems

Yield monitors are a combination of several components (Figure 1). They typically include a data storage device, user interface (display and key pad), and a console located in the combine cab, which controls the integration and interaction of these components. The sensors measure the mass or the volume of grain flow (grain flow sensors), separator speed, ground speed, grain moisture, and header height. Yield is determined as a product of the various parameters being sensed. You must understand the function of these components in order to understand the interaction of the yield monitor, combine operator, and combine dynamics.

Yield monitors typically provide a periodic yield report. The operator can usually select the amount of data that is collected (e.g. 1-, 2-, or 3-second intervals). Consider a combine harvesting six 30-inch rows, operating at 5 mph and harvesting corn with an average yield of 150 bushels per acre. This combine requires about 15 sec-

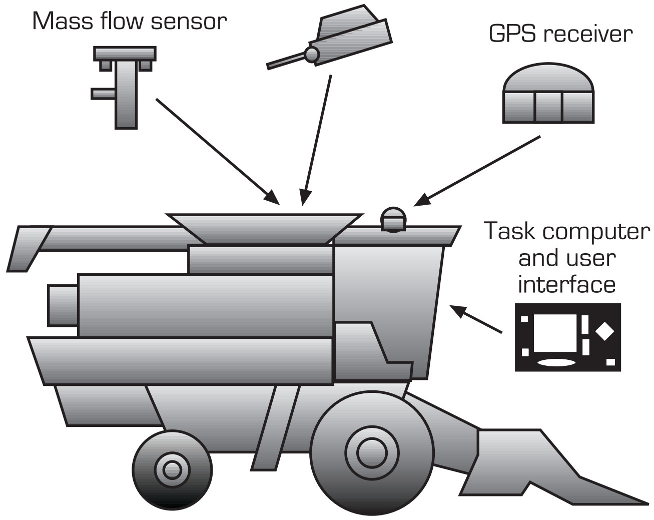

Figure 1. Components of a yield-monitoring system.

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onds before grain entering the header is fully flowing into the grain tank. The example combine using a yield monitor to collect data at 2-second intervals will collect about 200 yield measurements per acre, many more data points than any other precision agriculture tool.

Limitations of Yield Monitors

The combine operation is dynamic and the flow rate of material processed can vary depending on entering and exiting the crop. These varying flow rates can influence the results of the yield monitor data. Since the yield monitor measures the rate at which clean grain is entering the grain tank, time delays between the time grain enters the combine header and the time it passes through the clean grain elevator can be significant. Combines also smooth abrupt changes in yield; hence, the yield monitor measures delayed averages of yield.

The phenomena of time delays and smoothing are most obvious when a combine enters or leaves the crop at the ends of a field. The combine, in the example above, has a delay of 15 seconds to process the entering crop and would travel 110 feet and harvest almost 0.04 of an acre before an accurate or stable yield is displayed on the yield monitor.

Most yield mapping software compensates for equipment delays caused by the combine and corrects the yield data. The resulting yield map will not be perfect, but it will be very adequate for observing the magnitude and location of yield variability.

Yield data combined with mapping software and positional data are capable of producing a colorful map (see *Interpreting Yield Maps—I gotta a yield map, now what?*, VCE publication 442-509) showing variations in grain yield and moisture. If these maps are to be of any real value, the data generated from them must be incorporated into the decision-making, analysis, and overall planning process of the farm operation (see *Precision Farming: A Comprehensive Approach*, VCE Publication 442-500).

