

Precision Farming

An Introduction

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This document introduces the technology and terms describing the farm management practice called precision farming. An introduction to precision farming and how it can be used, as well as descriptions of the major components, a glossary of commonly used precision farming terms, and a list of agricultural suppliers that provide precision farming services are presented. The information has been tailored more or less to the row crop farmer, but reference to other farming operations are also discussed.

What Is Precision Farming?

Precision farming (PF) has emerged as a management practice with the potential to increase profits by utilizing more precise information about agricultural resources. In row-crop production, this means the management of input variables, such as application rates, cultivar selections, tillage practices and irrigation scheduling. *PF* management became feasible from a large-scale perspective through the development of new technologies. The technology has now been developed so that field information (such as yield and application rates) can be controlled and monitored about every 3 feet in the field at a reasonable cost to the farmer. Pesticides can be applied in areas of pest infestation, reducing the amount of pesticide applied and reducing the amount of pesticide which may potentially impact the environment. Fertilizer and lime can be applied only where needed. Plant population can be chosen to optimize soil nutrients, and plant variety selection can be chosen to take advantage of the field conditions. Crop yield can also be monitored to create maps that show the high and low production areas of a field for improved management decisions.

PF first found wide-spread acceptance as a management practice in the corn belt of the Midwest, helping to increase corn, wheat, and soybean yields and reduce production costs. However, the principles of *PF* management can be applied to almost any agricultural commodity. Current research in the Southeast is examining *PF* practices for several commodities including citrus, cotton, peanuts, vegetables, and livestock. When looking at row crops, the following operations require decisions: 1) application rate and time for fertilizers, lime, and pesticides, 2) planting dates, populations, and depth, 3) tillage practices, and 4) cultivar selection. Each of these decisions has generally been controlled at the field level, even though it has been known for many years that within-field variation in soil characteristics, topography, drainage, etc., results in yields below field capacity.

Precision Farming Technologies

There are five major components of technology used for *PF* management practices. They are *Geographical Information Systems (GIS)*, *Global Positioning Systems (GPS)*, *sensors*, *variable rate technology (VRT)* and *yield monitoring (YM)*. A brief description of the individual technologies is provided in the following paragraphs.

GIS

GIS refers to computer software that provides data storage, retrieval, and transformation of spatial (field) data. *GIS* software for precision farming management will store data, such as soil type, nutrient levels, etc, in layers and assign that information to the particular field location. A fully functional *GIS* can be used to analyze characteristics between layers

to develop application maps or other management options. The field location is usually stored by the latitude and longitude of that position, which is typically found using a *Global Positioning System (GPS)*. Several maps can be created showing the variability of nutrient levels, soil type, topography, pest incidence and yield. Most *GIS* software packages also have some form of data smoothing or contouring (*kriging*). The accuracy of a smoothed map depends on the sampling or distance between sample points (location where data was taken) and the smoothing technique. It should be noted that all maps are not generated from *GIS* code. Depending on your level of *PF* need, a *GIS* may not be required.

Software to create these maps are generally of three types. First is software that automatically creates maps from a given data set with a minimal ability to modify the default map attributes. This is technically just mapping software. Examples of this software include JMap, Agleader Precision Map 2000, Micro-Trak utilities, and FarmWorks Quick Yields. A second classification of software provides more flexibility to change map parameters and create maps of several attributes (designed from ground-up for farm *GIS*). Examples include SGIS, Crop Growers VisAg, Farmsite, and AgINFO. The third classification of *GIS* software has a front-end added to it so that it can be used for agricultural mapping, such as SSToolbox, FarmHMS, RDI AgMAPP, and AgLink. Some software requires several days of training to use it appropriately. It is advisable to enlist the aid of an expert to help determine the best software for your needs. If your needs exceed your capabilities, ser-

VICES are available for the creation of maps. In the case of commercial yield monitors, the mapping software that comes with the yield monitor is probably adequate. However, a combination of software packages may be necessary as your needs change.

