NATIONAL COTTON COUNCIL

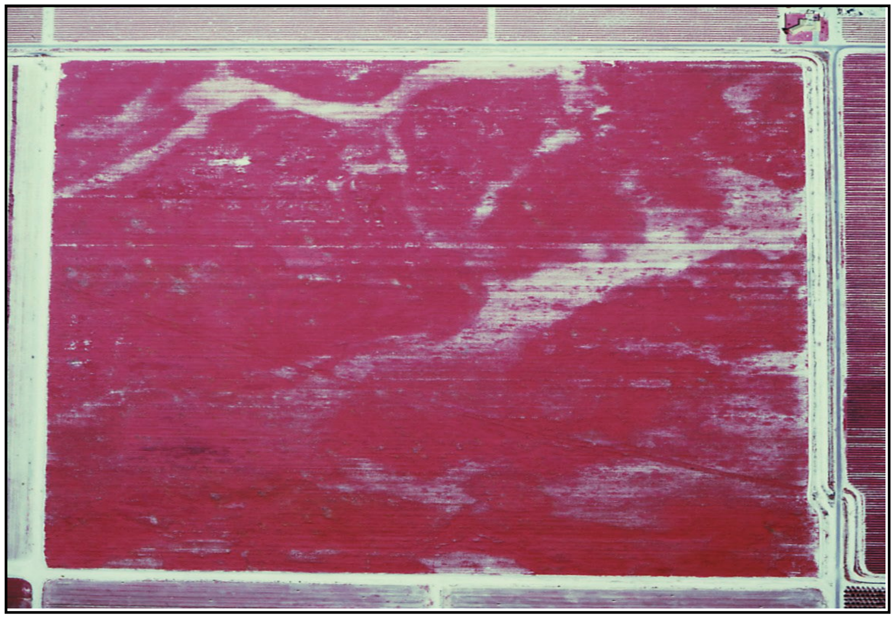
Cotton Physiology Today

Newsletter of the Cotton Physiology Education Program

Volume 9, Number 2, 1998

Precision Agriculture's Value

Precision farming has been talked about, tried by some, and has aroused the curiosity and hopes of many. Just how useful is precision farming? What help does it bring to a cotton grower trying to reduce production costs and increase yields? Researchers from all regions of the U.S. Cotton Belt comment here about how precision ag is currently helping growers and how their experiments are designed to further enhance the value of precision farming.



R Plant

Figure 1. False color image of California cotton field.

Remote Sensing: Value in a Bird's-Eye View

A false color image of a cotton field in Fresno County, California is shown in Figure 1. The red parts of the field are good stands of cotton. The gray streaks are poor stands due to sandy soil. If a grower suspects that his field is not uniform, he can contract with an aerial photographer to obtain false color images such as this one. [The picture is part of a set that costs about $40 per picture plus about $300 for the cost of the airplane.] It is a simple matter to estimate yield loss by getting an 8.5 by 11 inch print of the picture, laying a piece of graph paper over it, and counting squares. Using this method, we estimated that the grower lost about $11,000 in lint yield from the sandy areas.

Remote sensing means gathering data about something without actually touching it. The use of a hand-held infrared gun for irrigation scheduling is an example of remote sensing. In areas of the Cotton Belt that rely on irrigation, efficient use of limited water resources is a must to maintain profitability. In this

INSIDE:

Remote Sensing 13
Site-Specific Management...... 16
Variable Rate Application 17
Yield Monitoring 18
Compatibility Caveat............... 19

The Cotton Physiology Education Program (CPEP), now in its ninth year, is funded by a grant to the Cotton Foundation by BASF, makers of Pix®Plus plant regulator. CPEP's mission is to discover and communicate more profitable methods of producing cotton.

AUTHORS:

Anne F. Wrona (editor), National Cotton Council; Judith M. Bradow, Phil Bauer, Stephen J. Maas, E. John Sadler, USDA/ARS; Rex Clark, Craig Kvien, Stuart Pocknee, Dan Thomas, University of Georgia; Ahmad Khalilian, Francis Wolak, Clemson University; Juan Landivar, Steve Searcy, Texas A&M University; Richard M. Johnson, Texas Tech University; Richard Plant, University of California; Gene Stevens, University of Missouri; Tommy Valco, Cotton Incorporated

article, we focus on remote sensing from a high altitude, either from an aircraft or satellite.

