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A Comparison of Three Popular Yield Monitors & GPS Receivers

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A yield monitor used in conjunction with a Global Positioning System (GPS) receiver records field and crop information during harvest that can help producers make sophisticated farm management decisions.

Field testing a GPS system.

The system performs three functions:

- The yield monitor measures the amount of grain in the hopper by using a flow measuring device and other devices, such as a grain moisture sensor.
- The Global Positioning System (GPS) determines the combine's location from a satellite radio signal.
- Together, data from the monitor and the GPS system is used to create a yield map for every location in the field. This map can then be used, along with other data, to make crop input and other decisions as a part of a Precision Farming system.

How precise does Precision Farming have to be?

Precision Farming is not a perfect technology—but then it doesn't have to be. The term "Precision Farming" implies that the technology is able to pinpoint precisely what is happening or should happen at every exact location in a field. The term "farming by the foot" has also been used to advance this notion. But there are technological limitations and variables that prevent Precision Farming from offering this implied degree of accuracy. While reading this report, keep in mind that this technology is not as precise as sometimes is implied, but the degree of detail it does offer is still significantly advanced compared to traditional methods used to measure yields and application rates.

What is the Global Positioning System (GPS)?

The GPS is a network of 24 U.S. Department of Defense satellites orbiting the globe, transmitting signals that can be received anywhere on the planet. A GPS receiver uses these signals to calculate its location on Earth.

However, the signals from these GPS satellites alone do not provide an accurate enough location for Precision Farming. To obtain an accurate location, a second signal, called a differential correction signal, is needed. This signal can be received from either another satellite or from a ground-based beacon. Most combine yield monitor/GPS receivers used in Western Canada use a satellite-generated differential correction signal. Standard GPS signals are free of charge to everyone, but the differential correction signals can only be obtained through a paid subscription service. This service can cost several hundred dollars per year.

The satellite that provides the differential correction signal is located over the equator. If the combine is in a location where the antenna's view to the south is blocked, the differential correction signal may be temporarily lost. In the tests conducted by PAMI, the antenna was mounted on the highest point of the combine to minimize this problem.

Are all yield monitors created equal?

While this technology has a lot of potential benefits for agriculture, it is an emerging technology. The accuracy of results provided by yield monitors is sometimes difficult to assess. The intent of this research project was to:

- operate three yield monitor/GPS receivers in the field,
- measure their performance, and
- report the results to producers to help them make informed decisions about the use of this technology.

The tests were conducted in the fall of 1998. All of the units were operated in wheat and oilseeds during harvest. The tests were intended to answer three questions:

- How well did the yield monitor indicate the amount of grain in the hopper?
- How well did the GPS receiver indicate the combine's location?
- How well did the entire unit function to indicate the yield at any given location in the field?

The Tests

The accuracy of each yield monitor was tested by weighing the actual amount of grain in the combine hopper with a grain truck equipped with a weighing mechanism calibrated against a grain elevator scale. This weight was compared to the weight indicated by the yield monitor.

To test the accuracy of the GPS receivers, each was removed from the combine and the antenna was mounted on a mast in the box of a ½ ton truck. The truck was driven over a track at different speeds and directions, and the path the receiver recorded was compared to the actual track location. The actual location and shape of the track was determined using conventional land surveying methods.

Three methods were used to assess the system's ability to report the yield at a location in the field.

The first method involved marking and harvesting 10, 20, 30, and 40-foot sections of swath with the yield monitor turned off. This created "holes" in the swath of varying lengths. The swath, "holes" and all, was then harvested with the yield monitor turned on. Ideally, the resulting map was expected to record the "holes" in the swath as a section of "zero" yield in the correct location. The actual map produced was compared to this ideal.

In the second test, 20-foot sections of swath were removed by hand and placed on top of the existing swath either before or after the resulting "hole". The ideal map should then have shown a section of normal yield, a section of twice the normal yield, and then a section of "zero" yield (or vice versa, depending on which side of the hole the removed section of swath was placed). The actual map produced by the monitor was compared to this ideal.

For the third test, a known quantity of grain was placed in a dump bucket and mounted at the combine feeder house intake. A stake was placed in the ground next to the swath to mark the start of the test. When the combine passed this stake, a mechanism was tripped that dumped the grain from the bucket onto the swath entering the feeder house. The yield increase recorded by the monitor was compared to the actual yield increase and location.

A yield monitor is generally available as an accessory on a combine harvester. The tests were conducted on three popular, commercially available units:

√ A ***Case IH AFS*** system factory-installed on a Case IH 2188 combine.

√ A ***John Deere GreenStar*** system factory-installed on a John Deere 9610 combine.

√ An ***Ag Leader PF3000*** system field-installed on a John Deere 7720 combine.

Yield Monitor Test Results

With sensors installed inside the combine, a yield monitor records a variety of information such as yield, grain moisture, distance, and other data onto a PC Card plugged into the monitor. The data is logged onto the PC Card at time intervals of every one, two or three seconds, and some monitors allow the operator to set the logging interval.

When properly calibrated, all three yield monitors displayed the weight of grain in the hopper within ±3% of the actual weight. Actual test results are given in Table 1.

It was important to calibrate the yield monitors against an accurate scale, since the calibration needed to be repeated if the characteristics of the grain changed significantly. Calibration involved harvesting an amount of grain, weighing it, and comparing the actual weight to the data produced by the monitor. Any necessary adjustments to the yield monitor were made to bring it in line with the actual recorded weight of grain in the hopper.