Whether you decide to create your own maps, or enlist the aid of an expert, it is important to analyze maps carefully. Figure 1 is a map of peanut yield distribution. In this case, a yield monitor measured yield at one second intervals and then stored that yield amount at the location in the field determined by the *GPS*. The amount of variability displayed in a map depends on the variability within a field and the number of discrete categories set up. In Figure 1 and 2, a color scheme was chosen to show at least four distinct categories. Dark green represents the highest peanut yield (>6000 lbs/acre). Light green represents

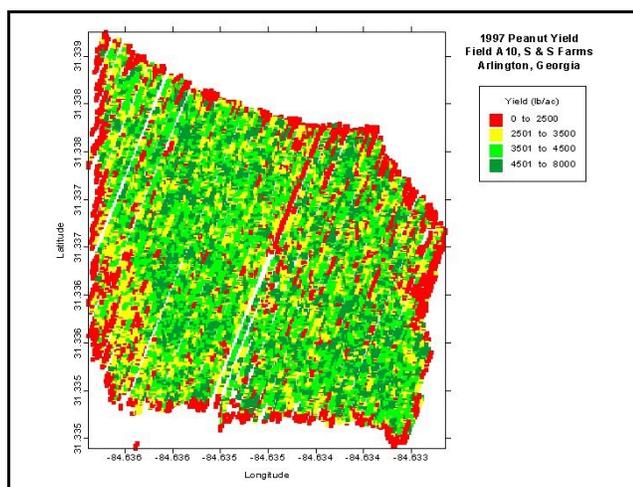


Figure 2

a range of 4800 to 6000 lbs/acre. Another map (Figure 3) shows the same data using a different color scheme. In this case, a color was removed, and the yield range for each color was changed. In figure 3, dark green still represents a peanut yield of >6000 lbs/acre, but the light green represents a yield of 4500 to 6000 lbs/acre. By choosing slightly different ranges, the yield variability looks different. Different ranges should be examined to verify that no variability is being masked or accentuated by the choice range for each color.

For *GIS* to be fully functional, additional maps of fertilizer required, aerial photographs, etc., can be added. The key to management with the *GIS* is to be sure variables are directly associated with a particular problem before making major changes. Several years of maps may be necessary to find field problems in our variable climate (drought and excess rain can change maps dramatically).

GPS

GPS is a set of 24 satellites in high altitude orbit above the earth developed by the Department of Defense (DoD) for pin-pointing objects on the surface of the earth. These satellites continuously transmit radio signals that are picked up and deciphered by special receivers. A *GPS* receiver requires at least four satellites to determine its position on earth. The accuracy of the calculated position is reduced by a deliberate offset in the signal (put in by the Department of Defense) and atmospheric conditions. The degraded signal reduces accuracy to about 300 feet; therefore, the raw *GPS* signal is not sufficiently accurate to determine position within a field. An additional signal from a known position (reference) is needed to provide the necessary accuracy. This additional signal can come from a land-based reference signal, or from another satellite. In general, the land-based reference signals, such as the Coast Guard land beacons, do not require a fee to gain access, but require that the receiver be within range of the beacon. The satellite reference signals do require a fee be paid for access to the satellite signal. *GPS* that utilizes a reference signal to gain more accurate positional data is a *differential global positioning system (DGPS)*.

DGPS receivers with positional accuracy within 3 to 5 feet are adequate for tracking field positions and are the types of receivers on most agricultural tractors and harvesters. Receivers are mounted on the top of the cab or on some high point to get a clear view