Yield and Moisture Sensors

A sensor in the stream of clean grain measures the mass flow. Yield sensors can measure one or more of the following: (1) the force of the grain hitting a plate, (2) the attenuation of light passing through the grain stream, (3) the weight of the grain collected for a period of

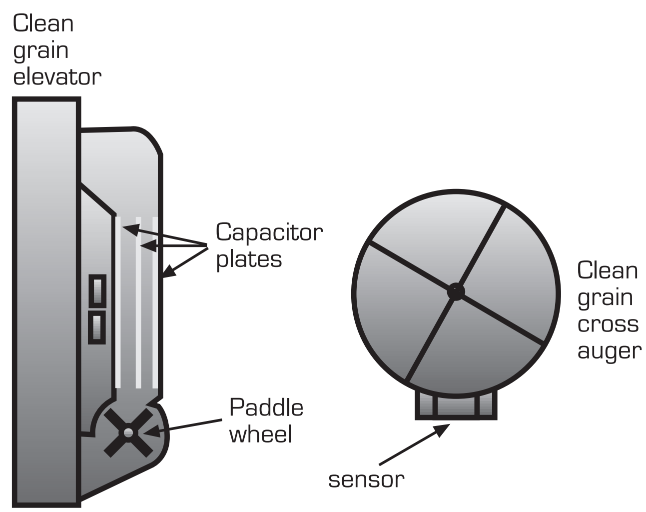
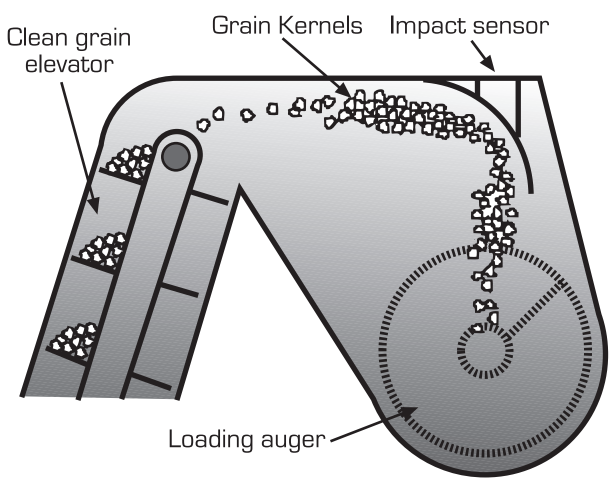


Figure 3. Moisture sensor installation on yield-monitoring system.



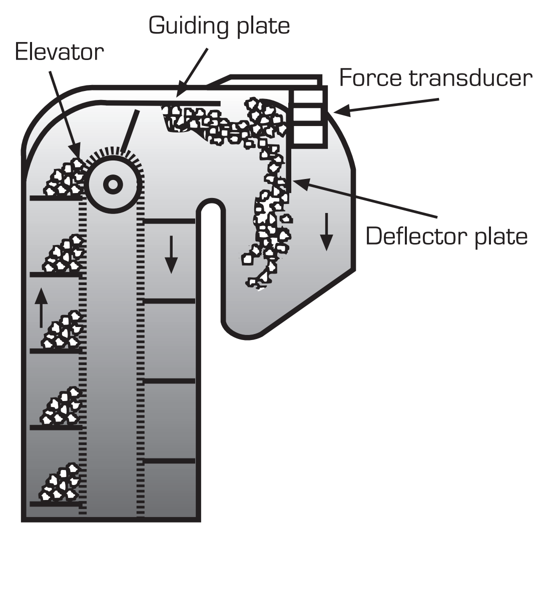


Figure 2. Mass flow sensor on yield-monitoring system.

time, or (4) the volume of grain on an elevator paddle. The most common method is to measure the force of the grain striking a plate located at the top of the clean grain elevator (Figure 2). The calibration of these units will depend on the elevator speed, the type of crop, and the moisture of the grain.

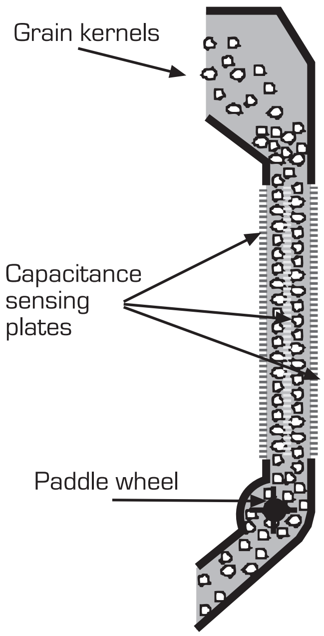


Figure 4. Moisture sensor installation on the clean grain elevator for yield monitoring.