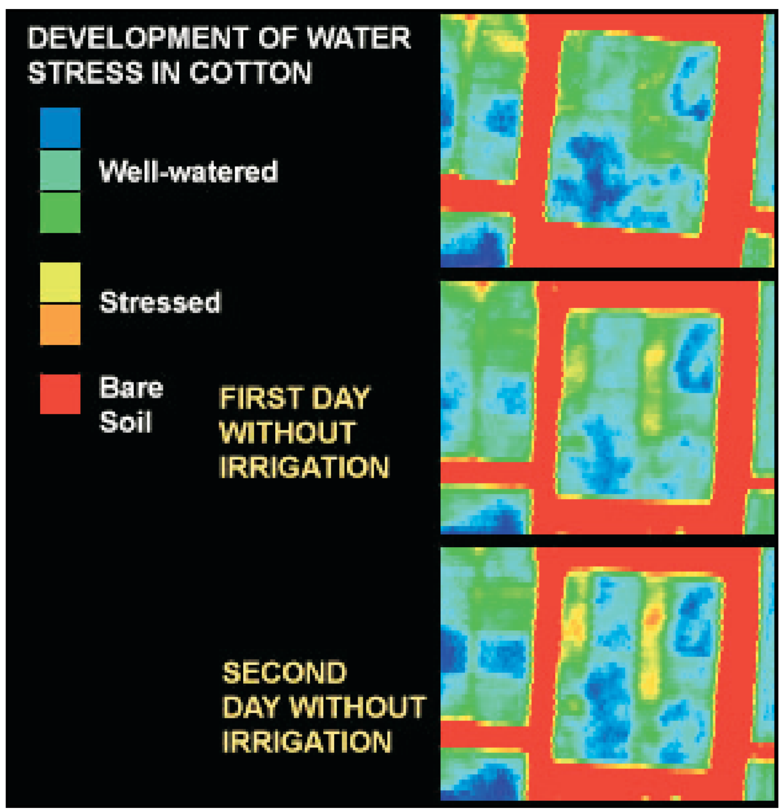
High altitude remote sensing uses sensors that measure electromagnetic radiation such as light. Electromagnetic radiation is classified according to its wavelength. For example, visible light has a wavelength of between about 0.4 and 0.7 micrometers (0.00001576 to 0.00002758 inches), near infrared radiation is between 0.7 and 1.0 micrometers (0.00002758 and 0.0000394 inches), and thermal infrared radiation is around 10 micrometers (0.000394 inches), television and radio are around 100 meters (109.4 yards), and so forth. Any electromagnetic radiation can, in principle, be used in remote sensing, but as a practical matter for crop management the most commonly used are in the visible light, near infrared, and thermal infrared radiation ranges.

Thermal infrared radiation is emitted from an object at a rate that depends on the object's temperature. The infrared gun and the "night vision" goggles seen in spy movies both detect thermal infrared radiation. Satellites such as LANDSAT measure thermal infrared radiation. The temperature of a crop canopy relative to ambient temperature depends on crop water status. This relationship has led researchers to develop a thermal infrared radiation-based crop water stress index that can be used to measure crop water stress level and schedule irrigations. Commercial services now provide thermal infrared radiation images of fields for this purpose.

Thermal imaging was used to obtain the remotely-sensed image of a cotton canopy at the USDA laboratory in Shafter, California shown in Figure 2. Because the change in cotton canopy temperature can be observed well before changes in the height or biomass of the crop canopy, canopy temperature is a sensitive indicator of crop stress. By knowing her cotton crop's canopy temperature, the careful manager can schedule irrigations before her crop is harmed by water stress.