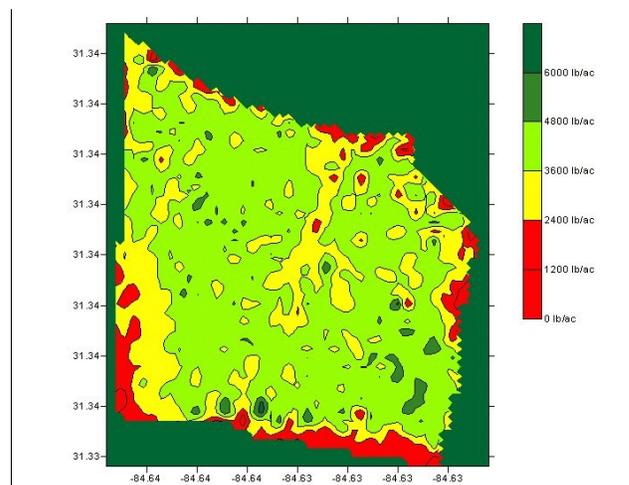


Figure 2

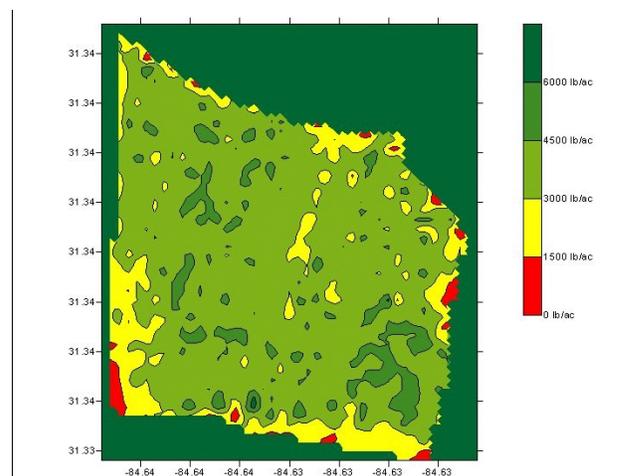


Figure 3

of the sky. More accurate survey grade *DGPS* systems can improve accuracy to within an inch, at a cost increase. These highly accurate and more expensive *DGPS* units have been used to develop field topographical maps.

The primary need for a system like *GPS* is the ability to return to a particular location, again and again. By obtaining a soil sample, which indicates a fertilizer need, it is essential that the fertilizer spreader place the fertilizer in the proper location and in the right amount.

Sensors

Sensors are being developing to determine crop stress, soil properties, pest incidence, etc. Sensors can be used to measure soil and crop properties as the tractor passes over the field, as a scout goes over the field on foot, or as an airplane or satellite photo-

graphs the field from the sky.

Measurement of plant and soil properties as the tractor or combine travels over the field is a developing area in precision farming. Currently, yield monitors are the primary sensing system that make measurements “on-the-go.” Commercial sensing systems are available that claim to measure soil properties and make application rate changes “on-the-go.” The companies claim to have systems that measure soil conductivity, among other properties, and make recommendations on the appropriate application rates of nitrogen and other nutrients. These have had very limited exposure to the southeast. Other types of “on-the-go” sensors currently undergoing research and development with some commercial applications are designed to detect weeds, nitrogen levels in plants, and soil properties.

There are also sensors that can be carried by a scout to the field and used to spot check the health of plants and soil properties. They use light reflectance on the leaf to determine chlorophyll levels. It has been shown that nitrogen levels in the plant are directly proportional to the chlorophyll production. Several soil chemistry kits are also available to measure soil pH, nitrogen, potassium and phosphorus in the field without waiting for soil sample results.

Remote sensors are generally categorized as aerial or satellite sensors that can provide instant maps of field characteristics. An aerial photograph is an optical sensor that can show variations in field color that correspond to changes in soil type, crop development, field boundaries, roads, water, etc. Both aerial and satellite imagery can be processed to provide vegetative indices that also reflect plant health.