When the AFS and Ag Leader were calibrated, at least four loads of each type of grain were needed to perform a proper calibration, and it was recommended that these loads be harvested at different ground speeds. The GreenStar system only required one load to perform a calibration, but the resulting accuracy could sometimes be only within 8-10% of actual yield. In reality, four or more loads were also needed with the GreenStar to get the accuracies shown in Table 1.

Table 1.

Model	Accuracy	
	Wheat	**Canola**
AFS	-0.2% to +2.9%	-1.8% to +0.2%
Ag Leader	-1.8% to +3.1%	-3.5% to +2.8%
GreenStar	-1.9% to +2.2%	-2.8% to +1.2%

Once the actual weights of each load were obtained, the procedure for calibrating each unit was fairly easy. With the AFS and Ag Leader, the calibration data could be entered at any time after it was collected, and all of the yield data for that grain would be automatically adjusted. The yield map would not be affected by this recalibration, so to make the map as accurate as possible, the calibration should be done at the beginning of harvest.

With the GreenStar, only the yield data collected after the recalibration was affected. The yield map data could be adjusted within the mapping software after harvest. It was important to check and possibly adjust the zero reading with the GreenStar a few times a day. This was a simple procedure that only took a few minutes.

GPS Test Results

Both the Ag Leader and AFS units used a Trimble antenna and receiver, so only the Trimble and the John Deere GreenStar receivers needed to be tested.

Both receivers did a very good job of recording the actual combine location, indicating on average, the recorded location to within one metre or less of its actual location. This degree of accuracy works well for this application. The results were not affected by speed or direction of travel. It was very important to be receiving both the GPS signal and differential correction signal, as the level of accuracy was not acceptable without the differential correction signal.

Yield Mapping Test Results

In reality, it is probably unrealistic to expect the monitors to record the yield changes exactly as they occur in the field. This is due to varying delays in the combine grain handling systems depending on adjustments and other factors. However, the closer the information produced by the yield monitor is to reality, the more accurate the maps will be. Better maps allow better management decisions.

On the whole, all three monitors recognized the yield changes in the field tests quite well. All were good at reporting the magnitude of the yield change, but some did not report the location of the yield change as well as others, which is why the yield graphs appear to be recording yield changes before or after any changes actually occur in the field. This is because while the GPS receiver automatically and continuously records the location of the combine, the yield monitor must estimate machine lag time before matching the measured yield to a location on the map. The resulting overall yield calculation by the mapping software should be quite accurate, but the yield at each location on the map may be shifted slightly from where it actually occurred in the field. The magnitude of this shift could be up to 25 ft. It should be noted that many implements are wider and have an operational lag that is similar to this distance.

About The Dump Test Graphs: *The same measured amount of grain was used for the dump tests on all models of yield monitors. However, since yield amounts varied from field to field, there is no purpose in applying a yield value to the y-axis of the dump test graphs. The relationship of the actual swath yield to the yield monitor readout is what's important when interpreting the dump test trials.*

About Lag Time: *All of the tests results reported here were obtained using factory settings. The lag time in the AFS and Ag leader monitors is adjustable by changing some calibration numbers. Entering the numbers is simple, but a dealer or manufacturer's representative should be consulted for the procedure to obtain the correct values.*

AFS

The AFS recognized all the “holes” in the swath, but were recorded on the yield map ahead of where they actually occurred in the field. The results for the double yield (double swath) test were similar. The AFS reported the yield increase from the dump tests quite accurately, but they were also located on the map ahead of where they actually occurred in the field.

