Virginia Cooperative Extension

PUBLICATION 442-500

Precision Farming: A Comprehensive Approach

Robert "Bobby" Grisso, Extension Engineer, Biological Systems Engineering, Virginia Tech
Mark Alley, Extension Agronomist & Professor, Crop & Soil Environmental Sciences, Virginia Tech
Phil McClellan, President, MapTech, Inc., Blacksburg, VA
Dan Brann, Extension Grain Specialist, Crop & Soil Environmental Sciences, Virginia Tech
Steve Donohue, Extension Agronomist & Professor, Crop & Soil Environmental Sciences, Virginia Tech

Precision Farming (PF), also referred to as precision agriculture or variable rate technology, is the process used to vary management of crop production across a field. Midwestern farmers have been using PF technologies for several years and it is now becoming popular in Virginia. This publication introduces the principles and terminology used in PF. Crop producers can use this information to gain a working knowledge of PF and develop the ability to implement PF technologies in traditional crop production.

Precision Farming Terminology

Precision farming is a comprehensive approach to farm management and has the following goals and outcomes: increased profitability and sustainability, improved product quality, effective and efficient pest management, energy, water and soil conservation, and surface and ground water protection. Table 1 provides a glossary of terms used in PF. These terms may be confusing at first, but you will soon become familiar with the language of PF.

Figure 1. The learning cycle is on-going, and precision farming tools provide a means to record and save information for year-to-year comparisons of a location.

Precision Farming vs. Traditional Agriculture

In PF, the farm field is broken into "management zones" based on soil pH, yield rates, pest infestation, and other factors that affect crop production. Management decisions are based on the requirements of each zone and PF tools (e.g. GPS/GIS) are used to control zone inputs. In contrast, traditional farming methods have used a "whole field" approach where the field is treated as a homogeneous area. Decisions are based on field averages and inputs are applied uniformly across a field in traditional farming. The advantage of PF is that management zones with a higher potential for economic return receive more inputs, if needed, than less productive areas. Therefore, the maximum economic return can be achieved for each input.

Information, Technology, and Decision Support

PF relies on three main elements: information, technology, and decision support (management).

VirginiaTech Invent the Future

Produced by Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, 2009

Information

Timely and accurate information is the modern farmer's most valuable resource. This information should include data on crop characteristics, hybrid responses, soil properties, fertility requirements, weather predictions, weed and pest populations, plant growth responses, harvest yield, post harvest processing, and marketing projections.

Precisionfarmers must find, analyze, and use the available information (Figure 1) at each step in the crop system. An enormous database is available on the internet. This data is both accessible and quickly updated.

Technology

Precision farmers must assess how new technologies can be adapted to their operations. For example, the personal computer (PC) can be used to effectively organize, analyze, and manage data. Record keeping is easy on a PC and information from past years can be easily accessed. Computer software including spreadsheets, databases, geographic information systems (GIS), and other types of application software are readily available and most are easy to use.

Another technology that precision farmers use is the global positioning system (GPS). GPS allows producers

Table 1. Glossary of some precision farming terms.

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

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 in two dimension space (Lat, Long).

GIS (Geographical Information Systems) - Software that imports, exports, and processes data that are 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 the receiver's position on earth.

Grid sampling - A method of breaking a field into square grids that generally range from 1 to 2.5 acres, and sampling soils within those grids to determine appropriate application rates.

Kriging – A statistical method of smoothing or "averaging" geo-referenced data.

Management zone – A 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.

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 - Going through a field and making observations, documenting impacts and collecting data to determine levels of pest infestation and/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) – Application equipment that includes the controllers used to vary fertilizer, pesticide and lime outputs as prescribed by an 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 on harvesting equipment used to measure crop yield and field position during harvest.

and agricultural consultants to locate specific field positions within a few feet of accuracy. As a result, numerous observations and measurements can be taken at a specific position. Global information systems (GIS) can be used to create field maps based on GPS data to record and assess the impact of farm management decisions.

Data sensors used to monitor soil properties, crop stress, growth conditions, yields, or post harvest processing are either available or under development. These sensors provide the precision farmer with instant (real-time) information that can be used to adjust or control operational inputs.

Precision farming uses three general technologies or sets of tools:

Crop, soil, and positioning sensors – these include both remote and vehicle-mounted, "on-the-go" sensors that detect soil texture, soil moisture levels, crop stress, and disease and weed infestations;

Machine controls – these are used to guide field equipment and can vary the rate, mix, and location of water, seeds, nutrients, or chemical applications;

Computer-based systems – these include GIS maps and databases that use sensor information to "prescribe" specific machine controls.