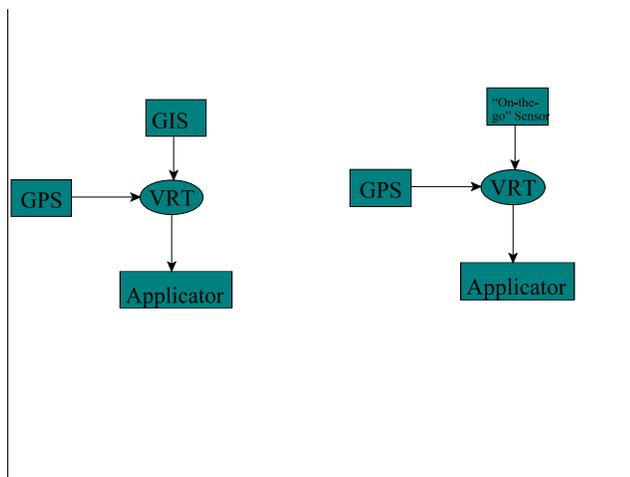


Figure 5

One common dilemma with aerial photographs is *geo-referencing* the data. The aerial photograph can be linked to a known field position by placing flag targets, of known location, in the field prior to the fly-over. It is important to know the altitude of the plane and the aperture of the lens.

Variable Rate Technology

Variable rate technology (VRT) includes computer controllers and associated hardware to vary the output of fertilizer, lime, and pesticides. Controllers are manufactured by several companies and can generally take an application map, along with the *GPS* to locate your field position, and control the hardware that varies the application rate.

One example of variable rate technology is in the application of fertilizers. Variable rate fertilizer application is used as an example because it can be associated with soil sampling, *GPS*, and *GIS*. Figure 4 shows a diagram of how all the components fit together to produce a variable rate system. The *GPS* tells the operator where on the field the tractor is located. The *GPS* links with the *GIS* to tell the controller what the field characteristics are at that location. The pre-determined yield goals will then dictate the precise amount of fertilizer to apply at that spot. The controller then manipulates the machinery to apply the correct amount of fertilizer.

Variable rate application of insecticides and herbicides will operate similarly, but there may be an “on-the-go” sensor to tell the controller where the weeds or insects are located. Currently, there are very few systems commercially available that measure parameters “on-the-go” as discussed previously. Consequently, maps to apply variable rates of pesticides would need to rely heavily on manual field scouting to create a map of infestation level.

Yield Monitoring and Yield Mapping

Yield Monitoring is the most direct method to assess the field production and how it should be better managed. A yield monitor measures the crop as it is harvested. YMs usually measure crop weight, impact forces, or the time an array of light beams are broken. Other methods are also being investigated that show promise for future yield monitors. As the yield is measured, data are stored on a computer along with the *GPS* coordinates at the point where the yield was measured. Mapping software can then create a yield map (Figures 1, 2 and 3). The yield map can immediately provide two important pieces

of information, yield variability, and yield production. Yield variability is illustrated on a map by a change in color, where each color represents a range in yield (as shown in the *GIS* section). To maintain some level of convention, red is suggested to represent low yields and green high yields. The map legend will tell you how to read what each color indicates. In all mapping situations, it is important to check the legend first. Lack of yield variability would mean that the map shows mostly one color. Yield production can be found by calculating the yield for the entire field.

Grain yield monitors have been on the market for a few years. On the other hand, some of Georgia's largest crops; peanuts, vegetables, cotton, peaches, and pecan, do not have commercial yield monitors available at the present. Commercially available yield monitors have been introduced for cotton, but none that currently come as optional equipment from the harvester manufacturer.

A *peanut yield monitoring system (PYMS)* has been developed at the Coastal Plain Experiment Station in Tifton and has undergone extensive testing during the past four seasons. It accurately weighs the peanut basket as it is loaded in the field and has achieved accuracies to within 1 percent on a basket load basis. Foreign matter and moisture are measured at the buying station and adjustments to the yield are made in the collected data. This system has been licensed and should be available commercially for the 2000 peanut harvest.

Yield monitors are in the development stages for pecan, citrus, and vegetables. As these systems move from testing to application, hopefully commercial systems will not be far behind.