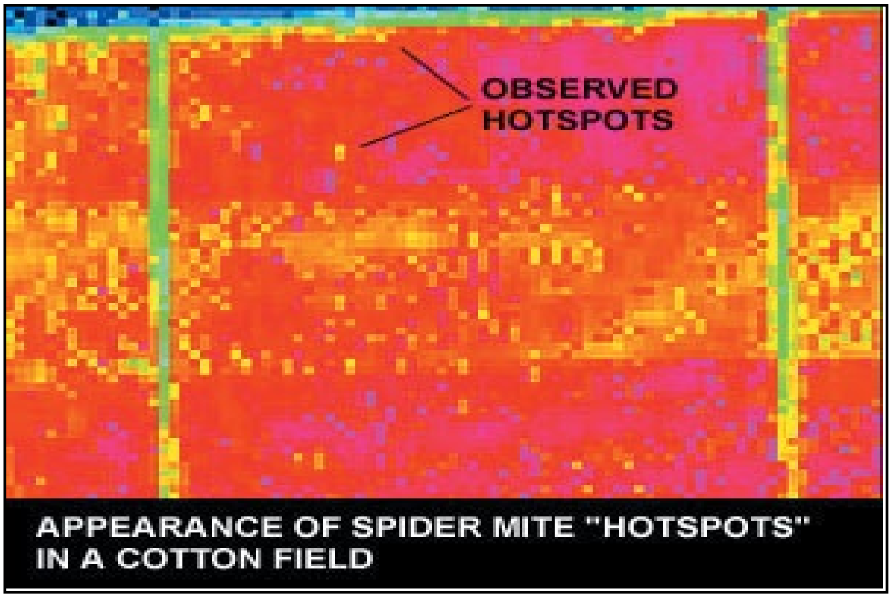
A more difficult task for remote sensing is the detection of pests in cotton at an early enough stage so the pests can be controlled before significant loss in productivity occurs. A high-resolution, false color image of a cotton field experiencing the onset of a spider mite infestation at Shafter, California is shown in Figure 3. Localized hotspots of insect activity corresponded with those noted by field scouts. These areas are only a few feet across, but are clearly visible as yellow spots as a result of the insects' feeding on the leaves of the crop canopy. Although remote sensing imagery may not identify specific pest problems, it can call a scout's attention to suspicious areas in the field which may represent the onset of pest problems. When managing large fields that would normally be difficult to scout completely on foot, remote sensing can be particularly helpful.

Visible light and near infrared radiation are reflected rather than emitted and thus depend on the crop's reflectance rather than its temperature. Healthy vegetation absorbs most red and blue light for



S Maas

Figure 2. Thermal image of cotton canopy at Shafter, California. Frames top to bottom show progression from a well-watered canopy to first and second days without irrigation.



S Maas

Figure 3. High resolution, false-color image of a cotton field at Shafter, California showing onset of spider mite infestation (yellow spots).

photosynthesis and reflects most near infrared radiation. Stressed vegetation reflects proportionately more red light and less near infrared radiation, providing an indication of the crop's vigor. Images of vegetation that include near infrared radiation are usually displayed as "false color" images in which the near infrared radiation is displayed as red, red light is displayed as green, and green light is displayed as blue. In such pictures, vigorous plants look red because they reflect so much more near infrared radiation than red or green light.

Using the remotely-sensed image data in a quantitative analysis requires that the image be scanned or taken with a digital imaging system and imported into specialized software. Images made from a digital system are more expensive, but have the advantage that they are a more accurate representation of actual conditions on the ground. At present, very little commercial image analysis software specifically for crop management is available, although it will be in a few years.

We are developing equations that link remotely sensed data with cotton plant mapping data to provide better estimates of plant growth rates and nutrient requirements, cutout date, and defoliation date and coverage. Until these methods are satisfactorily worked out, interested individuals can explore the possibilities of working with digital, remotely-sensed data by scanning the pictures on a flatbed scanner and importing them into imaging software such as Adobe Photoshop or JASC Paint Shop Pro.

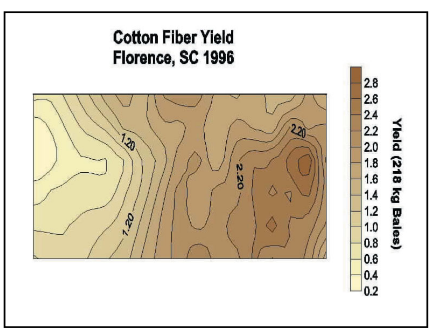
You do not need any expensive software to make effective use of the images, however. Just by taking them into the field and visually correlating them with what you see on the ground you can determine where to focus your scouting and where the problem areas of your field are located. They provide a "bird's eye view" that is a very useful complement to what you can see on the ground.