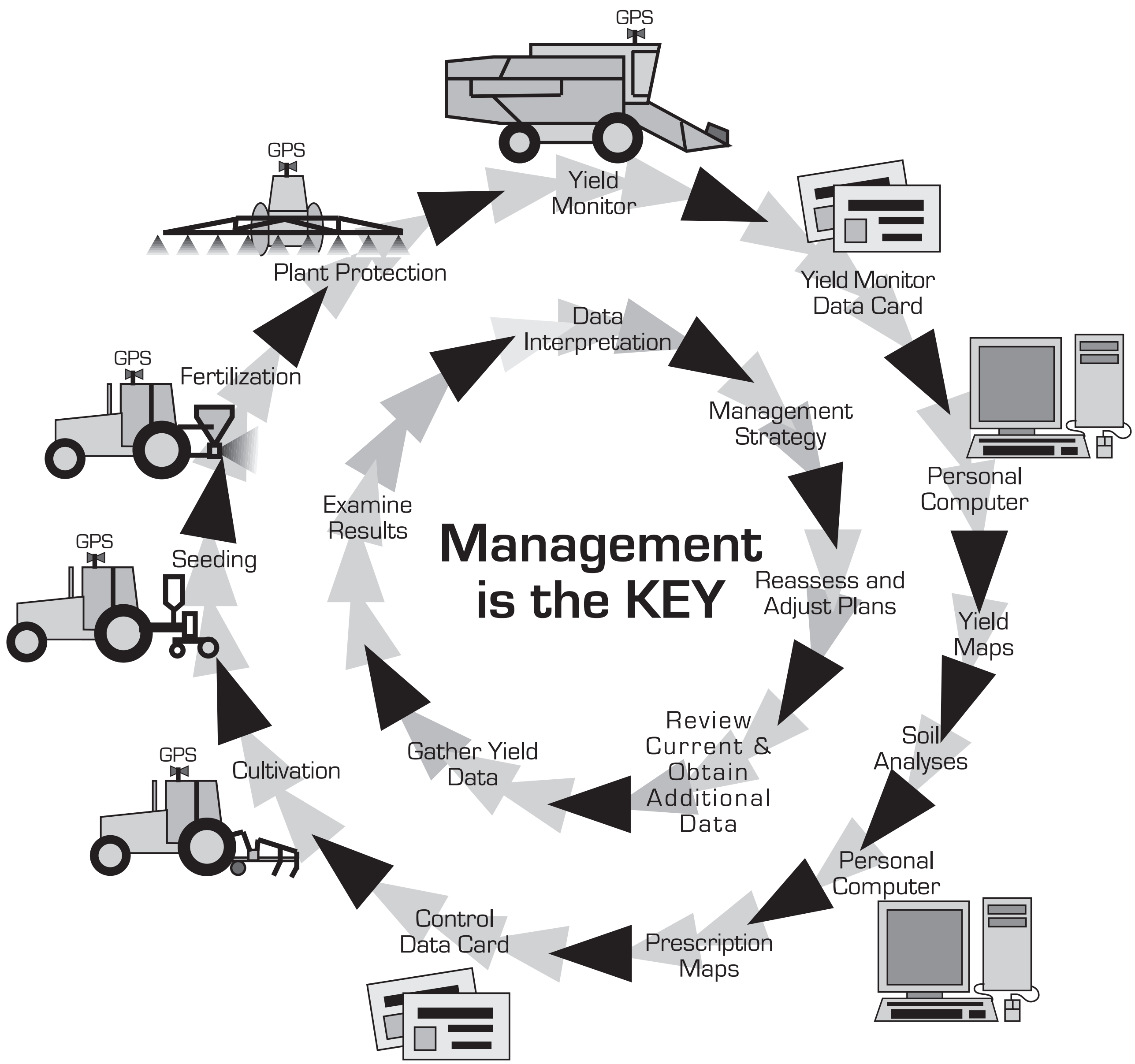

Figure 2. The learning cycle with equipment use and technology overlaid. The precision farming tools provide a means to record and save information for year-to-year comparisons of a location.

Decision support (management)

Decision support combines traditional management skills with PF tools to help precision farmers make the best management choices or "prescriptions" for their crop production system (Figure 2). Unfortunately, decision support has many times been either unreliable or difficult to understand. Building databases based on the relationships between input and potential yields, refining analytical tools, and increasing agronomic knowledge at the local level are yet to be accomplished. Most agricultural researchers agree that decision support remains the least developed area of PF. Diagnostic and database development will eventually replace technologies as the real benefit of PF.