SOURCES OF YIELD VARIABILITY: If the yield monitor reveals a lot of yield variability, the natural question is why? In some cases it is usually known by the farmer where the trouble spots are. But, not always. While it may be apparent that yield is low in certain places, you may not know how low it actually is and what the main reasons are. There are several sources for yield variability:

1. Water stress in an unirrigated portion of field or on high spots
2. Lack of nutrients for good plant growth and production
3. pH imbalance for poor release of available nutrients

4. Weed pressure competing with crop for water, nutrients, and sunlight
5. Disease pressure reducing crop energy for production
6. Insect pressure reducing crop energy for production
7. Poor drainage (topography and soil texture)

Yield reduction may also be within the control of the farmer in other ways. Equipment and/or operator error can cause:

1. Planter problems (clogged, deep/shallow planting, etc.), which may cause plant stand problems, reducing yield potential
2. Lime spreader missing some spots and over application on others, which affects the pH balance
3. Faulty nozzle(s) on herbicide, insecticide, or fungicide applicator, leaving some plants vulnerable.

Once the problem is identified, a course of action should be initiated to correct obvious problems causing low yields. The best course of action can only be determined on a case by case basis since everyone's farm is unique to some extent. Consequently, it is suggested that any involvement with precision management practices include the enlistment of an advisor, county agent, or some other specialist.

PROFIT MAPPING: A profit map can be created using records of field inputs and records of crop yield and sales. The profit map is used to determine what areas of the field are making or losing money. For each point where yield was measured in the field, profit can be calculated as follows:

$$P = GI - I$$

where:

- P = profit (\$/acre),
 GI = gross income (\$/acre), and
 I = costs, fixed and variable (\$/acre).

First convert the yield to the income acquired. Then, calculate the fixed costs, such as amortized land costs, rentals, irrigation, equipment and variable costs such as fertilizer, pesticides, and energy/fuel, and subtract from the income. If inputs were varied over the field, the equation must account for variable inputs over the field. The yield map can then be processed into a profit map. Taking the yield from the map in Figure 1, calculating the profit for the field, and smoothing the data creates a preliminary profit map as shown in Figure 5. In this case, the red areas indicate low yielding portions of the field that did not provide any profit, and actually cost the farmer \$200 to \$800 to operate. In other words, the net income for that field would have been higher if these low yielding locations were not planted. Unfortunately, “not planting” an area is not always a feasible option. This field does have a center pivot irrigation system which requires some management for the pivot to run and would increase the cost/acre to operate the pivot if some land were not in production. “What-if” scenarios could also be tried to see what management practice changes affect profits. Profit characteristics may change due to a land rental agreement, increase or reduction in quota peanuts, leaving land unplanted where it has cost money to farm, or reducing inputs on marginal land. One other management option is to evaluate the most productive land for potential to increase profit (change seeding rate, increase management of pests, etc.). This economic view of

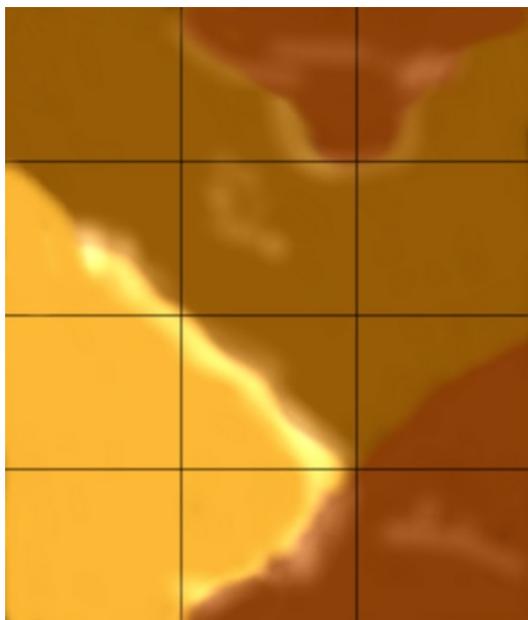


Figure 7

precision farming has sparked interest because it is an indicator of where money is lost or gained on the field. Research will continue to examine equipment use cost, land cost and other economic factors that could improve the benefits of PF management.

Soil Sampling and Scouting

Soil samples are collected and sent to a lab to determine soil characteristics. The lab analysis determines the soil pH and nutrient levels. Typically, soil sampling has included collecting several samples within a field, mixing the samples, and sending in a portion of that mix for analysis. This method averages all the soil types, nutrient levels, etc. for the entire field. The recommended fertilizer application rates for this scenario will only be optimized where the field just happens to have the same soil type, nutrient level and pH over the entire field. Otherwise, soils needing extra fertilizer will have less than optimum yield and soils needing less will be over-fertilized.

