Cotton Yield Monitors

The Entrance Exam & Final Exam for Precision Agriculture

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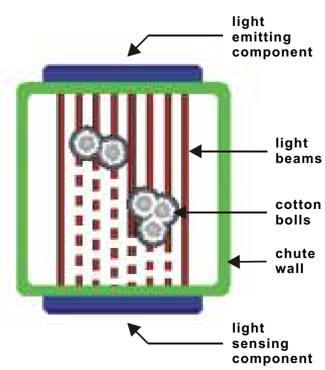
The most essential component of precision farming is the yield monitor – a sensor, or group of sensors, installed on harvesting equipment that dynamically measure spatial yield variability. Yield maps are extremely useful in providing a visual image which shows the variability of yield across a field. Yield maps can be viewed as both the entrance and the final exam for precision farming: as an entrance exam because yield maps can be used to determine if there is enough variability to justify the use of precision farming; as a final exam because they can subsequently be used to determine if precision management strategies such as variable rate application of fertilizers or pesticides were successful.

HOW COTTON YIELD MONITORS WORK

Currently, all commercially available cotton yield monitors use optical sensing techniques to measure yield. The sensors consist of 2 parts – a light emitting component and a light sensing component.



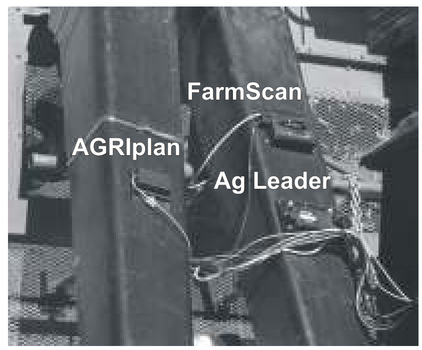
The two components are mounted on opposite sides of a cotton picker's delivery duct such that cotton passing between the emitter and receiver pair reduces transmitted light. The measured reduction in light is converted to pounds of cotton by a calibration formula unique to each yield monitor. Sensors may be installed on 2, 4 or 6 ducts (see table 1 below). Cables from the sensors on the ducts lead to the cab of the picker where a user interface console is installed. The console receives and processes data from the sensors, displays yield information and stores the data for later use.

Table 1. Operating features of the 4 commercially available cotton yield monitors.

Parameter	Ag Leader®	AGRIplan®	FarmScan®	Micro-Trak®
Sensor sets recommend by manufacturer for 4-row picker	2	2 or 4	2	2 or 4
Photo detectors per sensor	5 (see figure)	3 (see figure)	4	8
Method used to attach sensor housing to mounting brackets installed on picker chute	2 thumb screws	hinged	magnetic	hinged with 2 retaining clips
Size of rectangular holes cut into chutes for sensors	8 × 3.75 in (20.3 × 9.5 cm)	4.75 × 3.4 in (12.2 × 8.6 cm)	5.7 × 1.1 in (14.4 × 2.8 cm)	9.2 × 1 in (23.4 × 2.5 cm)
Required external sensors or inputs	head height, fan speed, ground speed optional	none	none; head height optional	head height, ground speed
GPS requirements	DGPS	DGPS	DGPS	DGPS
Data storage card type	standard FLASH PCMCIA	standard FLASH PCMCIA	SRAM 2 Mb PCMCIA	SRAM 2 Mb PCMCIA
Approximate cost of 2 sensor sets excluding DGPS	$5000	$5000	$5000	$5000
Cost of mapping software	$500	included	included	included

YIELD MONITOR ACCURACY

One of the first questions potential users ask is "what is the accuracy of the system?" The trick is to understand how accuracy is defined. Instantaneous accuracy is the accuracy of each yield data point (very difficult to measure). Load accuracy or load error is the accuracy over a basket load of cotton. Field accuracy or field error is the accuracy over an entire field. Field accuracy is most commonly used by sales people when discussing a yield monitor because it is usually the smallest number of the three. This occurs because over an entire field, measurement errors average themselves out. We have conducted several tests over the past five years to measure the field, load, and instantaneous accuracy of commercially available cotton yield monitors.



Agri-Plan, FarmScan, and Ag Leader sensors mounted on chutes 3 and 4 of the NESPAL John Deere 9965 cotton picker during evaluation. Sensors were also mounted on chutes 1 and 2.

In a study to evaluate the instantaneous accuracy of cotton yield monitors, we bagged and weighed cotton passing by the yield monitors for 3, 5, and 7 second intervals which corresponded to 15.6, 26.0, and 36.4 feet of travel, respectively. We then compared the weights of the bagged cotton to the yield recorded by the yield monitors for that same interval. We found that instantaneous accuracy was not affected by yield or by the 3 harvest intervals we selected. Accuracy errors ranged from 0% (remarkable) to 40%. In general, most yield monitor readings were within 15% of the bagged weights.