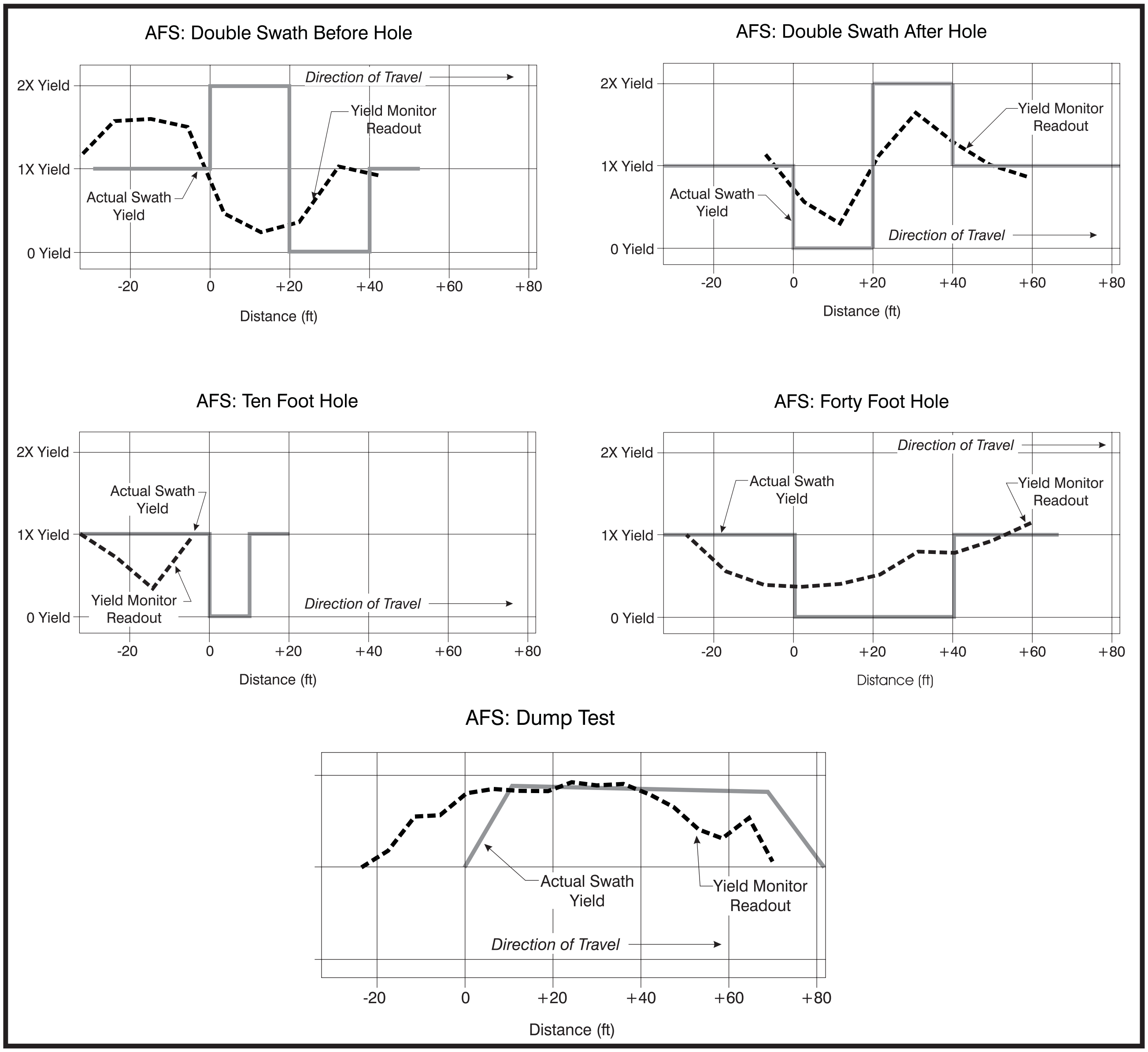
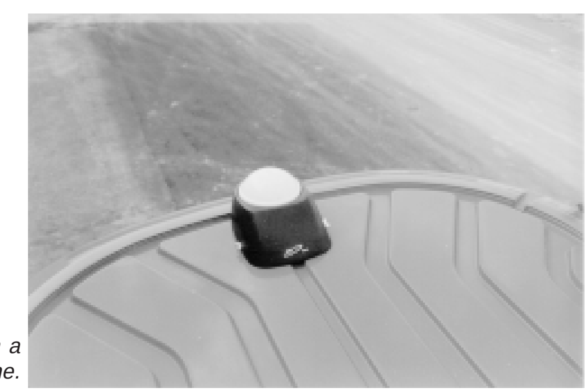


Figure 1. AFS Graphs



AFS antenna positioned on a Case IH 2188 combine.

Ag Leader

The Ag Leader recognized all "holes" in the swath, but the reported yield changes were not as distinct as the actual changes. The yield map also located them ahead of where they actually occurred in the field. Results from the double yield tests were similar. The Ag Leader reported the yield increases from the dump tests quite well, but they were also located on the map ahead of where they actually occurred in the field.