Soil sampling for precision farming separates the field into smaller segments. Currently, two primary methods are used to segment a field. One, called grid sampling, uses square grids of about 1 to 2.5 acres. An example of the use of grids is shown in a representation of a hypothetical field (Figure 6). This hypothetical field is shown from an aerial view that has the grids drawn on the picture. Each “grid” section in this picture represents 2.5 acres. In the grid-sampling method, each grid point/area is sampled in several locations, mixed, and sent into the lab for analysis. Once these samples are analyzed, the

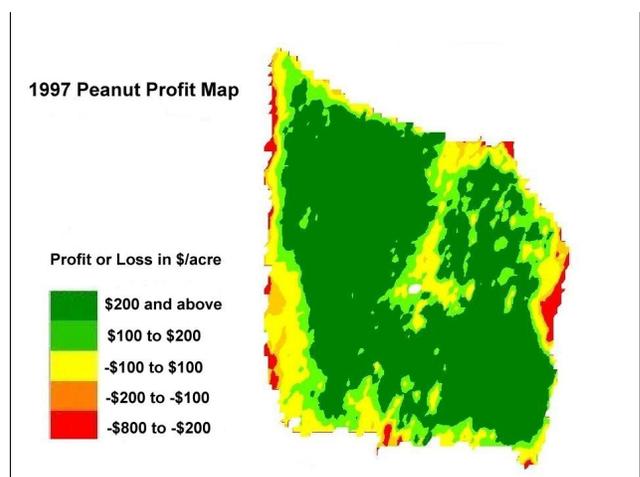


Figure 6

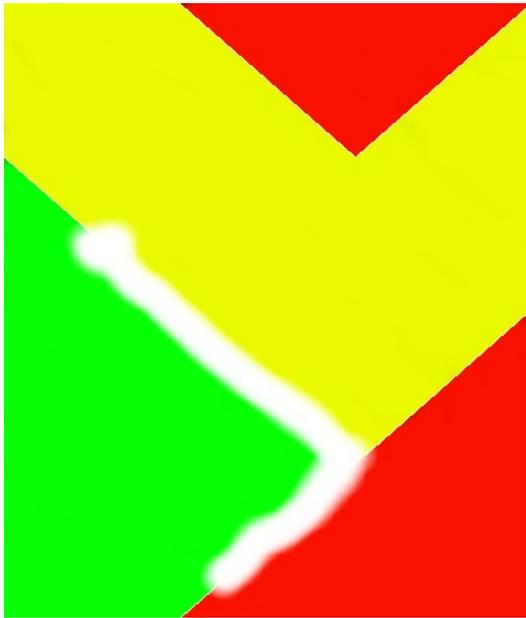


Figure 9

nutrients, lime, etc necessary in each particular grid are calculated. The application rates can then be determined and input to an application map (from white to green is low to high application rate). The resulting application prescription may look like Figure 7 when using the grid method. The application map and a *GPS* receiver will control the sprayer or spreader output rate.

Grid sampling can inherit the same problems that occur when soil sampling using a field average sample of soil. A grid can exhibit one, two, or more types of soil within the grid. Therefore, the application rates within the grid will not be correct for all the soils within the grid. As an example, the northeast corner of the field in Figure 6, has a change in soil type within the grid. Several other grids have different soil types within the grid. While this was a hypothetical example, it illustrates that arbitrary square grids in a field do not guarantee optimum application of fertilizer and lime.

Another method used to sample and manage a field is called *management zones*. *Management zones* are grouped by similar soil types and field conditions identified by the farmer using the aerial photographs, soil surveys or other resources. When sampling in a zone, you assume that the soils within a zone have a fairly consistent soil chemistry. This method is winning favor over grid sampling. Figure 8 represents an application map based on management zones for the field shown in figure 6. In this case, the management

zones were created by looking at changes in the soil types based on the hypothetical aerial photograph in Figure 6.