Most of our work has concentrated on measuring load accuracy during which we found that when properly calibrated and properly maintained, the Ag Leader® and AGRIplan® cotton yield monitors reliably deliver load accuracies of 5% or better. Because their sensors tended to get blocked by dust and trash, the FarmScan® and Miro-Trak® systems were less accurate – generally delivering load accuracies of 10% or better.

Yield monitor manufacturers recommend that their systems be calibrated whenever field conditions change (variety, irrigated versus non-irrigated, defoliation quality, yield, etc.). The fact is that most users find it difficult to calibrate systems several times during a season because of the time required for calibration and difficulty in locating certified scales in close proximity to the fields.

Table 2. Statistical summary of the "real world" test.

Field	Mean Load Error (%) (Standard Deviation)					
	Ag Leader		FarmScan		AGRIplan	
1	3.78	(3.12)	1.64	(1.66)	7.79	(7.41)
2	12.36	(4.43)	7.25	(3.06)	16.28	(9.68)
3	9.02	(2.03)	3.19	(0.95)	2.19	(1.59)
4	11.56	(3.79)	14.16	(3.81)	4.98	(6.11)
5	14.34	(6.34)	24.78	(4.50)	8.94	(5.00)
Season	**9.39**	**(6.01)**	**9.90**	**(9.51)**	**8.62**	**(7.87)**

To test yield monitor response under such "real world" conditions, we calibrated the Ag Leader, FarmScan and the AGRIplan systems at the beginning of a season and then harvested five fields, each with a different variety – some irrigated and some non-irrigated, some with good defoliation and others with poor defoliation. As we anticipated, none of the systems were consistently accurate throughout the season. However, the magnitude of the errors was higher than we expected (see table 2).

Ag Leader tended to over-predict, FarmScan tended to under-predict, and AGRIplan's response was mixed.

In general, yield monitors provide a realistic estimate of the "relative" yield differences within a field; however, when field conditions change from those used in the calibration, the absolute yield estimates in pounds per acre should be treated with caution. The gin weights reported for the modules from the field can be used to see how accurate the yield monitor estimates were and then correct the yield monitor data accordingly. For example, if the total module weights for a particular field were 140,000 lbs and the yield monitor total for the field was 100,000 lbs, all of the yield monitor data would be multiplied by 1.4.

Ag Leader

User interface – PF3000.

Yield monitor sensor in a closed position mounted on the front of a chute.

Yield monitor sensor in an open position. This sensor has 5 photo detectors.

AGRIplan

User interface – Compaq iPAQ®.

Yield monitor sensor in a closed position mounted on the front of a chute.

Yield monitor sensor in an open position. This sensor has 3 photo detectors.

Qualitative Performance

We identified the following strengths and weaknesses of each commercially available system:

Ag Leader Strengths

- multifunctional console, will work with both cotton & grain crops and control a variable rate applicator
- quality of console and sensors surpasses the competitors
- excellent diagnostics built into console
- ability to display many different parameters on console including weights of individual loads
- superior mapping software
- user friendly calibration procedure
- standard data storage card
- thorough documentation & good technical support

Ag Leader Weaknesses

- complicated installation as it uses additional sensors (head height, ground speed, fan speed)
- mapping software must be purchased separately

AGRIplan Strengths

- ability to map spatial yield differences of very small areal extent (e.g. pivot tracks)
- no requirement for additional sensors
- standard data storage card
- *most accurate system evaluated*

AGRIplan Weaknesses

- old console least "user-friendly" – hard to use with limited display options; iPAQ is very flexible but some software features not functional
- documentation barely adequate
- occasional failure of sensors
- hardware sometimes defective
- limited technical support

FarmScan Strengths

- multifuncitonal console
- no requirement for additional sensors
- *simplest to install and maintain*
- adequate documentation

Farmscan Weaknesses

- non standard memory card
- sensors getting blocked by dust and trash
- no automated calibration procedure
- limited display options on console
- technical supported limited by time zone differences (Australian company)

Micro-Trak Strengths

- flexible console
- ability to display weights of individual loads

Micro-Trak Weakness

- problems with blocked sensors
- limited technical support
- non-standard memory card
- complicated installation, uses head height and ground speed sensors, difficult to install interface box under cab