Yield and moisture data are collected simultaneously to obtain accurate yields. Moisture sensors are often located in the clean grain elevator or the clean grain auger (Figures 3 and 4). Grain passing over the moisture sensing plate can leave deposits that can affect moisture readings. Buildup can introduce bias into the moisture measurements. The moisture sensor is essentially a conductive shell or a series of metal plates with an electrically isolated internal metal fin. As grain rises in the clean grain elevator, a small amount enters the top of the moisture sensor and moves between the metal plates. A small paddle wheel located in the bottom of the sensor housing ensures that grain always covers the plates. The paddle wheel also controls the rate at which grain reenters the clean grain elevator.

Periodically take manual measurements to check the performance of the moisture sensor, especially when operating in severe conditions that can coat the sensor with soil or plant sap. Over-estimated moisture readings from a malfunctioning sensor will underestimate yield. Clean the plates often when the combine is operated in weedy or moist grains. These conditions can cause a buildup of dirt or plant residue on the sensing elements, which interferes with grain moisture measurements.

Yield Monitor Console

The yield monitor console (Figure 5) is a data collection unit and computer that records data from the yield sensor, moisture sensor, and DGPS receiver. The console is also used to enter field names, grain type, calibration numbers, correction factors, and other user-specified data.

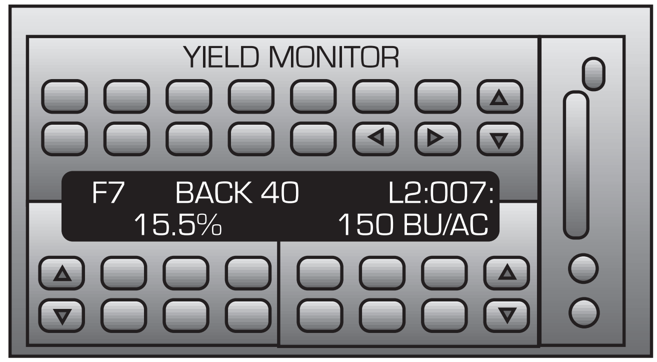


Figure 5. Yield-monitor console.

The console may also monitor or record elevation, elevator speed, ground speed, swath width, header height, and electronic flags manually set by the operator. Electronic flags are often used to record the location of weeds (known to be highly correlated with yield reductions). These flags may locate and identify other problems or obstacles such as rocks, terrace failures, standing water, etc.

A yield monitor equipped with a DGPS receiver stores data in a format that includes position information. These spatially indexed data are later used to produce maps of yield, moisture, elevation, or any other information collected during harvest. Most yield monitors can display instantaneous readings of yield and moisture and provide statistics for loads or batches of grain from a field or within an area of a field.

Data Collection and Storage

Data are often recorded on removable memory cartridges, such as a Personal Computer Memory Card Industry Association (PCMCIA) cards. Data from these cards can be downloaded to a computer. Download data daily to ensure that the yield monitor is working properly and to protect against accidental data loss.

Memory cards may store several megabytes of data. The card capacity is sometimes stated in hours of operation since data are typically stored on a periodic basis. One megabyte of memory can store 15 to 45 hours of information for yield data collection intervals of 1 to 3 seconds.

Yield Monitor Calibration and Accuracy

A yield monitor must be calibrated to provide accurate yield data. Calibration must be performed for each type of grain harvested at the beginning of the harvest season. Accuracy usually improves when several loads are used to perform the calibration. Recalibration should be performed as necessary, especially later in the season as average moisture content drops or when there is a significant change in crop conditions.