Getting Started

Precision farming is not appropriate for every situation. Steps that should be taken to determine if specific areas in your farming operation would benefit from precision farming management. One of the first steps would be to obtain an aerial photograph of your field. Photographs may be available from the Agricultural Farm Service (AFS). The AFS photographs most fields two to three times a year. Obtaining a bare-field photograph and a couple during various vegetative stages of the crop are useful. If you find it necessary to hire an aerial photographer, the resources at the end of this document may help identify locally available candidates. This is a relatively inexpensive investment (about \$130.00/ hour in 1999 dollars, minimum of 3 hours). Once photographs are in hand, identify known property characteristics, such as fence lines, sandy areas, poor drainage areas and other features. During the season, keep notes about the characteristics of the field in those areas you have identified in the aerial photograph. These notes will include such information as the length of time and place where the field was flooded, weed pressures, disease and any other important characteristics. It would also be wise to enlist the service of the county agent or other specialist to help

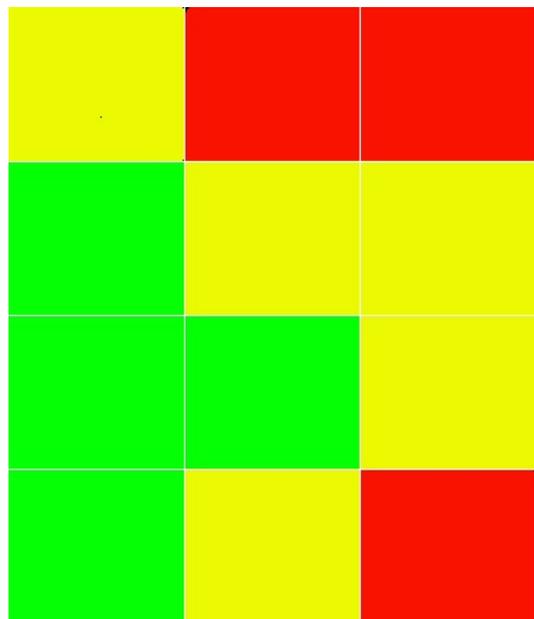


Figure 8

analyze these photos. Finally, if at all possible, get an idea of yield variation within the field. The best method is to use a yield monitor as discussed earlier in this bulletin. Some monitors can be retrofitted to the combine. If purchase of a yield monitor is too much of an initial investment, or if a yield monitor does not exist for the particular crop you are interested in, you can get a rough estimate of field yield by either spot checking the yield in your field or harvesting by zones. To spot check, cut out a 10 foot section of the crop in sections of the field where it appears that the yield is representative prior to machine harvest. Weigh the crop and calculate overall yield by the following formula:

$$\text{Yield (lbs/acre)} = \text{YM} * 52272 / \text{RS}$$

where:

YM = pounds collected in 10 foot section,
RS = row spacing (inches)

Adjustments for moisture content can be made accordingly if needed.

To harvest by zones, keep low yielding areas separate from other areas. This method does require estimating the area of the field representative of low yields.

With the *aerial photograph*, mark the yield measurements taken and their values. It may be easier to look at by color coding with a felt marker or crayon. We suggest using green for good yield, yellow for medium yield, and red for low yield. Compare your resulting yield with aerial features and field notes. If an obvious pattern of cause and effect occurs, such as a very heavy weed infestation where you have a reduced yield, you may have a need for increased management. It may also pay to soil sample field sections and determine if soil nutrient levels were limiting the yield. To help organize your information, keep a notebook of each field with notes, photographs, and maps for each years harvest.

The initial practices described above can be conducted with very minimal cash investment (except for the yield monitor). However, it may be invaluable in determining whether a more intensive precision farming management scheme is warranted.

Glossary

Application Map - Map that shows the different application rates over a field. The application map is used by the variable rate controller to meter out the appropriate chemicals.