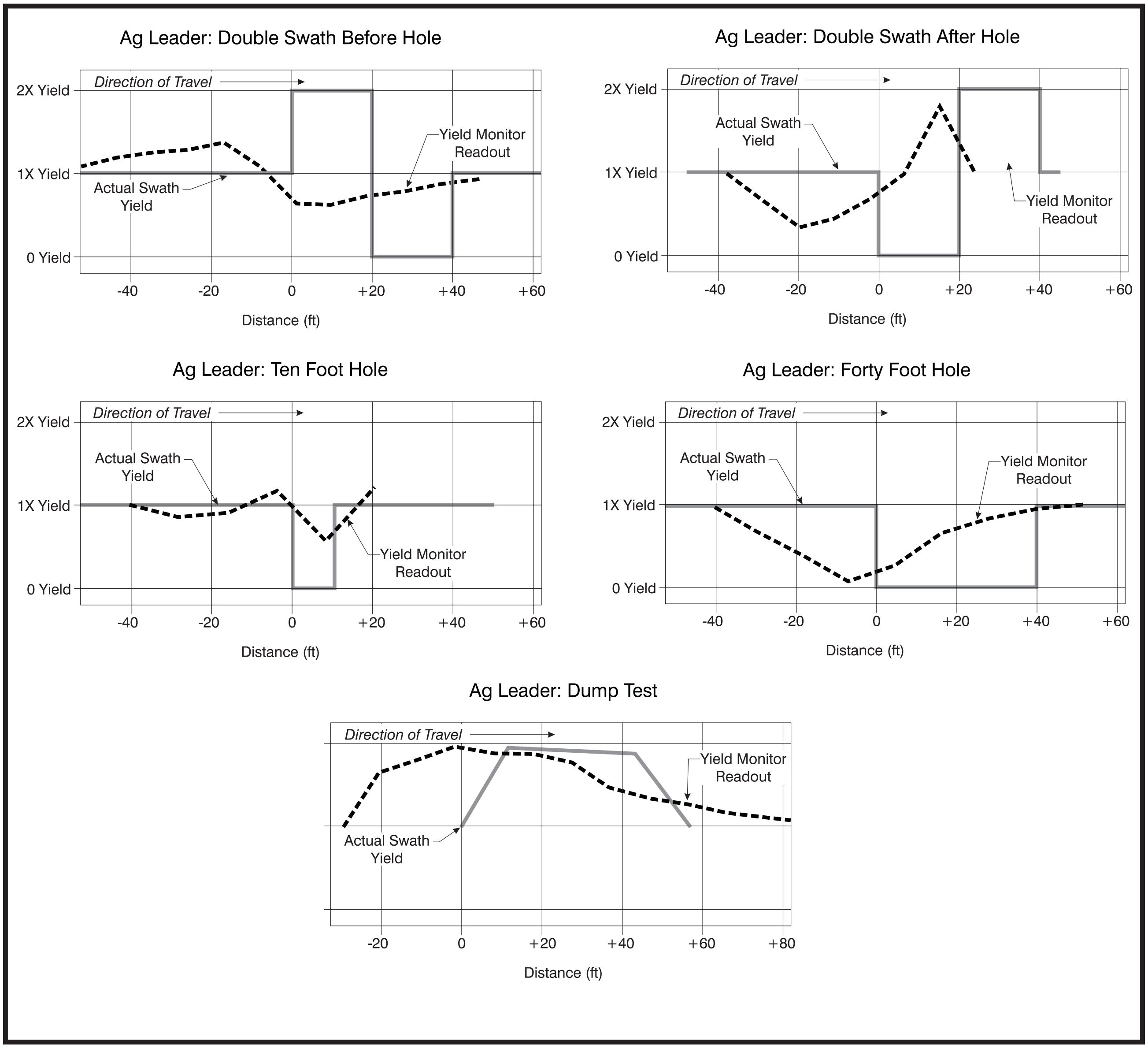


Figure 2. Ag Leader Graphs

Ag Leader antenna positioned on a John Deere 7720 combine.

GreenStar

The GreenStar recognized all "holes" in the swath and did a good job of matching the location on the yield map with the actual location in the field. Results from the double yield tests had the GreenStar locating the yield changes after they actually occurred in the field. This was also true of the yield increases from the dump tests.

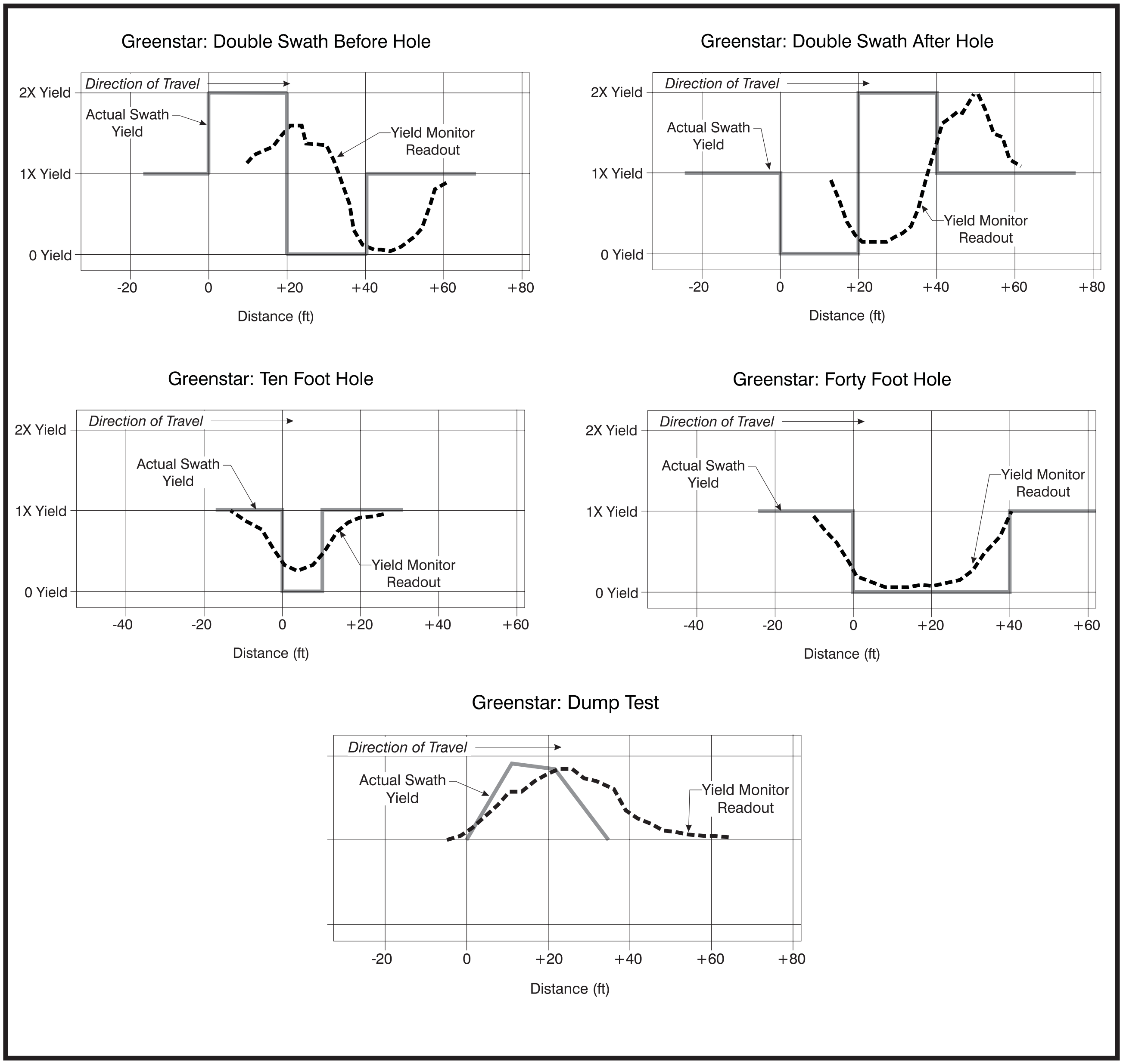


Figure 3. GreenStar Graphs

GreenStar antenna positioned on a John Deere 9610 combine.