Calibration is usually as simple as weighing and recording the moisture of the first several loads collected under a variety of conditions, such as various operating speeds or grain flow rates. Consult the operator's manual for specific instructions.

The accuracy of a yield monitor depends not only on its design, but on how carefully the calibration procedure is followed. Some companies offer a training session or videotapes to teach calibration. These procedures vary considerably among manufacturers, but all require carefully weighing several loads of grain, which can become a logistical problem on some farms.

Factors Involved in Calibrating a Yield Monitor

Yield monitor manufacturers make every effort to build accuracy into their systems; however, every combine and installation may have different errors. You must consider four elements when calibrating a new yield monitor:

- distance
- header height
- mass-flow rate of grain
- grain moisture content

Distance: A speed sensor in the transmission is used to determine ground speed. The calibration procedure relates the actual distance traveled to a specific number of pulses from the sensor. The sensor is calibrated by operating the combine over a known distance (e.g., 400 feet or length specified by the manufacturer) at typical harvest speed and field condition. The yield monitor then generates a scale factor to calibrated travel speed. When calibrating the speed sensor, match the actual operating conditions of the combine at harvest as closely as possible. For example, operate a loaded combine on soft ground or a hillside if this is typical of field conditions at harvest. Ground speed radar must be calibrated in the same manner. Yield monitors that rely on the use of GPS for ground speed determination do not require calibration for speed.

Header Height: Header height determination is important as it establishes the beginning and ending of data logging and area accumulation. There are principally three different methods for sensing header height. One method is a magnetic sensor that opens a contact when the header reaches a predetermined position. A second method uses a rotary potentiometer for sensing the angle or elevation of the header. At the option of the combine operator, the start and stop positions determined by the potentiometer can be adjusted on a control panel located in the combine cab. The third method involves tracking the length of time the header height control switch is in the "up" or "down" position. Once the actuation time exceeds a predetermined value (e.g., 1.5 seconds), area accumulation and data logging is either turned on or off, depending on whether the header is being lowered or raised.

Regardless of the methodology you use to start and stop data logging and area accumulation, you should read the operator's manual and thoroughly understand the operation of this feature because the quality and integrity of yield data depend heavily on its use.

Mass-flow Rate of Grain: To calibrate the mass-flow sensor, weigh grain harvested over a certain interval and then enter the actual weight of grain harvested into the yield monitor. This interval might consist of one to several combine tank loads. Based on a defined approach, the yield monitor uses this information to fit a calibration curve, or a series of factors, to the particular impact sensor, grain type, and combine/sensor geometry. If any of these factors change, the system must be recalibrated. Changes in grain properties such as test weight and moisture content may require more frequent calibration.

Although the approach is similar from manufacturer to manufacturer, the quantity and nature of the internal calibration approach differs. While the factory or default calibration numbers provide a reasonable starting point, they are not a substitute for on-farm calibration. At the very least, one truckload of grain must be weighed. One manufacturer recommends weighing several individual combine tank loads of grain. This process is greatly simplified when a weigh wagon with digital readout is available for obtaining load weights.

Grain Moisture Content: A sample of grain from the moisture sensor or tank-loading auger should be collected, analyzed, and then compared with the moisture sensor reading from the instant in time when the grain passed over the sensor to arrive at an accurate calibration offset. Use caution when adjusting moisture calibrations, particularly when considering the accuracy of the moisture-measuring device that will be used to determine the reference moisture content of the grain. Offsets vary with grain type, and each grain type requires calibration to determine the appropriate offset.

Yield Monitor Calibration Tips

The first step is to become familiar with your yield-monitoring equipment. Information provided by a dealer or manufacturer through on-site support, training sessions, user manuals, and videos are good ways to learn about your equipment. Check with your yield monitor dealer and manufacturer for this information and additional tips on calibration. Each yield monitor has a specific way to be calibrated, which is outlined in the manufacturer's calibration procedures manual. The Appendix of this publication has calibration tips to maximize the benefits of yield-monitoring equipment.