Site-specific Management and Cotton Fiber Quality

Many growers are already practicing site-specific management by improving drainage in wet zones, leveling portions of fields, and applying fertilizers and pesticides only where and when needed. How do these different management zones in a field relate to fiber quality?

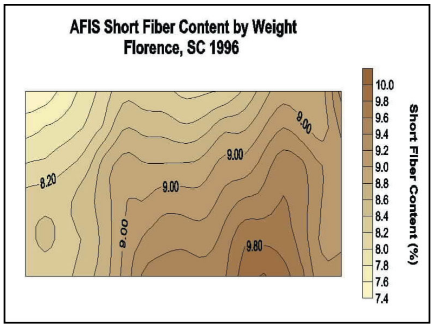
USDA researchers divided a field in Florence, South Carolina into grids of 25 foot intervals. Soil samples (from 0 to 8 inches depth) were taken from each grid or section. The Upland cotton variety, LA887, was planted, hand-harvested, saw-ginned and classed for each grid section. Because some of the low-yielding grids did not produce enough fiber to be classed by HVI (High Volume Instrumentation), AFIS (Advanced Fiber Information System) was used to determine the fiber properties.

Yield (Figure 4), soil property, and fiber quality maps (Figures 5 and 6) were made of the field. The yield map looks very much like a topographic map that one might refer to before planning a backpacking trip. The contour lines denote areas of the same yield. Lowest yields were at the left edge of the grid; highest near the center of the right side of the grid. Average yield within the grid was 1.58 bales.



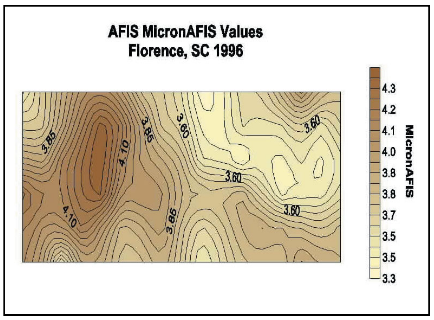
JM Bradow, R Johnson, P Bauer, EJ Sadler

Figure 4. Variability in yield of cotton from researched field in Florence, South Carolina. A 218 kg bale is equivalent to a 480 lb bale.



JM Bradow, R Johnson, P Bauer, EJ Sadler

Figure 5. Variability in short fiber content from researched field in Florence, South Carolina.



JM Bradow, R Johnson, P Bauer, EJ Sadler

Figure 6. Variability in micronaire from researched field in Florence, South Carolina.

Usually differences in cotton staple length have been attributed to varietal differences and not to growth environment. However, in this field, different soil properties throughout the field resulted in a range of fiber lengths by weight from 0.86 to 1.00 inches, and an AFIS-determined staple length average of 0.93 inches (Figure 5). It is interesting to note that the portion of the grid with the lowest yield contained a zone of lower short fiber content. The short fiber content increased as the yield increased toward the lower right side of the grid map. These results indicate that there are variations in short fiber content within varieties and that short fiber content can be influenced by the growth environment.

In addition to staple length, producers are concerned about micronaire. Price penalties are assessed for micronaire levels outside the 3.5 to 4.9 range. Micronaire is partially determined by fiber maturity and by variations in the growth environment that affect boll maturation. Again, clear differences in micronaire can be seen across the study grid (Figure 6). MicronAFIS (the AFIS version of HVI micronaire) ranged from 2.78 to 4.73 in the grid sections with an average of 3.78. The sites that produced the highest yields also produced the fiber with the lowest micronaire (micronAFIS).

These yield and fiber property maps represent a single year in a preliminary study of the applicability of precision agriculture to cotton production. Additional comparisons of the soil property maps with the fiber quality maps suggest complex interactions occur. However, even in their "rough," preliminary form, these maps can help producers.

For example, when the grid sections that produced fiber within the non-penalty micronaire range were identified, it was readily seen that the right side of the grid contained the largest percentage of the non-penalty fiber. By harvesting the field in sections, as suggested by the maps, both quality and profit can be optimized.

Variable Rate Applications to Optimize Inputs

In cotton production, plant height can be used as an integrator of the environment. Before bloom, plant height reflects changes in physical soil properties that affect water availability. After bloom, plant height responds to physiological stresses caused by the developing fruit load. It is also sensitive to insect damage. [Insect damaged crops grow rank, particularly in well watered and fertilized conditions.]

