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Precision Agriculture: Putting Information Systems to Work on Farms

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We read about precision agriculture, variable-rate management, yield mapping, and color-infrared imaging in the farm magazines. But we wonder whether it is another ploy to get farmers to buy expensive equipment and services, or whether it is truly a new approach to farming. In our view, it is the latter, although we still need to do a lot of work to make it work effectively for the average farmer.

What is precision agriculture? We define it as the application of computerized data acquisition / control systems and information systems to land management. In that respect, crop production follows the manufacturing industry in incorporating computer-based technology into the production process, allowing for more efficient and consistent product output. Precision agriculture is based on the premise that soil, crop, and pest-related processes are variable in space and time within fields. Information on these processes will allow for more efficient crop production and environmental protection. Precision agriculture is strongly tied to several new or improved technologies, notably Global Positioning Systems (GPS), Geographical Information Systems (GIS), fast computers, and new sensors. Precision Agriculture also builds on new statistical procedures, for example "geostatistics" which recognizes spatial patterns in fields.

Precision agriculture (PA) technology may involve many different types of equipment. Essential components are a Global Positioning System, an on-board (i.e., on the tractor or combine) computer, and a desktop computer. The GPS is a device that allows you to determine your position on the land in terms of geographical coordinates. The unit typically does that by evaluating its position relative to a constellation of satellites and a land-based beacon. The GPS units generally sold for agricultural purposes are accurate within about 3 feet. It is a very essential component of a precision agriculture system, because it is essential to know exactly where you are in a field to use the technology effectively.

The on-board computer can acquire data (e.g., from a yield monitor), or control an applicator (e.g., a fertilizer spreader). These tasks are performed while simultaneously evaluating the position of the field equipment using the Global Positioning System, i.e., the field data are *georeferenced*. The on-board unit is typically designed for just those tasks, hence the need for a desktop computer with Geographical Information System software to allow for the processing of such georeferenced field information.

Figure 1 shows a flow diagram that captures the information streams in a sophisticated precision agriculture application. In the field, information is gathered (e.g., soil samples, yield data) which are subsequently processed in the office with the specialized software (GIS and statistical packages). The field data may be combined with weather information, remotely-sensed images or other information sources. Based on this information, a prescription is developed for the application of crop inputs such as fertilizer, lime, pest control methods, organic amendments, etc. This prescription is based on a knowledge base that allows for the best management recommendation for each part of the field. The prescriptions are then entered into the on-board computer to control various types of application equipment. Precision agriculture systems may therefore include different types of applications, some of them providing *information*, while others allow for *variable rate management* (Table 1). Let's discuss them in a little more detail.

The most widely adopted information gathering tool is the *yield monitor* which provides yield data for every second (or so) of combine travel time. For most farmers, yield mapping is an entry point into precision agriculture.

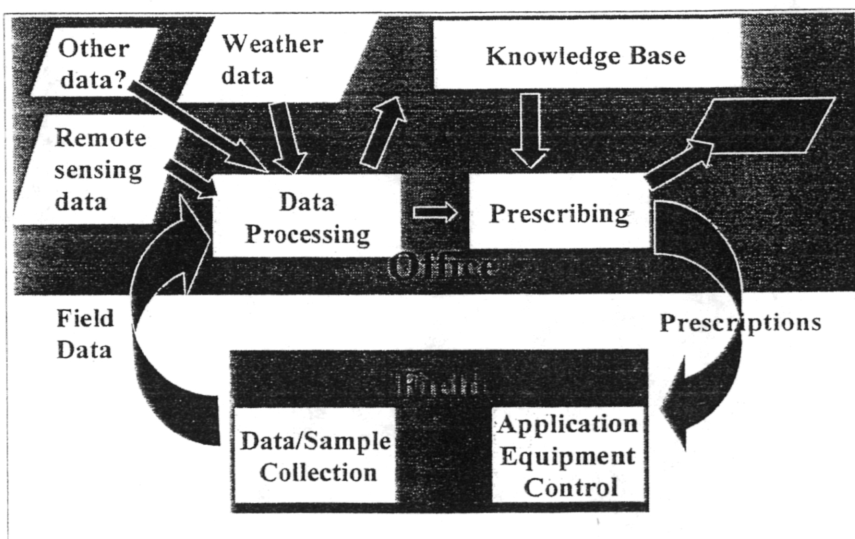

Figure 1: Precision agriculture information flow.

Precision Agriculture Components

Information	Variable Rate Management
• yield mapping	• variable fertilizer and lime rates
• mapping of "amendments"	• variable organic amendments
• intensive soil/crop sampling	• variable seeding rates
• weather data	• differential hybrids
• remote sensing	• variable pest control
– in field, on-the-go	
– air, space-based	

Table 1: Precision agriculture components.

It provides good quantitative information on yield variability that may be used to make field management decisions. In addition, it provides an effective way to keep yield records for each field.

For better fertilizer and lime application, intensive soil sampling is now being employed. This typically involves samples being taken within a field on a grid or by soil type. This information may then be used to apply these crop inputs at variable rates within a field. In most cases, the increased costs of soil sampling and analysis are offset by more efficient use of the crop inputs. For New York, this appears to be especially the case with lime application since soil pH levels often vary widely within a field.

There are several other information sources that are now being applied in precision agriculture. Notably, remote sensing has become more affordable. Services are now available to farmers that provide images from aircraft or satellite that can be used for a multitude of management decisions. Such information typically involves reflectance patterns in multiple spectral bands (including near-infrared, which is useful for assessing plant health), and is now available in digital, georeferenced format that allows for effective incorporation into a Geographical Information System. Although the knowledge base is still being developed to effectively use this information, the potential applications for more effective crop management appear very promising. It is expected that remotely-sensed information will become increasingly affordable and useful to crop management. Such images may allow for more targeted fertilizer application and pest management. For example, research is currently under way to evaluate the use of remotely-sensed images for determining N sidedress application rates. Also, they may allow a field scout to more effectively identify pest patterns in a field and recommend partial treatment of a field rather than the entire field. Remotely-sensed images of bare soil can identify areas prone to drainage or drought problems, and may be a very effective tool for evaluating hydrologically-sensitive areas in a watershed. *Weather data* can also be more effectively used in precision agriculture. After all, weather is the primary source of *temporal* variability in crop growth and we can employ weather information to better manage crops and pests.

Besides fertilizer and lime, several other crop inputs may be more efficiently managed with PA. Current or emerging technologies include variable seeding rates (e.g., higher plant densities in areas of higher yield potential), differential use of crop hybrids based on adaptability to variable field conditions, variable pest control, and variable application of soil amendments such as manure, composts and sludges. For the Northeast, the use of PA technology in manure application will be very valuable. Imagine in the near future having a record of the amount, timing, nutrient content, and location of manure being applied. This will provide important information that can assist farmers in more effectively using manure for crop production, and providing greater protection of the environment. Future manure spreaders may even be programmed to exclude applications in hydrologically-sensitive areas.

Besides the model described in Figure 1, we may see increasing use of on-the-go interpretation of field information, as shown conceptually in Figure 2. Such systems may involve sensors that are mounted on field equipment that will provide information that is immediately used to control application equipment. Currently, experiments are conducted with tractor-mounted sensors that identify weeds in a field and directly control a pesticide sprayer. In the future, we may see sensors that can estimate soil nutrient contents on-the-go and directly control a fertilizer applicator. This ultimately may be the most promising approach to precision agriculture, although we have a long way to go before this technology is operational.

In general, precision agriculture will be attractive in providing more efficient and environmentally sound ways to grow crops. In the past years, we have experienced a tremendous leap forward in the development of hardware