Getting Started

PF is not appropriate for every field. To determine if a specific field will benefit from PF, use the following steps:

1. **Review current data.** Review existing information such as soil survey maps, cropping practice records, historical characteristics, and hand-drawn maps that show weed and disease problems, wet areas, and other field characteristics. Use existing maps or aerial photographs and draw boundaries around areas that have different characteristics (e.g. soil type, crop yield, or soil pH).

2. **Obtain additional data.** Several government agencies have produced maps including the following:
   - digitized soil surveys (SSURGO)
   - digital line graphs (DLG)
   - digital ortho-photo quarter quads (DOQQ)
   - Topologically Integrated Geographic Encoding and Reference (Tiger) files, which describe roads and boundaries

   Each of these maps contains unique data for a specific purpose (e.g. roads, soil type, contour). Most information can be acquired at little or no cost.

   Obtain recent aerial photographs of your farm. Photographs taken when fields were barren and at two or three vegetative stages are especially useful. These should be available from your local office of the Farm Service Agency (FSA). Use the photographs to identify known property characteristics such as fence lines, sandy areas, poor drainage areas, livestock usage, and other features.

3. **Gather yield data.** Determine the yield variation within each field by using a yield monitor. Many yield monitors can be retrofitted to your combine. Sometimes, the purchase of a yield monitor is too expensive or a yield monitor does not exist for a particular crop. In these cases, you can obtain a rough yield estimate by spot-checking various areas of the field with a weigh wagon.

4. **Examine results.** Mark areas with different yield values on an aerial photograph. Color-coding with a felt marker or crayon makes referencing easier. For example, use green for areas with high yields, yellow for areas with medium yields, and red for areas with

Table 2. Guide to interpreting (or detecting) variability within a yield map (or field). Visual observations from a yield map can be seen as having uniform or irregular patterns (from Lotz, 1997).

Pattern Description/Explanation			
Uniform Patterns		**Irregular Patterns**	
With Direction of Application	**Against Direction of Application**	**Irregular Line**	**Irregular Area/Patch**
• change in planting date	• drain tile patterns	• topography changes	• change in soil type
• change in hybrid/variety	• historically different fields	• herbicide drift	• drainage patterns
• change in chemical application	• old traffic patterns	• border shading effects	• weed infestations
• selected rescue treatment	• manure applications	• insect infestation from bordering lands	• soil fertility changes
• chemical skips and misapplications	• pipelines/phone lines underground	• improper manure application	• previous crop activity
• equipment errors	• previous compaction	• waterways	• disease infestations
• poor straw/chaff distribution			• herbicide carryover
• compaction			• historic occurrences
			• insect infestations
			• changes in organic matter
			• animal damage
			• wet areas

low yield. Compare yield data with physical characteristics of the field and field notes. If you notice a pattern of cause and effect, such as a very heavy weed infestation where yields are reduced, you probably need to increase your management of that area. You may wish to collect soil samples across the field to determine if soil nutrient levels limited the yield in less productive areas. Keep a notebook for each field that contains notes, photographs, and maps of each year's harvest.

5. **Data interpretation.** You may notice patterns of uniform and non-uniform variability throughout the field when interpreting yield maps. Table 2 provides a guide to interpreting variability within a yield map. Use this information to evaluate management techniques and other influences on crop production. Verify the reasons for non-uniformity found in yield maps by on-site inspection.

   Use a systematic approach to storing information when collecting data. Make paper or electronic copies of your information. Store this information in different places from your usual record keeping area to prevent theft or damage from fire, water, or some other disaster.

   Computers with PF and record keeping software help manage and retrieve data. GIS programs overlay geo-referenced information for further analyses. You may find working with a computer difficult at first. If so, use services that collect, handle, analyze, and interpret data for you.

6. **Management strategy**. Determine a course of action once a problem has been identified. This is sometimes difficult since each farm is unique and a prescribed solution may not be available. Use the services of an agricultural consultant, county Extension agent, or Extension specialist to evaluate your management strategy.

Reassessment

Precision farmers must continuously reassess the profitability of their PF program. This can be done by comparing yield monitor data to the financial records for a specific field. If a decision based on PF did not improve profitability, a more or less intensive PF management scheme may or may not be warranted.

Examples of Site-Specific Crop Management

Developing management strategies is the most difficult part of the PF process. Precision farmers must consider the steps of crop production that can best be controlled and managed to provide the greatest economic return. The following examples provide a framework for developing a PF management plan. Although conceptual in nature, these examples are common occurrences on farms and could be used with any management strategy.

Example 1. Nutrient Management Plan.