Mapping

Once the yield data is collected during harvest, the next step is to enter the data into a computer and make yield maps. With all units this was done by removing the PC Card from the monitor, inserting it into a card reader connected to a computer, downloading the information into the computer, and using mapping software to make maps. The software will print maps in colour, providing the user has a colour printer.

Each unit had mapping software supplied as a part of the system. The Ag Leader used Precision Map 2000 and the AFS used Instant Yield Map. Precision Map 2000 and Instant Yield Map were nearly identical in operation and are discussed as one in this report. The GreenStar used JD Map.

Instant Yield Map/Precision Map 2000

Both of these programs were easy to use. Unloading the data from the PC Card only took a few minutes and was straightforward. Making a map was also easy, and these programs could produce yield, moisture, and elevation maps. There were four degrees of contouring available ranging from individual dots on the map to a fully contoured map that smoothed and averaged the raw data. Moving around each map and between fields was easy.

Both programs used a hierarchy system of fields and farms to arrange the data for many growers over several years. Each grower could have several farms with several fields in each farm. Data from two yield monitors on the same field could be matched within the program. Several types of reports and summaries were available. Instant Yield Map was also packaged with the field management programs Instant Survey and Instant Crops.

Features were available to determine yield averages of different areas in a field, and areas or points could also be deleted. Monitor calibration numbers used to collect the data could be checked for each field.

Both programs could import data from AFS, Ag Leader, GreenStar, and Micro-Trak yield monitors. Data could be exported as a text file.