Operating a Combine Equipped with a Yield Monitor

The final appearance of a yield map depends on how the combine is operated. Frequent stopping or sudden changes in speed can cause erratic yield data due to the delay and smoothing phenomena associated with the combine separating system.

The combine must be operated on a uniform swath width to ensure accurate yield data. You must enter the width of the header into the monitor manually to accurately calculate yield. Yield will be underestimated if fewer rows are harvested. Many yield monitors allow you to change the number of rows or the percent of width harvested to correct yield for point rows or field edges. For best results, keep the mass-flow rate of the combine constant. This represents a constant flow of material moving through the combine. You can set the yield monitor display to show the instantaneous mass-flow rate (typically close to the calibration rate). This rate can be maintained near a constant rate by adjusting the travel speed to compensate for the amount of material entering the combine.

Yield Monitor Installation and Service

A yield monitor is a precision electronic device that requires careful installation to operate properly. Improper installation of cables usually causes the monitor to be inoperable. Improperly installed sensors can cause faulty yield data.

Today, many combines can be purchased with factory-installed yield monitors. After-market yield monitors are also available for installation on late-model combines. The flow-measuring device (impact plate) is placed in the service door at the top of the clean grain elevator, or in an opening at the top of the elevator. In some cases, the impact sensor can be mounted only by cutting a hole in the top of the clean grain elevator housing.

The proper installation of a yield monitor requires positioning the mass-flow sensor relative to the position of the upper elevator sprocket. A new adjustment mechanism must also be installed on the lower end of the clean grain elevator. After calibration, only the lower sprocket should be changed to adjust elevator chain tension. Any movement of the top elevator sprocket changes the impact angle of grain, thereby requiring a new calibration.

Yield Monitor Maintenance

Because a yield monitor is an electronic device, little or no maintenance of the monitor console should be needed. However, the sensors may require periodic cleaning and inspection to ensure they are in proper operating condition. Periodically perform calibration checks to determine the accuracy of the yield and moisture data.

Moisture sensors are more likely to need cleaning under harsh conditions, but yield sensors may also collect debris that can affect the accuracy of the sensor. If moisture or yield readings seem to change suddenly without a logical reason, stop the combine and check the sensors for dirt or plant sap. Spot-check moisture with a moisture meter to determine if there is a problem with the on-board moisture sensor. Weigh a load of grain to determine if there is a problem with the yield sensor. Do not ignore unusual or sudden changes in moisture or yield readings.

Summary

Yield maps are only as accurate as the data collected to produce them and only demonstrate that yield variability exists. Monitors must be correctly installed and periodically checked to provide accurate data.

You should use yield map data with soil test data, scouting notes, and other observations to learn why variability exists. The knowledge you gain from site-specific crop management equips you to make better management decisions that have positive environmental benefits and that result in improved productivity and profitability.

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Appendix.

Calibration Tips for Yield Monitor Equipment

Before Operation

- Back up any PCMCIA memory card data from the previous season if you have not already done so. Keep several back-up copies of the raw data in different locations in case a copy is lost, stolen, damaged, or modified.

- Check your PCMCIA card to be sure it works properly.

- Contact your local dealer or the manufacturer to determine the most recent software and hardware upgrades for your yield-monitoring and mapping systems. Information about these upgrades is available through manufacturer's web site or by contacting technical support.

- Check all cables, connections, and sensors for wear or damage.

- Make sure elevator-mounted moisture sensor units are cleaned of grain and the manual clean-out motor is functional.

- Inspect the flow sensor. Look for wear on the grain elevator and missing or worn paddles. Check to make sure that the spacing between the paddles and the top of the elevator meets the manufacturer's requirements.

- Look for wear on the flow sensor's impact or deflector plates and replace if plates appear worn.