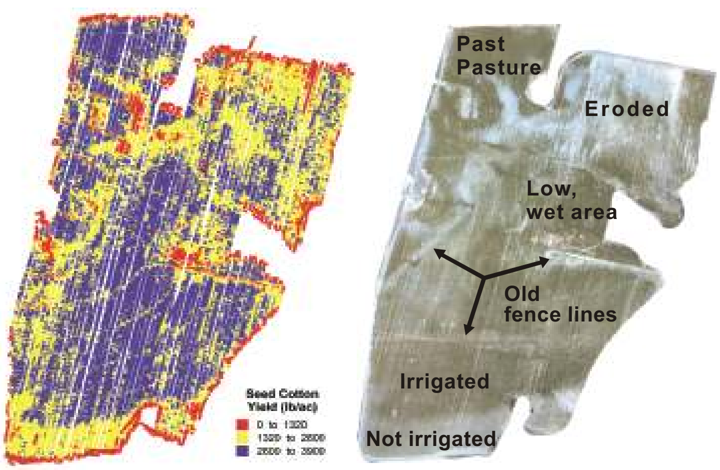
HOW TO SELECT A YIELD MONITOR

Each of the yield monitoring systems we assessed have something to offer the grower interested in creating yield maps. All the systems are capable of producing an adequate yield map provided the system is properly calibrated, operated, and maintained. The issue appears to be how much calibration and maintenance is required for good performance.

All potential users should carefully research prospective cotton yield monitoring systems for the following attributes before purchasing: quality of the product, "user-friendliness", ease of installation, GPS requirements, availability and responsiveness of technical support, skill level required of the picker operator, and time available for downloading data files.

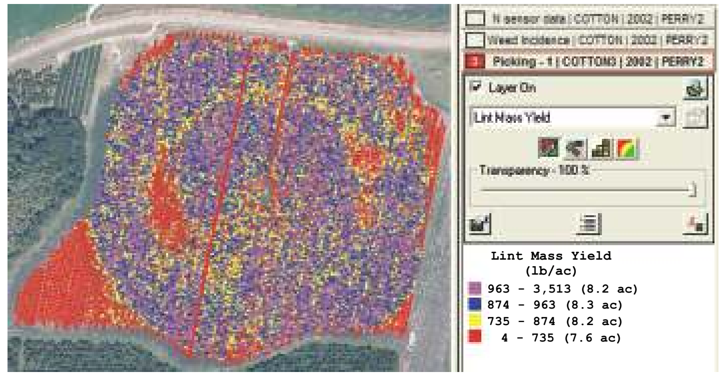
IMPROVE YOUR BOTTOM LINE WITH YIELD MAPS

The yield map (at left, in the figure below), was created with an AGRIplan yield monitor. It is detailed enough to see the tracks of the center pivot irrigation system in the lower portion of the map (arcs). The map also exhibits a high level of yield variability which is typical of most fields.



In this 104 acre field, the variability is attributed to many factors. As shown in the aerial photo (at right, in the above figure), the lower end of the field is not irrigated and consistently yields less than most irrigated areas. The low wet area at the center right of the field generally produces lower yields in wet years because it receives nutrient-rich runoff from the surrounding slopes which results in rank growth rather than high yields. The top center and top right areas of the field are eroded and generally have poor stands and consequently low yields. The top left area of the field was recently brought into production after being in pasture for decades. High soil organic matter and good soil structure resulted in excellent yields. With a yield map, a farmer can compare the yields between highly productive and less productive areas and make appropriate management decisions and answer questions such as: "is intervention a good investment?"

The figure below shows how a yield map can have an immediate management benefit. The low yielding arc in the center of this 32 acre field was caused by partially



blocked sprinklers on the field's center pivot irrigation system. The problem was not discernable while the pivot was operating nor was their an obvious difference in plant growth. But with the yield map, created with an Ag Leader system, the farmer was able to immediately diagnose the problem and even calculate the resulting yield loss. Using SMS Basic, the Ag Leader mapping software, the area of the arc was calculated to be approximately 2.4 acres with an average lint yield of 752 lb/ac and a total production of 1855 lb of lint. The areas immediately adjacent to the arc had an average lint yield of 927 lb/ac. The estimated lost yield was 175 lb/ac or 420 lb of lint. The financial loss from the malfunctioning sprinklers at a price of $0.52/lb was $218. Knowing that this loss will be incurred most years unless repairs are made, is it worth repairing the sprinklers?

The average lint yield of the non-irrigated 2.3 ac corner at the bottom left of the field was 575 lb/ac or a total of 1325 lb of lint which produced $689 of revenue. Compared to average dry-land production costs of $460/acre in Georgia, this area resulted in a net loss of $369. Should this area be farmed?

Providing detailed information which can be used to make management decisions based on their financial impact is the great advantage of yield monitors – in cotton or any other crop. The best decisions can be made if yield maps are available for two or more years.

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