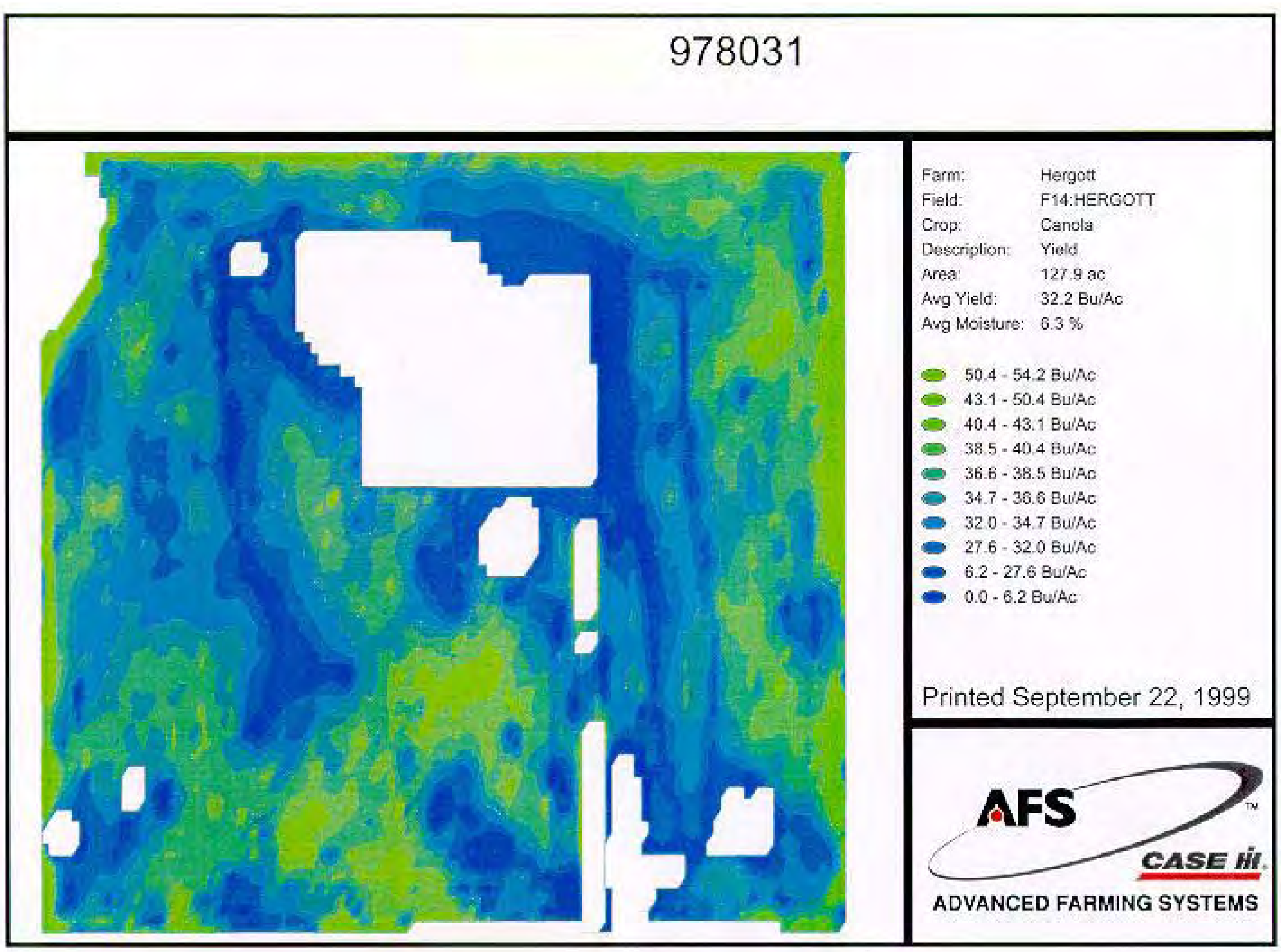


Figure 4. AFS Sample Map

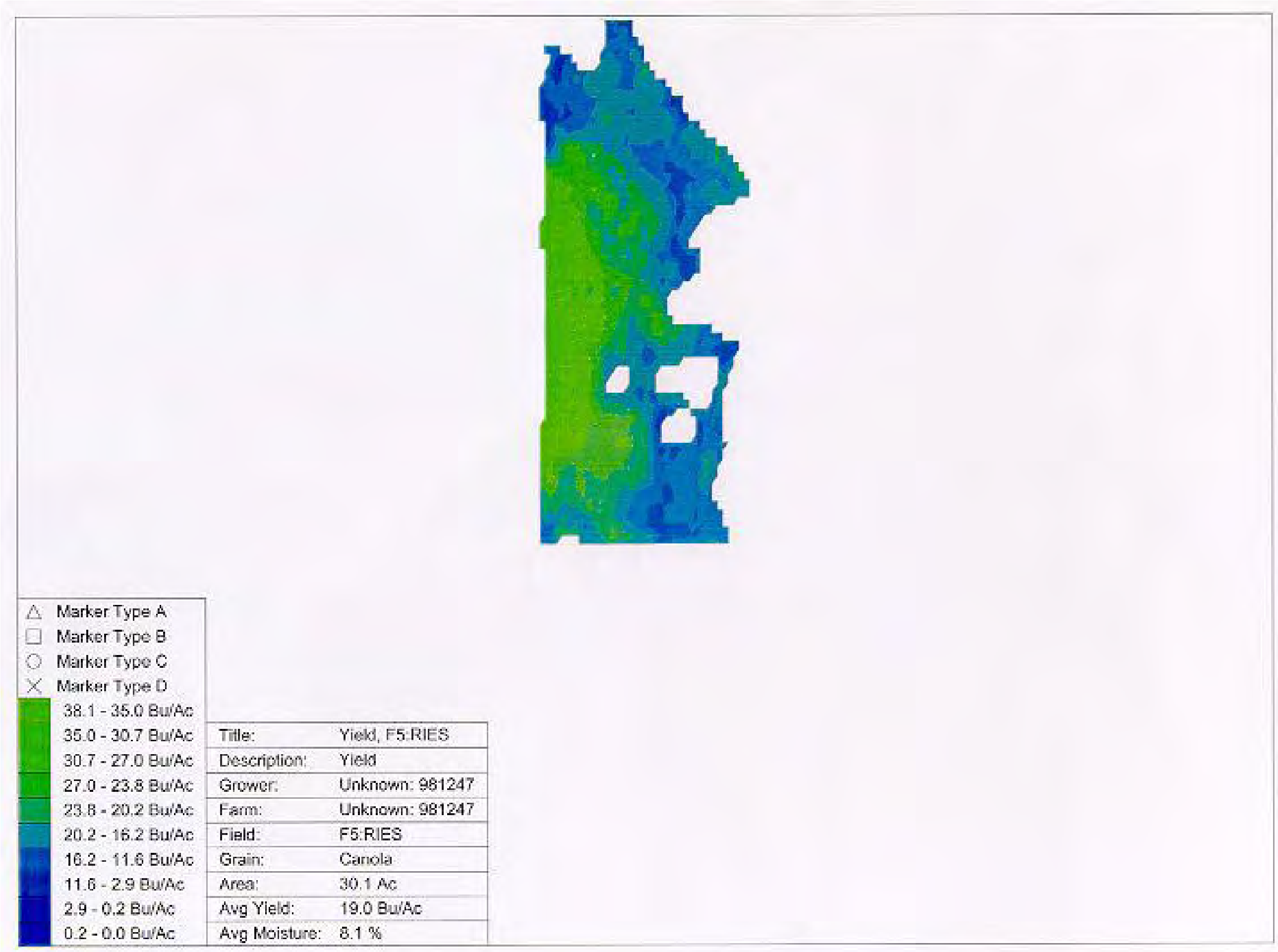


Figure 5. Ag Leader Sample Map

Do You Need a Yield Monitor/GPS Receiver?

A lot of excitement has been generated by the possibilities of this technology, and its potential should not be minimized. The system and a subscription to the differential correction signal can be relatively costly, but the benefits may outweigh the costs, depending on your specific situation.

Yield monitors and GPS receivers essentially provide harvest data. Using other Precision Farming components, such as variable seeding, fertilizing, and sprayer guidance systems, maximizes your benefit by integrating the other input aspects of your operation that affect yield. This integration will reduce the payback period for the system.

Before taking the first step toward investing in this technology, ask yourself the following questions.

- Do you thrive on detailed management and record keeping?
- Are you prepared to make a long-term commitment to using the technology, analyzing the information for trends, and making management decisions based on this information?
- Is your farm big enough that small changes to seeding/fertilizing/spraying could significantly increase your efficiency and profitability, ultimately paying back your initial investment?
- Are you prepared to invest the time and money in other components of Precision Farming to optimize the entire system?
- Are you interested in doing on-farm check-strip research of different varieties or treatments?

A closer look at this technology is justified if you answered "Yes" to these questions.

JD Map

JD Map was easy to use. Unloading a PC Card took only a few minutes and was straightforward. Making a map was also easy, and this program could also make yield and moisture maps. The maps could be displayed as individual yield or moisture points or as a contoured map that smoothed and averaged the raw data. Moving around each map and between fields was easy.

JD Map also used a hierarchy system of fields and farms to arrange the data for many growers over several years. Each grower could have several farms with several fields in each farm. Data from two yield monitors on the same field could be merged within the program. Several types of reports and summaries were available. This program was also used to set up the field and farms that were loaded into the yield monitor via the PC Card. This feature made set up easy, as it could be done on a home computer instead of in the combine cab.

Features were available to determine yield averages of different areas on the field and areas or points could also be deleted. If sections of a field were harvested with different calibration factors, this calibration could be adjusted within the program.