Texas researchers are using plant height to assess variability in growth potential within cotton fields. Two methods of obtaining plant height are being used. One method uses a tractor-mounted sensor to measure plant height continuously while traveling through the field. The other uses a crop simulation model.

MEPRT is a computer program developed by Texas A&M researchers to estimate the optimum rate of PIX application. The model determines the application rate by estimating the amount of product needed to increase the concentration to a predetermined level. An estimation of plant weight is needed to calculate the amount of product to apply. The program estimates plant weights with a regression model that uses plant density, number of main stem nodes, and plant height as independent variables.

A strong correlation between plant height and weight exists prior to the development of the fruit load. Plant height is plotted in relation to total plant weight for eight cultivars ranging in maturity from early to full-season. The relationship is linear until 77 days after emergence (DAE, early bloom). As the boll load develops, mainstem elongation rate is reduced and eventually stops. However, plant weight continues to increase reflecting reproductive weight gain. Plant height and weight can be used up to the second week of bloom to estimate rates of Pix required.

In Missouri, dealing with soil acidity and water stress are concerns to growers maximizing cotton yields and reducing costs. By maintaining proper soil pH, growers can prevent aluminum and manganese toxicity in cotton and, at the same time, maximize the availability of nutrients such as phosphorus.

Starting with a field with an average soil pH_{salt} of 4.4, researchers made variable rate applications of lime (between 1 and 5 tons per acre) to correct the soil environment to maximize the plants' uptake of required nutrients and minimize uptake of toxic elements (Table 1).

Cotton lint yields were significantly different between treatments (Pr>F 0.06). Gross returns were calculated based on $0.70/lb lint. Costs of soil sampling, testing and lime application were prorated over three years. Costs of soil sampling were based on a survey of local consultants and fertilizer dealers. Average cost of soil sampling and analysis on 2.5-acre grid was $8.50 per acre and variably applying lime was $1.50 acre. Soil sampling and analysis for 20-acre composite samples was $3.75 per acre.

In a similar experiment on a field that started with an average soil pH_{salt} of 5.0, researchers did not find a significant increase in cotton yield by variably applying lime.

A simple irrigation-alert system has been used in parts of Missouri. Tensiometers that measure the moisture content of the soil in which they are buried are wired to flags that pop up to alert farmers that the soil in that particular part of the field has dried to the point of needing irrigation.

Georgia researchers and growers, in cooperation with Gold Kist, have made variable rate applications of fertilizers, nematocides, and lime to cotton. They based their applications on soil sampling of 1 acre grids to determine rates. Cost savings in decreased chemical useage more than paid for the soil sampling and variable rate application technology.

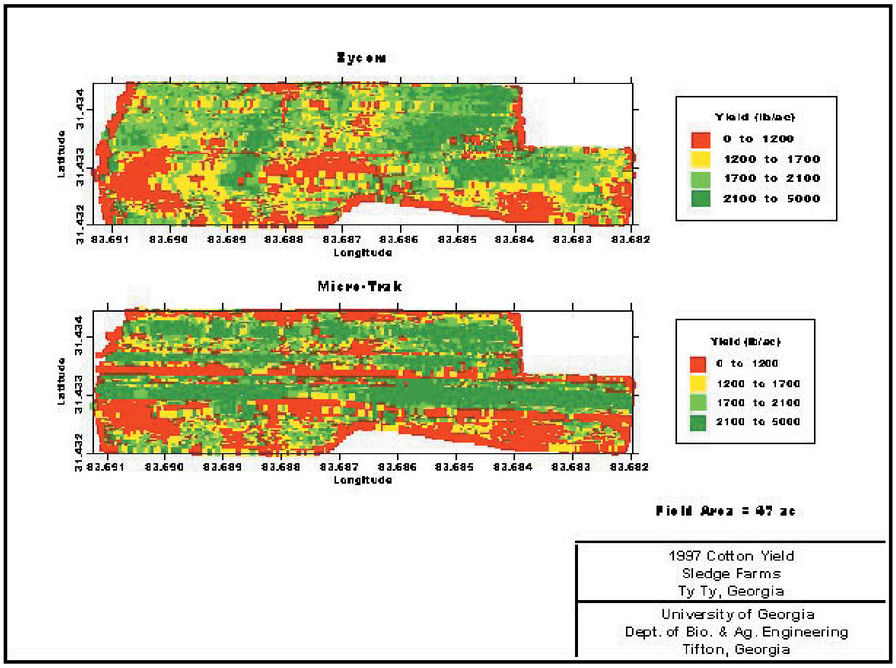
Table 1. One year average yields and gross returns per acre from liming a 125-acre irrigated cotton field in East Prairie, Missouri. G Stevens

