



## Educational Needs of Precision Agriculture

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**Abstract.** Reluctance towards implementation of precision agriculture seems to be based upon accessibility to well-trained, knowledgeable people, and the cost and availability to obtain quality education, training, and products. Given that precision agriculture is rapidly changing and the current trend for accelerated information exchange, educators of precision agriculture face the challenge of keeping pace and providing quality educational programs. This paper addresses how precision agriculture educational programs can be improved. Specific barriers to adoption of precision agriculture are discussed. The learning process of precision agriculture technologies and methods are outlined as six sequential steps. These steps represent a process of increased learning and skill proficiency against which those individuals developing precision agriculture education can use to build and target their programs. The optimal value of information for precision agriculture will be best achieved by producers, agribusinesses, and educators as they improve their: 1) agronomic knowledge and skills, 2) computer and information management skills, and 3) understanding of precision agriculture as a system for increasing knowledge.

**Keywords:** adoption, needs, learning process, technology, precision agriculture

### Introduction

In little more than a decade, precision agriculture has emerged from a concept to production-scale, multiple-task operations implemented on a field-by-field basis. Although implementation of precision agricultural technologies was initially rapid, it has slowed due to difficulty and confusion about how the full power of precision agriculture can be maximized, and thus how the true value can be determined. Early users were primarily self-taught who shared an aptitude for electronic-based information technology and decision making. Adoption of precision agriculture technologies and methods has evolved as the general user profile has changed and as analysis demands have increased. The challenge for users of precision agriculture technology is to effectively measure, collect, and analyze relevant variable and manageable factors to make efficient management decisions.

Given both the recent emergence of rapidly changing precision agriculture and the current trend for accelerated information exchange (e.g., web-based systems), educators of precision agriculture face the challenge of keeping pace and providing quality educational material. Precision agriculture education programs need to reflect these dynamics of change, but they should also be scientifically sound and responsive to the wide range of abilities and skills of individuals. To illuminate how precision agriculture educational programs can be improved and expanded, this paper addresses three questions:

1. What barriers to the adoption of precision agriculture are the result of inadequate or ineffective educational efforts?
2. Is there a natural learning process for precision agriculture technologies and methods? And if so, what is it?
3. What are the unique needs of the different precision agriculture players (e.g., producers, agri-business, and educators)?

#### **Barriers to the adoption of precision agriculture: identifying opportunities for improved education**

Producers, as the end-user of precision agriculture technologies and methods, will ultimately dictate the rate and extent to which precision agriculture is adopted. Research investigations and/or marketing strategies will fail in the end unless producers can realize value in such efforts, whether implicit or in absolute dollar terms. Thus, an understanding of the specific concerns that producers have about precision agriculture technology should provide insight into research, development, education, and commerce opportunities.

In 1998, producer focus group discussions yielded information to determine the barriers that prevented or inhibited increased adoption of precision agriculture (Wiebold et al., 1998). These discussion groups included U.S. Midwest producers, both with and without precision agriculture experience. Table 1 classifies the specific obstacles identified by these groups into six primary barrier categories. Are these barriers the result of inadequate or ineffective educational efforts? While educational programs should be integrated into all efforts to improve precision agriculture, some of the barriers found in this study clearly point to a problem of insufficient or ineffective education (italicized points in Table 1). These points suggest that producers want to know how to incorporate precision agriculture management into their operations. The reluctance towards implementation seems to be based upon accessibility to well-trained, knowledgeable people, and the cost and availability to obtain quality education, training, and products.

The producer discussion groups revealed a wide range of different precision agriculture needs. For example, curriculum and teaching methods for precision agriculture education ought to be responsive to the changing needs of producers and agribusiness. As precision agriculture continues to mature, educational programming will need to be tailored to address the range of educational needs represented by both the beginner and advanced user. Over the last couple of years, beginning and advanced training/classes have begun to be offered at workshops, conferences, and on college campuses. To promote adoption, the development of more narrowly specialized levels, ranging from novice to advanced, will be needed in future years to keep up with the increasing diversity in precision agriculture knowledge and skills.