JD Map could export data as a text file, but could not import data collected with other brands of yield monitors.

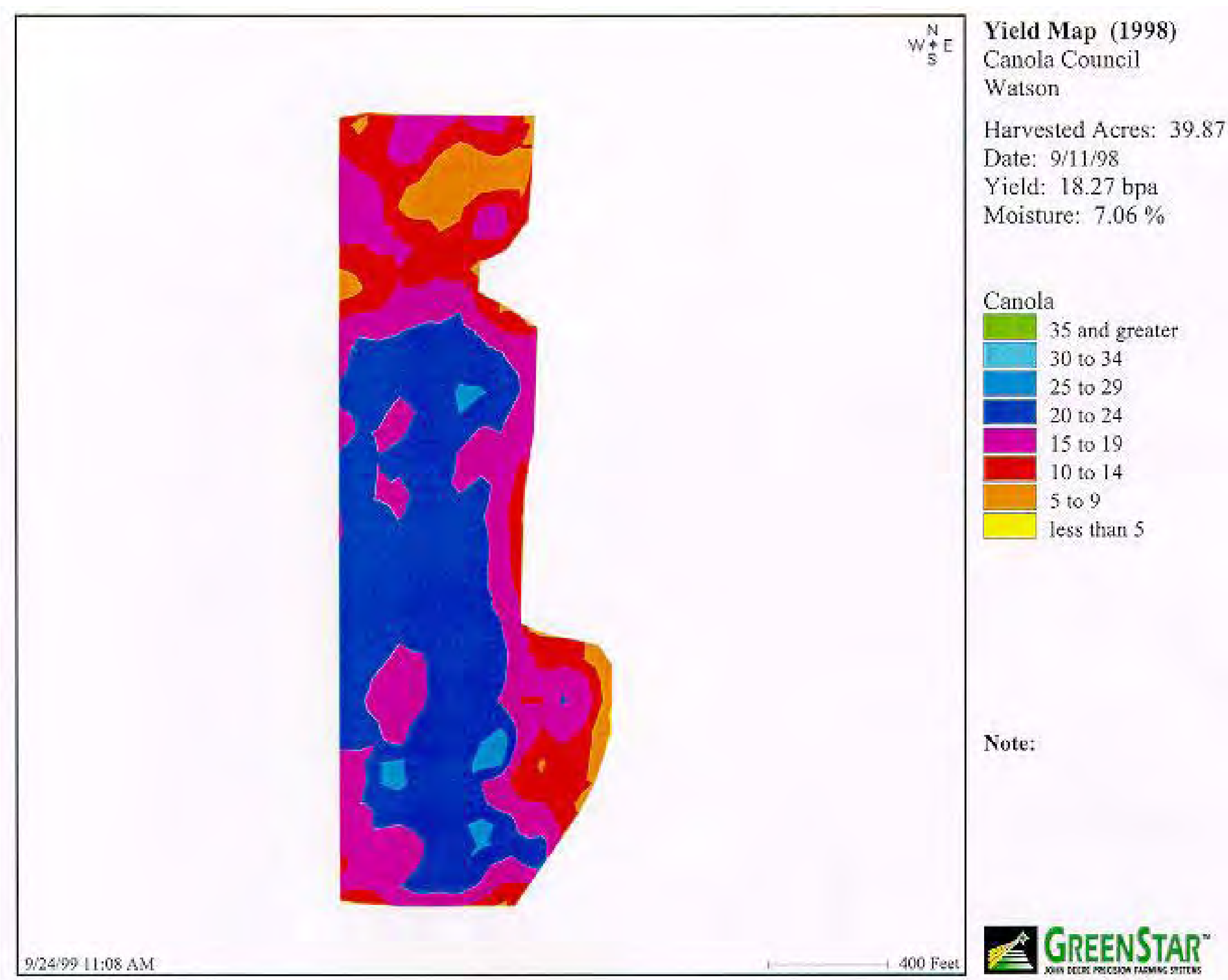


Figure 6. GreenStar Sample Map

Ease of Use

Case IH AFS

The Case IH AFS yield monitor had a 24-button touch keypad and a 2-line LCD display. The display was divided into three areas and each area could be set to display different information, such as instantaneous yield, ground speed, moisture content and so on. The display was easy to read in all lighting conditions. The display was easy to operate, and an audible beep confirmed that a button had been pressed. However, when pressing the top row of buttons, the operator's arm blocked the view of the display. A red light and a series of beeps indicated when the combine header was up and area counting had been suspended. This was convenient, as it informed the operator of the monitor's status without having to look at it.

All of the setup information for the AFS was entered on the monitor itself. This was not difficult, but because of the number of keystrokes needed, doing this in the combine was inconvenient. The monitor could easily be removed from the combine and an AC adapter used so programming could be done at a desk. The monitor automatically logged all mapping and yield data to a PC Card during combining.

With the logging interval set to 2 seconds, about 31 hours of data could be saved on a 1 MB PC Card. Up to 209 hours of data could be saved on a 4 MB PC Card with a 3-second logging interval. The AFS had an optional flagging module that was not tested in this project. This unit could flag up to four items in either a continuous or spot mode.

The Case IH AFS Yield Monitor and display

Ag Leader

The Ag Leader PF3000 had a 15-button touch keyboard and a four line LCD display. Any line on the display could be set to display any available parameter, such as ground speed, instantaneous yield, moisture content, etc. This made the display very versatile and adaptable to different operator's needs. The display was sometimes difficult to read in direct sunlight, but it was very easy to read at night. The buttons were easy to operate, but because the monitor was on a swivel mount, the monitor had to be held from moving with one hand while the other hand was used to press the buttons. An alternate method was to grasp the monitor with one hand and use the thumb for all button pressing, but this was somewhat inconvenient.