Method of Application	Lint yield 1996 average 1996	Tons of lime applied in 1996	Gross return on lint	Prorated lime costs application costs	Prorated sample, test, and lime sampling and lime	Gross return after
Uniform from 20-acre composite	481	2.8	$336.70	-$18.67	-$1.25	$316.78
Variable rate from 2.5-acre grid points	493	2.1	$345.10	-$14.00	-$3.33	$327.77

Yield Monitoring

Yield monitoring has been the beginning point for many grain farmers. They have collected data over several seasons so that trends may be established and have avoided looking for answers in data from just the current year. Yield monitoring, or yield mapping, is one of the most essential components of a fully integrated precision farming program. To date, reliable cotton yield monitors have not been available.

As cotton yield monitors are improved and brought to commercial use, creating “profit maps” will become an option for farmers (Figure 7). This example profit map from a Georgia peanut field shows the value of knowing yield variability and potential across one’s field. Clearly the grower lost money in some parts of his field and had varying degrees of profit in other sections. In future years, he may decide it wise not to farm the entire tract and to let some of it revert to wildlife habitat. In that way he can reduce his costs and concentrate on those areas of his farm that maximize his bottom line.



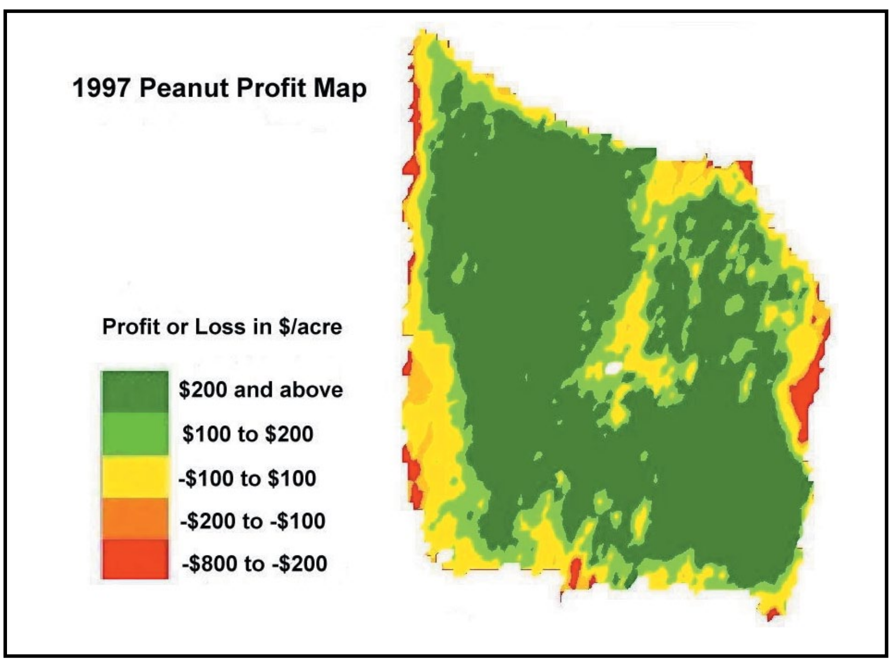
D Thomas

Figure 8. Yield maps for trial yield monitors from Zycom and Micro-Trak, 1997 season.

In the 1997 crop year, at least two commercial yield monitors were available for cotton. Both the Zycom and Micro-Trak monitors use a similar light-based approach. Light emitters and receivers are mounted on either side of the cotton shoot or duct. As cotton is blown up the duct and blocks the light, computer algorithms determine the yield by how often and how long the light is blocked.