Table 1. Results of producer focus groups examining the barriers that prevent or inhibit increased adoption of precision agriculture (PA) (Wiebold et al., 1998)

Barrier Categories	Specific Obstacles*
Costs of technology adoption	<ul style="list-style-type: none"> <li>• Equipment costs</li> <li>• <i>Time involved in learning how to use complicated equipment/software</i></li> <li>• Time consuming when time is already at a deficit (e.g., harvesting)</li> <li>• Software packages are not compatible</li> <li>• Service providers unable to keep up with PA obligations</li> <li>• Obsolescence potential of hardware and software</li> <li>• <i>Producers and/or hired help without basic electronic equipment skills</i></li> <li>• Issues associated with long-term investing for rented vs. owned land</li> </ul>
Training programs and consultation resources	<ul style="list-style-type: none"> <li>• <i>Training deficiency for producers and service providers to use technologies correctly, especially software and data management and analysis</i></li> <li>• <i>Gaps between getting information and finding answers</i></li> <li>• Lack of confidence that current PA tools give the most relevant information</li> <li>• <i>Lack of technical infrastructure to help get through the PA learning curve</i></li> <li>• <i>Lack of easy-access troubleshooting help</i></li> <li>• <i>Lack of local experts</i></li> </ul>
Data quality control	<ul style="list-style-type: none"> <li>• <i>Difficulty in maintaining quality data</i></li> <li>• <i>Difficulty in storing and retrieving data with different formats</i></li> <li>• Sensors that are unreliable or inaccurate</li> <li>• <i>Methods to analyze yield data to help understand yield limiting factors</i></li> <li>• Better agronomic data for inputs (e.g., seed) explaining responsiveness under different environmental stresses</li> </ul>
Consumer guide for precision agriculture	<ul style="list-style-type: none"> <li>• <i>Information providing comparative advantages/disadvantages of PA equipment, techniques, and software</i></li> </ul>
Environmental aspects of precision agriculture	<ul style="list-style-type: none"> <li>• Documented environmental benefits without compromising yield</li> <li>• Mechanism for demonstrating good stewardship with PA management</li> <li>• Development of linkage between PA and soil health</li> </ul>
Need for new technology development	<ul style="list-style-type: none"> <li>• New sensors and methods for detecting and treating biotic factors, such as weeds and diseases</li> <li>• Influence of soil moisture and applications of variable irrigation</li> <li>• Crop varieties responsive within a PA system</li> <li>• Improved data storage devices</li> <li>• Development of remote sensing equipment</li> <li>• Standardization of equipment and data formatting</li> <li>• <i>Basic agronomic research on the relationships between yield and soil</i></li> </ul>

\* Italicized points are mostly the result of inadequate or ineffective educational efforts.

In general, the outcome of the referenced discussion groups may reflect what producers think they want and not necessarily what they need. On the other hand, who other than producers has the intuition of whether precision agriculture will reasonably work? The new management complexities that precision agriculture technology adds to an operation require expanded skills and tools not previously taught or provided from an educational standpoint. An obligation exists to provide information and training from any relevant source in order to ensure that precision agriculture tools are properly applied. Meanwhile,

producers also shoulder the obligation to express their relevant needs and concerns so that these issues can be properly addressed from an educational and training standpoint.

### **A natural learning process for precision agriculture**

The knowledge and skill that people gain through precision agriculture are acquired through a natural, orderly learning process that has been experienced by producers, agribusinesses, and researchers. Although individuals will not necessarily follow the learning process in the exact order presented here, the stages have been and will continue to remain somewhat sequential. Six learning steps involved in the adoption and application of precision agriculture, along with supporting points and examples are presented below:

**Step 1:** Learning and understanding the concept of spatial data management, including the importance and value of spatial data, is fundamental. Opportunities for successful precision agricultural decisions are founded both in the variability that is present in a field and in the ability to accurately predict and influence those variable factors.