A series of beeps indicated when the header was up and area counting had been suspended, but the beep was not loud enough to be consistently heard in the combine cab used for these tests. This limited the usefulness of the audible signal for yield monitor status determination or button press confirmation.

All of the setup information for the PF3000 was entered on the monitor itself. This was not difficult, but because of the number of keystrokes needed, doing this in the combine could be inconvenient. The monitor unit could easily be removed from the combine and an AC adapter used so programming could be done at a desk. The monitor automatically logged all mapping and yield data to a PC Card during combining.

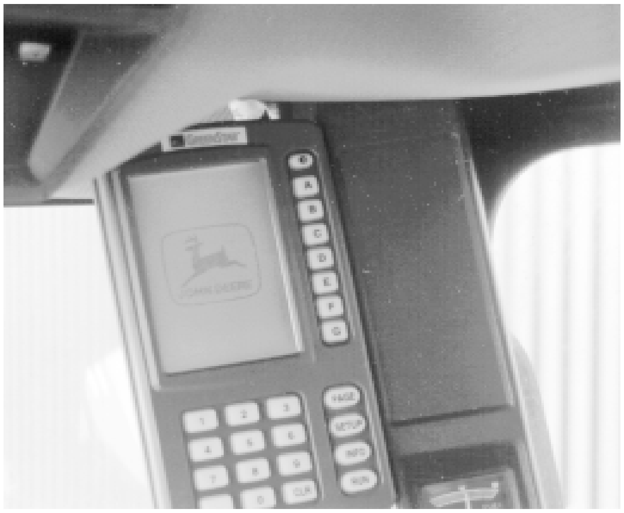
With the logging interval set to 2 seconds, about 31 hours of data could be saved on a 1 MB PC Card. Up to 209 hours of data could be saved on a 4 MB PC Card with a 3-second logging interval. The PF3000 could flag up to four items in either a continuous or spot mode. This feature was easy to use with only a few keystrokes.

In addition to being a yield monitor, the Ag Leader PF3000 could also be used as a controller for variable-rate application of fertilizer, seed or chemicals. This made the unit more versatile, as it could be used for other purposes rather than just for harvest. A site verification feature could also be used to map field boundaries or other simple mapping duties.

The Ag Leader PF3000 Yield Monitor and display.

John Deere GreenStar

The John Deere GreenStar had a 24-button keypad and a multi-line LCD display. There were several screens of displayed data available to the operator, and the buttons and screens were organized in a way that made navigation



The John Deere GreenStar Display.

around the screens easy. This display was easy to read in all lighting conditions. The buttons were very easy to operate and had an audible beep to confirm each button press. An audible beep also notified the operator when area counting had been suspended or when the satellite signal was lost or recovered.

All of the setup for the monitor was done on a computer using the JD Map Program. This required some planning by the operator, as only simple changes to the fields and types of crops could be done once the unit was in the combine. Having to set up the monitor before the start of harvest ensured that the operator was prepared before harvesting a field, and simplified data storage and organization. This setup information was saved from the computer to the PC Card, and then loaded into the GreenStar when the PC Card was inserted into the card reader in the combine.

All data, including yield information, was automatically logged to the PC Card during the operation. About 250 hours of data could be stored on a 5 MB Card. There were 125 flags available to record weed patches, different varieties or rocks. This made the GreenStar quite versatile. Flags could be turned on and off with a few keystrokes.

The GreenStar display could be removed from the combine and used with a controller for variable rate application of fertilizer, seed, or chemicals.

The PAMI test crew sets up the for the dump box test.

NOTES

In Conclusion

All of the systems tested worked well if they were calibrated correctly. Therefore, to make the best of a yield monitor, access to an accurate scale is necessary. Another consideration is that annual cost of a subscription to the differential correction signal is currently in the hundreds of dollars. This cost could be applied to other uses if the GPS receiver was used for other operations, such as variable-rate fertilizer application or sprayer guidance.

Any farmer using precision farming will also need a computer that is powerful enough to run the mapping programs (a Pentium is sufficient) and has a PCMCIA slot to read the PC cards and colour printer to print maps. A PCMCIA slot is a universal expansion slot for accessories commonly found on laptop computers.

Precision farming is an integrated system that involves several components. Yield monitors and GPS receivers are one component of this system, and this project shows that they can work well. Other components, such as variable-rate applicators and decision-making tools, are also needed to make Precision Farming completely effective. The benefits of these systems are expected to be maximized over a period of years.

Recent Updates: Since this project was completed, the following changes have been added to the three units tested.

- Case IH has changed to a different monitor unit that can also be used as an application controller. The mapping software has also been changed so field and farm setup can be done on a home computer and loaded into the monitor via the PC card.
- Ag Leader has updated the monitor operating software so an on-screen map is now available.
- John Deere has added a system that automatically re-zeros the yield about every three seconds. This eliminates the need to perform this operation periodically throughout the day.

More Information

The John Deere and Case IH equipment can be obtained from your local Deere and Case dealers. AgLeader systems are available from Ag Depot, Giannotti Technical Services, and a growing number of independent and non-independent dealers throughout Western Canada.

For more information on precision farming and the equipment PAMI tested, visit their respective websites:

www.casecorp.com/agricultural/afs/index.html

www.deere.com/greenstar/

www.agleader.com/

www.giannottitech.com

www.ag-depot.com/agleader-pf3000.html

Additional copies of this report can be electronically downloaded from PAMI's web site at:

http://www.pami.ca/pamipubs/download.htm

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