Limited field evaluations in Georgia indicated the capability of these systems to monitor medium to low cotton yields (Figure 8). Each system had benefits and disadvantages which will be used to redesign the monitors. Another player in the 1998 season is TSI which has designed a monitor which uses ultrasound to determine yield.

South Carolina trials in 1997 with yield monitors showed good accuracy in clean conditions. However, keeping the sensors clean proved a challenge. Trash and dirt accumulation on the sensors (Figure 9) interfered with accurate measuring of yields. Fine-tuning of these early yield monitors should eliminate these problems.



D Thomas

Figure 7. Peanut profit map showing the actual costs and profits of producing peanuts on a variable Georgia field.

F Wolak

Figure 9. Trash and dirt accumulation on the infrared sensor interfered with accurate yield measurements.

Research and development on other cotton yield monitors is continuing. A load-cell based system is being tried in Texas. A University of Tennessee prototype is working on another light-based system. Additional cotton yield monitor alternatives should be available in the near future.

Compatibility Caveat

The technologies involved in precision agriculture still have some distance to travel before they achieve maturity in usability. One of the main problems is hardware and software compatibility. [By hardware we are referring to all physical components of precision agriculture such as yield monitors, computers, variable rate controllers, memory cards, etc. Software includes all the programs that operate these devices and run word processing, spreadsheet, Internet access, and accounting applications, etc. on your computers.] Sometimes hardware and software do not "speak to each other" (transfer data) as they are supposed to. Examples of such incompatibilities currently are plentiful and include, but are not limited to, the following: 1) the John Deere flash card will not work in an AgLeader yield monitor, 2) a Falcon spreader controller requires different commands than a Mid-Tech controller, 3) an Agris FieldLink file cannot be directly read by a MapInfo GIS package. Watch out for such incompatibilities before making your purchases so you can avoid expensive duplication of components or becoming trapped with a certain supplier once their data is in that supplier's format.

Although there is nothing wrong with using a single equipment supplier, if he can meet your needs, there are some compelling reasons why you may want to avoid such a situation at this time. For precision ag applications, the needs of individual farmers are so different, it is unlikely that any one supplier will have the exact system that will suit his needs. Add to this the fact that the technologies are changing so rapidly and in directions few can predict. It is quite unlikely that the precision ag systems of today will be the same as those used in the future.

Everyone agrees that the data collected is more valuable than the tools used to collect it. So what happens to your data when you change technologies? This is a crucial question. If you have planned well and use technologies that store your data in standard formats, you should have little trouble transferring the data to your new system. If your data is stored in an obscure proprietary system, however, you face an uphill battle. In the worst case scenario, you may have to simply abandon everything you did with the old system.

Precision agriculture standards are "shaking themselves out" over time. If you use a little foresight and common sense, you should be able to avoid getting caught up in a dead-end situation. Here are some tips to help you avoid the modern day equivalent of buying Beta video tapes:

1) support products that adhere to open standards
2) look for standards that are applied at a wider level than just precision agriculture
3) be wary of systems that claim to be a "total solution," especially if they use proprietary formats
4) if you cannot get software that uses open standards natively, be sure that it has the ability to at least import and export in one or more standard formats (Table 2).

Table 2. Current safe standards to look for when purchasing precision ag equipment. C Kvien

Geographic data	WGS 84, NAD 83
Yield monitor data	AL 2000 format
Global positioning systems (GPS)	NMEA 0183
GPS differential correction data	RTCM 104
Geographic information systems (GIS) file formats	Shape files, MID/MIF, GeoTIFF, Generic ASCII
Hardware	DB9 connectors with RS232 transfer protocol

Data Ownership and Management

Growers often use outside services for collecting data like soil nutrient levels, custom harvested yield maps, scouting reports, and more. Even if a grower does not currently have a computer system to display and manipulate the information, it is likely that somewhere along the line he will. Growers must demand that they be supplied copies of their information in both paper and electronic format. At a future date they will be able to reference and analyze their own data. They will also be able to have a third, independent party analyze or use the data. Precision agriculture data needs to empower, not entrap.

Conclusions

Precision ag is still the "new kid on the block." Much research is occurring to help refine the equipment and technologies currently available to carry precision farming of cotton successfully into the next century.

Mention of a specific product does not imply endorsement of it over any other product.

Additional copies $2 each.