- One should understand the concept of scale of variability. While thinking spatially is not totally new to agriculture, measuring and making decisions about how things vary in space is. Implications for the potential benefits and costs from each management decision include understanding the choices of relevant precision agricultural treatments for a location. This serves as a basic first step in the development of a precision agriculture management plan.
- Realizing that maps contain information beyond visual perception helps users to understand how mapped data can be used in analysis and management decision making. Precision agriculture management involves much more than simply creating “pretty maps.”
- Mapped information will vary in its relative importance for improving the crop-production system. Accuracy in sampling and data collection has significant implications for the inferences drawn from mapped data. Considerations of information accuracy, a return to agronomic principles to determine the hierarchy of yield limiting factors, and how these factors can be managed for successful crop production stand as the foundation of a precision agriculture data management.

**Step 2:** Learning the proper use of sensors makes it possible to obtain intensive sampling of quality information relatively inexpensively. Automated sensors and controllers can be used to collect information and vary inputs on-the-go. In many cases, the relative novelty of sensors and computer-controlled devices presents precision agriculture users not only with issues of how to manage spatial variability, but also with a Pandora’s box of cables, sensors, and computers. Education and training address the development of skills and confidence needed in the operation of these sensors. Examples of the kinds of sensors commonly used in precision agriculture include:

- Global Positioning System (GPS)
  - The evolution of GPS represents the one primary key factor that has allowed precision agriculture technology to progress to its current state.

- The information provided through GPS ties together all relevant layers of information obtained for a field.
- Yield Monitoring Systems
  - Yield monitors have given users of precision agriculture technology a baseline by which they can evaluate their management decisions.
  - Yield monitors collect data on-the-go across a field to provide a spatial representation of yield performance. However, to ensure quality data, a yield monitor must be installed properly and calibrated. This could increase harvest preparation and collection time, but it is a critical benchmark in the evaluation of precision agriculture management decisions.
- Remote Sensing Data
  - The use of remotely-sensed images is still an emerging piece of precision technology. However, it offers a frontier of within-season crop production information critical to the adjustment of a plan.
  - Challenges remain on how to interpret and manage remotely-sensed data within existing precision agricultural management programs. Inclusive with this challenge are issues associated with management of image data within a software package and availability of proper software.
- Variable-Rate Technology (VRT)
  - Although initially tied with the variable application of fertilizer, VRT can be used in all facets of the management of the soil and crop.
  - Development of a “spatial prescription” along with using a sensor to apply it requires additional calibration and training to ensure a product is properly applied.

All of the listed hardware technology, while not all inclusive, implies a need for additional educational efforts. Frustration in the learning process can be overwhelming, but time provides increased confidence and experience to obtain and apply information. This step in the learning process can be extensive, but given that data management lies at the heart of making informed decisions, this along with learning to use a computer may be one of the most important steps.

**Step 3:** Learning to use a computer and software is essential for mapping computerized maps. Large amounts of spatial information can be stored and summarized using Geographic Information System (GIS) software.

- GIS is the foundation of precision agricultural management from a decision-making perspective.
- GIS not only provides a storage and display mechanism, but more importantly, offers an analysis and query ability that lies at the heart of making site-specific decisions. Within GIS, visual methods for cleaning data and performing statistical analysis can be routinely accomplished.
- Desktop mapping packages provide the ability to create, view, and store spatial data with varying degrees of functionality, depending on the software. A GIS adds the ability to query and create new maps from old maps based on the question asked by

the user. The ability to progress from raw data to colored maps, to analyzing and asking questions, to making management decisions requires comfort and experience with computer operation as well as file management.

**Step 4:** Improved crop production decisions are made through assessment of yield variation and narrowing the potential causes. Identification of relevant and manageable yield influencing factors stands as the key to precision agriculture management. Adding the spatial dimension to traditional whole-field decision making enhances agronomic problem solving. The value lies in identifying those results that are an effect of management as well as the results of environmental factors (e.g., soil, weather, weeds, insects, etc.). Important items to consider include:

- Yield variation patterns point towards natural vs. management-induced variation
- Analyzing yield maps using methods, such as:
  - Visual association of yield maps to other maps (e.g., soil, topography, fertility, and remotely-sensed images).
  - Simple mathematical analysis (e.g., correlation, average, standard deviation, histograms, and scatter plots).
  - More complex mathematical analysis (e.g., multiple regression, non-linear statistical methods, and spatial modeling).
- The ultimate goal would be learning how to conceptualize and refine a hierarchy of yield limiting factors for each field from which management implications and decisions are drawn on a more site-specific basis than on a traditional, whole-field approach.