- Double check to make sure an existing yield monitor is installed properly on a just-purchased new or used combine.

- Avoid running electrical wires next to the GPS antenna. Close proximity may cause interference with the receiver signal. Running wires perpendicular to each other decreases the chance for electrical noise that may occur from other electronics.

During Operation, Prior To Calibration

- Install the memory card in your yield monitor before turning on your combine and yield monitor. Make sure there is proper communication between the card and the display monitor. Usually, the display will show an error message if there is no communication with the card.

- Check to see if you are receiving good differential correction from the Coast Guard, WAAS, or your satellite subscription provider. If you have a satellite subscription, make sure it is renewed so you will not be caught in the middle of the field during harvest without differential correction service.

- Raise and lower the header to make sure the stop height switch operates. Some monitors are equipped with a manual switch, which turns on and off data collection to your monitor. Adjust the header height switch to accommodate the preferences of different operators during harvest.

- Set row width according to number of rows for a row crop header and the appropriate width of a cutting platform header.

- Engage the separator and observe the elevator speed on the monitor.

- Put the combine in drive and check the ground speed indicator.

- Use accurate scales to weigh the grain. Certified scales or calibrated weigh wagons are recommended. When using weigh wagons, leave the wagon in one location in the field. Moving the weigh wagon through a field causes it to shake and bounce which can throw off its calibration. Use the same scales throughout calibration.

During Calibration

- Take temperature readings close to the moisture sensor on the combine. When collecting yield monitor temperature readings, make sure the combine has been operating at normal temperatures for several hours. For example, a temperature reading from the combine that has been in the shed or under a shade tree is much different than when it is in direct sunlight.

- Conduct moisture calibrations for each grain type. Take representative moisture samples of the grain harvested throughout the loads.

- When calibrating the monitor for ground speeds, use typical field conditions rather than a road or waterway. Tire slippage can create inaccuracy with calibration.

- Harvest calibration loads at different flow rates. Yield will vary throughout the field. Adjusting flow rates will improve accuracy.

- Calibration loads should be between 5,000 to 8,000 pounds. This helps reduce variability with excess grain that may be in the combine.

- Gather loads in well represented areas of the field. Avoid starting calibration loads on turn rows, weed patches, or areas of major topography changes in the field. Hillsides and rolling ground can impact calibration load data because of how the grain impacts the flow sensor. If you are unable to avoid topographical changes, get good representations of loads going up and down a hill(s) and side to side of a hill(s).

- Calibrate for each type of grain each year. The dynamics of the combine change from wear and tear and can influence the outcome of your yield data.

- When conducting on-farm research trials or harvesting fields with multiple varieties, consider creating a calibration load for each treatment or variety. For example, calibrate for regular corn and high oil corn separately due to the differences in test weight and moisture characteristics of the grain.

- Calibrate for different moisture levels per type of grain. For example, calibrate differently for corn below 22 percent moisture and corn above 22 percent moisture.

During Harvest

- Correct any malfunctions or errors indicated by the yield monitor. These can include moisture and flow sensors not working properly and loss of DGPS signal. Make sure the monitor is actually collecting data. Do not manually switch off data collection on the monitor and forget to turn it back on.

- Perform periodic calibrations throughout the season to check or improve accuracy. Recalibrate if there is more than a 5 percent difference in error, a 5 pound per bushel difference in test weight, or temperature changes greater than 10 degrees.

- Remove the PCMCIA card from the monitor and frequently back-up data onto a computer and data storage devices throughout the harvest season. A simple electrical shock from improper wiring or lightning can destroy the data on your card.

- Recalibrate if you make significant changes to the elevator chain, paddles, or flow sensor during the harvest season. Tightening the elevator chain, replacing old paddles, or changing the gap between the flow sensor and the paddles changes the outcome of the previous calibration.

- Check the trouble-shooting information in the operator's manual if problems arise with the monitoring equipment. Contact technical support to resolve problems.