A farmer wants to "fine tune" his nutrient management plans for optimal economic returns. He starts by evaluating the soil characteristics (the lower right corner of Figure 2) within a field. Next, the farmer classifies the field into areas or "management zones" based on common soil types or crop potentials. Within these zones, the farmer decides on the combination of operating strategies (e.g. conservation tillage with variable rate fertilizer application) needed to obtain the maximum profit from that field. He can fine-tune the nutrient management plan based on weather and market forecasts.

The fine-tuning job does not end at harvest. The farmer should gather yield data and information on the amount of residual nutrients not utilized by the crop. He should compare these results to his yield goals and economic returns to determine whether his management decision worked.

Example 2. Management Strategy to Reduce Chemical Costs.

A farmer wants to save money by applying pesticides to the correct target at the proper rate and time. The farmer selects a high accuracy applicator equipped with GPS-based controllers. Next, he obtains field scouting or remote sensing data of pest-infestation zones within a field and develops a geo-referenced map. The services of an integrated pest management (IPM) specialist may be used to determine the optimal time for pesticide application.

The farmer sprays only those areas that have both a high potential economic return and a high threshold of pest infestation. The GPS-based controls ensure that those areas receive the proper application rate. The controller also logs actual rate, time, and location data. As in Example 1, the farmer should compare his harvest to his yield goals and economic returns to determine whether his management decision worked.

Questions to Continually Ask

A farmer must continually ask questions to optimize his PF program. These may include:

- Is there error in the data collection process?
- How accurate is the information?
- What does the information tell me?
- Do any observations indicate variation from other influences?
- Is one year of information sufficient? (not likely)
- Can I justify making final management decisions based on this information?
- Do I need additional information?
- How much time and money have I spent on collecting information and making decisions?
- Have the decisions to correct problems influenced succeeding year's yield map?

Conclusion

PF is used to vary crop production management across a field. This practice requires farmers to use information, technology and decision support to increase economic returns. Although getting started in PF is fairly easy, making management decisions based on PF information can be difficult. However, agricultural consultants, county Extension agents, and Extension specialists are available to help farmers implement PF programs.

Look for these Extension fact sheets for more information:

Precision Farming Tools: Lightbar Navigation, (VCE Publication 442-501)

Precision Farming Tools: Yield Monitor (VCE Publication 442-502)

Precision Farming Tools: Global Positioning System - GPS (VCE Publication 442-503)

Precision Farming Tools: GIS - Mapping Geo-Referenced Data (VCE Publication 442-504)

Precision Farming Tools: VRT - Variable Rate Technology (VCE Publication 442-505)

Precision Farming Tools: Remote Sensing (VCE Publication 442-506)

Precision Farming Tools: Map-Based versus Sensor-Based (VCE Publication 442-507)

Precision Farming Tools: Soil Electrical Conductivity (VCE Publication 442-508)

Interpreting Yield Maps – I gotta a yield map, now what? (VCE Publication 442-509)

Developing a Prescription Map

Soil Nutrient Variability in Southern Piedmont Soils

Modified from:

Rains, G.C. and D.L. Thomas. 2000. Precision Farming: An Introduction. Cooperative Extension Service, University of Georgia, Bulletin 1186. *http://www.ces.uga.edu/pubcd/b1186.htm*

Roberson, G. 2000. Precision agriculture: a comprehensive approach. Cooperative Extension, North Carolina State University. *http://www5.bae.ncsu.edu/programs/extension/agmachine/precision/index.html*

Stombaugh, T.S., T.G. Mueller, S.A. Shearer, C.R. Dillon, and G.T. Henson. 2001. Guideline for Adopting Precision Agricultural Practices. Cooperative Extension Service, University of Kentucky, PA-2. *http://www.bae.uky.edu/~precag/PrecisionAg/Exten_pubs/pa_2.htm*

Watermeier, N. 2001. Considerations on Gathering and Interpreting Field-Based Information for Precision Agriculture Decision Making. The Ohio State University Extension.
http://precisionag.osu.edu/library/decision.html

References:

Lotz, L. 1997. Yield Monitors and Maps: Making Decisions. Ohio State University Fact Sheet AEX-550-97, Food, Agricultural and Biological Engineering, 590 Woody Hayes Dr., Columbus, OH 43210

Acknowledgments:

The authors would like to express their appreciation for the review and comments made by Paul Davis, Extension Agent, New Kent County; David Moore, Extension Agent, Middlesex County; David Parrish, Professor, Crop & Soil Environmental Sciences; Susan Gay, Assistant Professor and Extension Engineer, Biological Systems Engineering.