**Step 5:** With relevant information collected, summarized, and interpreted, one is ready to develop site-specific management (SSM) plans.

- The hierarchy of yield-limiting factors should lead one to prioritize management options.
- The final objective is to determine achievable goals and to invest in technology in order to help realize those goals, while recognizing that some results may not be instantaneous.
- Managers should not overlook that the value of SSM may increase by linking inputs (e.g., variable-rate corn planting population and variable-rate nitrogen rates).

**Step 6:** Strategic sampling and on-farm trials constitute the last step optimizing management. The process and level of detail precision agriculture technology affords can make a manager more efficient in the decision-making process. Examples of precision agricultural methods may include:

- Use of within-season remotely sensed information to monitor crop progress and stress caused by biotic factors and subsequent spot treatment.
- Strip trials of seed variety and creating difference maps.
- Fertility response plots or strips.
- Tillage strips.
- Timing of planting and crop inputs.
- Profitability mapping.

- Pesticide stress (degree of phytotoxicity) monitoring.
- Pesticide effectiveness trials.

We concede that a description of the learning steps does not represent a fundamentally new evaluation of precision agriculture education. However, the steps do represent a process of increased learning and skill proficiency against which those individuals developing precision agriculture education can use to build and target their programs.

### **Identifying the unique needs of precision agriculture players: recommendations for improvements**

Our experience suggests that there are three broad areas where improvements in precision agriculture can be made: 1) agronomic knowledge and skills, 2) computer and information management skills, and 3) the recognition and development of precision agriculture as a management system for increasing knowledge. Within each of these dimensions, educational efforts should emphasize the specific needs of the significant players interested and/or potentially involved in precision agriculture: producers, agribusiness, and educators. A discussion of each dimension by group follows.

#### **Agronomic knowledge and skills**

Producers: Producers are often skilled agronomists, who use their fields as a classroom, but agricultural production largely represents an ongoing laboratory that has no lecture. Firsthand observations can be obtained with each trip over a field. With a basic understanding of crop growth and how various environmental factors influence growth, producers' knowledge of their own operations can be their greatest resource for developing appropriate precision agriculture strategies.

*Need:* We recommend that producers make a life-long commitment to improving their agronomic skills. Precision agriculture technology gives producers the increased information needed to maintain a close connection to soil and crop characteristics on a field-by-field basis. Producers that have a sound basic understanding of agronomics are better positioned to discern appropriate management options for improving production and/or production efficiency for each field. However, this commitment demands an acceptance that current management can be improved and that finding this out takes time, which is a producer's most valuable resource. Over the growing season, producers respond to many time-sensitive management decisions. They may rely heavily on outside professionals (e.g., crop consultants or representatives of agricultural service/suppliers) to gather the necessary agronomic information and make management recommendations. However, overreliance on outside information may lead to management that is narrow in options, as it may be strongly driven by a marketing strategy represented by a local supplier. In this case, a producer's agronomic knowledge becomes the quality control for out-sourced recommendations.

Whether a field is managed uniformly as one area or on a site-specific basis, personal knowledge of the soil and crop gives the producer the greatest flexibility in developing management options agronomically in-tune for a given field. The optimal value of

information for precision agriculture will be best achieved as producers improve their agronomic knowledge in order to critically evaluate the site-specific information they are collecting. Thus, educators need to provide adult education workshops and classes that promote awareness of currently developing agronomic knowledge.

Agribusiness: The diverse types of business interested in precision agriculture range in size from large corporations to small out-of-the-garage sole proprietorships. These businesses include equipment manufacturers, computer hardware manufacturers, software developers, product manufacturers, agriculture product suppliers, scouting and application services, information providers, and data interpretation and warehousing groups. With such diversity, the role that each type of industry plays in the development and education of precision agriculture efforts is equally diverse. However, a deficiency in agriculture knowledge plagues many individuals trying to capture a piece of the precision agriculture market. Consequently, many products and services developed and marketed by businesses have little or no possibility of increasing value to producers. In some cases, a product developed and found to be valid under one set of conditions has been marketed widely without testing under a broader range of conditions. Customers of those products and services that do not meet marketed claims will walk away soured and reluctant to invest again.