Class Post Mapping - Class post maps identify different ranges of data by automatically assigning a different symbol (color) to each data range.

Geo-Referencing - Associating some piece of information (yield, pH, soil nitrogen etc.) with field position.

GIS (Geographical Information Systems) - Software that imports, exports, and processes data that is spatially and temporally distributed.

GPS (Global Positioning Systems) - A set of 24 satellites in earth orbit that send out radio signals that can be processed by a ground receiver to determine position on earth.

Grid Sampling - A method of breaking a field into square grids of about 1 to 2.5 acres and sampling soils within those grids to determine appropriate application rates.

Kriging - Specific method of smoothing geo-referenced data.

Management Zone - Sub-field area defined by some common characteristic or set of characteristics, such as soil type.

“On-The-Go” Sensing - Sensors that measure soil, plant, or pest properties as the tractor travels over the field.

Pixel - Smallest unit of information in a map or scanner image.

Precision farming - Farm management strategy which utilizes precise information and information gathering technology to increase profit and reduce environmental impact.

PYMS - Peanut yield monitoring system developed at the University of Georgia. The yield monitor is based on measuring the weight of the peanut basket as it is filled.

Remote Sensing - A sensor that measures the characteristics of a field (soil or plant) without having contact with the characteristic being sensed (includes aerial photographs, satellite imaging, and other non-intrusive sensing methods).

Scouting - When a person goes through a field and uses specific methods to determine levels of pest infestation or crop development.

Smoothing - A method of filtering, interpolating,

and extrapolating to smooth raw data into a map (One smoothing technique is kriging).

Spatial Resolution - The spacing between points in a field, such as the spacing between soil sampling points. The closer the points are to one another, the higher the spatial resolution.

VRT - Variable rate technology which includes the controllers used to vary fertilizer, pesticide and lime outputs as prescribed by a application map or the measurement made by an “on-the-go” sensor.

Yield Map - Map created using yield monitor and GPS data to reveal the spatial variation in yield within a field.

Yield Monitor - A device used to measure crop yield and field position as the combine harvests the field.

Recommended Reading

The Precision Farming Guide for Agriculturalists.

Available over the John Deere Web site or call 1-800-522-7448

Web Sites

Here are some discussion groups on-line that may help you get-connected on the world wide web with other farmers involved with precision farming:

www.agriculture.com/agtalk/

then click on **precision @g** in the right margin

www.agrialt.com/groups/precision/wwwboard.html

www.agrisurf.com

There is also an excellent links page that provides web sites on precision farming:

<http://nespal.cpes.peachnet.edu>.

Click on Precision Farming, then click on Resources & Links. A list of dozens of links to precision farming resources including university research and most companies involved in pre-cision farming is available.

The following site has satellite images of earth that are searchable. You can get a satellite image of your farm fairly easily:

<http://www.terraserver.com/>

Trade Shows and Expos

California Farm Show, Tulare, California, February.

National Farm Machinery Show - Kentucky Fair & Expo Center, Louisville, KY.

Western Farm Show - Kansas City, MO, Current web-site: www.westernfarmshow.com, February.

New York Farm Show, Syracuse, NY, Current web-site: www.farmprogress.com, February.

Mid-South Farm & Gin Supply Exhibit - Memphis, TN, March.

Michigan Ag Expo - Michigan State University, East Lansing, MI.

Western Canada Farm Progress Show - Regina, SK, Canada.

Precision Farming Trade Show and Exposition - Tifton Ga., for more information look at the following web-site: <http://nepsal.cpes.peachnet.edu>, June.

Agriland Expo, Duquoin, Illinois, current web-site: www.farmprogress.com, August-September.

Canada's Outdoor Farm Show - Woodstock, Ontario - Current website:

www.outdoorfarmshow.com, or call 800-563-5441, September.

Sunbelt Ag Expo - Moultrie, GA - for info call 205-877-6000, October

Carolina Farm Show, Kinston, North Carolina, Current web-site: www.farmprogress.com, October.

St Louis Farm Show - St. Louis Convention Center, St. Louis, MO , December

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