*Need:* We recommend that industries providing precision agriculture products should have an extensive understanding of agronomic principles and practices as a foundation for developing their products. They should at the least possess a basic understanding of the role and potential interactions of crop inputs, management strategies, soil and landscape variability, and climate. This has been a deficiency with many. Ideally, industry should understand that the success of any precision agriculture tool depends upon the development of a whole farm plan. The question an industry should ask itself is, "Can we show how our product or service improves crop production and/or efficiency over the area that we market?" Sound agronomic insights are a prerequisite to developing the products needed to answer such a query. Again, educational efforts will assist agribusiness in training and refreshing the existing base of employees.

Educators: Precision agriculture technology is new to the entire agricultural industry, including educators. With precision agriculture, the more traditional approach of research providing results that stimulated industry product development has been reverse, such that industry related technologies are driving research and education. Whether in the classroom, conference workshop, or field-day stop, educators of precision agriculture have struggled in keeping pace with the questions being asked. While teaching the basic concepts and principles of precision agriculture has been intuitive and relatively straightforward, training individuals how to use the technologies of precision agriculture has been complicated. Difficulty arises, in part, from deficiencies in computer skills and understanding the geographic and spatial concepts seldom taught in agricultural programs before the 1990s. Precision agriculture presents a complex process of learning through collecting, integrating, and interpreting spatial and temporal information. Therefore, the process of learning constitutes the most difficult step of precision agriculture, and consequently the most challenging to teach. The process becomes iterative and dynamic as new



crop and soil information is considered. Strong agronomic understanding is quintessential, since diagnosis of each field can be unique. The goal cannot be absoluteness; such an effort would undermine site-specificity.

Participants (producers, industry/agribusiness, and researchers) at the Fourth International Conference on Precision Agriculture addressed the curriculum needs of precision agriculture education for technical, college, and professional levels. A summary of their comments identified that basic education of agriculture (e.g., crops, soils, farm management, basic sciences), along with well-developed problem-solving skills were necessary and could not be compromised in educating precision agricultural professionals (Robert, 1999).

*Need:* We recommend that educators strengthen their curriculum in the basic crop and soil sciences, and with that as the foundation, they should develop precision agricultural education programs that emphasize the concepts of precision agriculture as a learning process. With this foundation, problem solving skills will follow. In addition to educating the students who represent the future site-specific managers for the agricultural industry, particular care needs to be taken not to overlook the adult education needs of existing producers, consultants, and other agribusinesses.

### **Computer and information management skills**

Producers: Now information and use of electronic equipment cannot be separated. Capturing more information with the aid of precision agriculture technologies denotes an extension of the electronic recordkeeping systems available to producers since the 1970s. Computer technologies have changed rapidly over this period, and they will continue to change. Producers committed to information-based decisions consign themselves to computers and other electronic devices.

*Need:* We encourage producers to actively improve their computer skills. With distance-learning readily available through the World Wide Web (WWW), producers enjoy the convenient option of developing various computer skills without leaving the farm. However, many producers lack the background needed for many data management and analysis needs associated with precision agriculture. Geographic Information System and other data management systems have become more user friendly over time, but their effectiveness still requires considerable training and experience. Thus, for most producers, we recommend that they look for opportunities to team-up with local computer and GIS expert(s) in meeting the needs of data acquisition, analysis, and storage. This might be accomplished through an agricultural consultant, service provider, or local producer precision agriculture clubs. In order to achieve the value of additional agronomic information that site-specific technology provides, producers will need to improve their computer skills and expand their understanding of GIS and spatial data analysis.

Agribusiness: As the developers and providers of precision agriculture data acquisition equipment, businesses have worked aggressively over recent years to simplify and to expand the functionality of their products. The pressures of providing easy, ready-to-use products has caused some to drop out of the market and others to merge in order to capitalize on the strengths of individual products. Changes will continue.

*Need:* The cost for easier, simplified products cannot reduce power and versatility. While tremendous progress has been made, improved methods of storage, access, cross-examination, and information summary need to be improved. Products need to encompass the diversity in skills and performance requirements that users have, versatile to serve both the beginner and the advanced individual while assisting in the natural learning process of precision agriculture. We implore developers to make products that integrate with other products on the market so that users can choose combinations of tools most relevant to their site-specific management scenarios. Though difficult to generalize across all situations, the guidelines that completely explain features, constraints, and limitations of the products should accompany equipment and software products. As an example, some GIS-based software packages currently include correlation data analysis techniques, but little or no explanation of what a correlation means and how it should be interpreted. Misunderstanding of the appropriate use of correlation coefficients is rampant.

Businesses should continue to maintain an active role in training producers, agriculture consultants, and agriculture service dealers for their equipment and software, as these efforts have usually been effective.

Educators: The participants of the Fourth International Conference on Precision Agriculture identified the use of precision agriculture equipment and software as being a high priority need area.

*Need:* Educators could do more to give hands-on experience for precision agriculture products. Simulators, for example, can be especially instructive. At the same time, the role of public-funded educators should avoid the endorsement of specific products and services over others. In this case, these educators need to be careful to communicate a non-endorsement. Educators do this with more emphasis on precision agriculture concepts and principles and less on the market-available tools. On the other hand, educators in a tenure-based university system who conduct applied research have come to rely on industry cooperation. The type of training the industry needs at the producer-, agribusiness-, and student-level involves a lot of applied, practical experience that incorporates the theory of agriculture production management. Extension and research resources continue to shrink, as does the grant money needed to buy equipment, thereby making it difficult for an educator to build and maintain a curriculum without industry support. Subsequently, the current situation seemingly promotes the perception of endorsement. We need increased cooperation between industry and education (including administration) so that the two sides can work together for the overall good of education without having to worry about endorsement issues.

### **Integrating precision agriculture into a system**

Producers: The initial concept that precision agriculture means variable-rate fertilizer application is slowly being dissolved. Producers who have yield-mapped their fields for several years are examining the yield variability and they are asking the basic questions necessary to understand its causes. Fertility issues are now viewed as just a small part of the variability story. Producers are beginning to use the tools of precision agriculture to conduct on-farm field trials of different management options. Precision agriculture

represents a way of learning through collecting, integrating, and interpreting spatial and temporal information. It is not a component of management nor the sum of different components of management.

*Need:* We encourage producers to embrace the ideas and technologies of precision agriculture commensurate with what their time and resources will allow. We advocate that producers recognize precision agriculture as a change in their management perspective and as a way to learn. If a producer seeks only immediate and guaranteed returns, that producer may be disappointed by precision agriculture technology.

*Agribusiness:* It is much easier to market a single component of management that can be directly evaluated for its increased profit potential rather than to show how a product or service will assist a producer in the precision agriculture learning process. Agribusiness representatives will need tools and training to assist efforts at broadening their approach to present a whole farm solution.

*Need:* We suggest that there are many opportunities for different agribusinesses, sometimes in collaboration with public research institutions, to work together to develop products that help pull information together for greater understanding of the overall crop production system.

*Educators:* Teaching a system requires an ability to discuss its parts; but if we only discuss the parts and the various discussions make no concerted effort to teach precision agriculture as a system, then we will fail. Precision agriculture works toward a multi-disciplinary approach of teaching that may be new to some educators. Additional effort may be necessary to involve and coordinate educators from other disciplines.

*Need:* Educators of precision agriculture need to organize and promote education and research programs in an interdisciplinary and cooperative manner, which historically has not been a strength of academicians. Precision agriculture represents an opportunity to meld the agricultural disciplines. For public-funded education and research, the recognition and reward of interdisciplinary, team-oriented activities have often fallen short of the level of acclaim given to narrowly defined studies. The reward and promotion structure for public and private-sponsored educators should encourage, not discourage, interdisciplinary programs.

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