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Precision Farming:
A New Approach to Crop Management

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What is precision farming? It is a management strategy that employs detailed, site specific information to precisely manage production inputs. This concept is sometimes called precision agriculture, prescription farming, or site-specific management. The idea is to know the soil and crop characteristics unique to each part of the field, and to optimize the production inputs within small portions of the field. The philosophy behind precision agriculture is that production inputs (seed, fertilizer, chemicals, etc.) should be applied only as needed and where needed for the most economic production.

Why should producers be interested in precision agriculture? Precision farming techniques can improve the economic and environmental sustainability of crop production. In today's agriculture, producers tend to farm each field as a single unit. Although they often recognize in-field variability, they have had few tools with which to manage that variability. As a result, producers have based management decisions on average conditions, hoping that the inputs would be adequate for most of the field. Precision farming uses information technologies to segment a field into smaller units and determine each unit's individual characteristics. In this way, the producer can apply production inputs in the precise location and quantity they are needed for maximum economic yield. To understand fully how precision farming works, one must become familiar with the tools and techniques that create the infrastructure of this modern form of agricultural management.

The Global Positioning System (GPS) is the heart of precision agriculture. A GPS receiver is a location device that calculates its position on earth from radio signals broadcast by satellites orbiting the earth. The U.S. government has 24 satellites that are constantly orbiting the earth. These satellites contain precise atomic clocks, and the exact time is encoded into the signals broadcast from each satellite. A GPS receiver uses this time information to measure the distance to each satellite from which a signal is being received. With at least four satellite signals, the receiver can use triangulation to calculate its position on the ground. However, this calculated position is inaccurate because of errors in the satellite signals. Some of these errors, such as those caused by atmospheric interference, are unavoidable. Another error source is government controlled for security purposes. This intentional degradation of the satellite signals is known as selective availability. Figure 1 shows a sprayer equipped with a 60-foot boom receiving positioning data with inaccuracies of up to 300 feet from its true position. These inaccuracies are not acceptable for site specific management. Errors of this magnitude require that the government-based system be

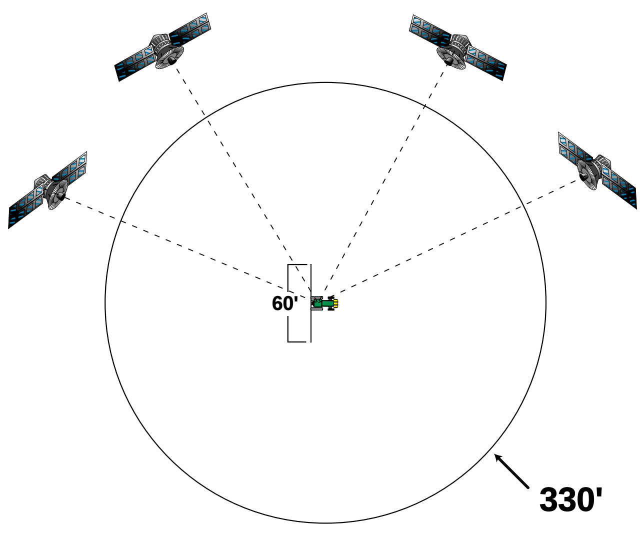

Figure 1. Position uncertainty for an uncorrected GPS receiver relative to machine operating width.

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augmented with another signal that can improve positioning accuracy. The additional signal is transmitted from a fixed base station with a precisely known position. The base station receives the satellite signals and compares its calculated position with its exact position. The amount of error is then broadcast to mobile receivers in the field so that they can correct for the same satellite errors. This system is known as differentially corrected GPS or DGPS. The accuracy of the DGPS receivers is 5 to 10 feet, which is acceptable when dealing with a 60-foot swath. (Fig. 2).

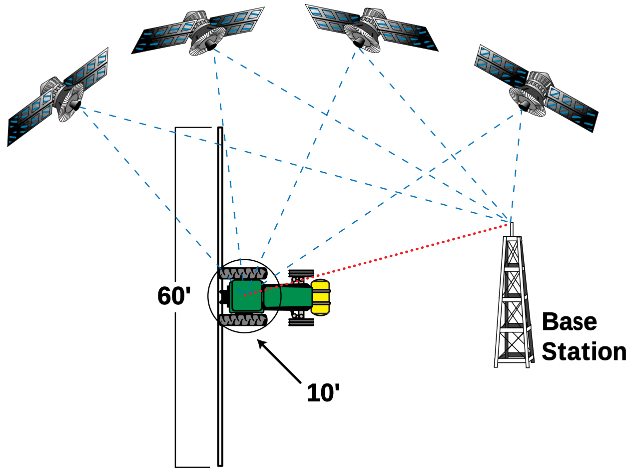

Figure 2.

DGPS receivers can be used in a wide range of situations to provide the latitude and longitude of a machine operating in a field, or of a field scout who is making observations and taking samples. Field images, or maps, can be made by recording parameters such as yield or fertilizer application along with position in the field. Figure 3 shows the path of a sprayer as it applied variable rates of herbicide across a field.

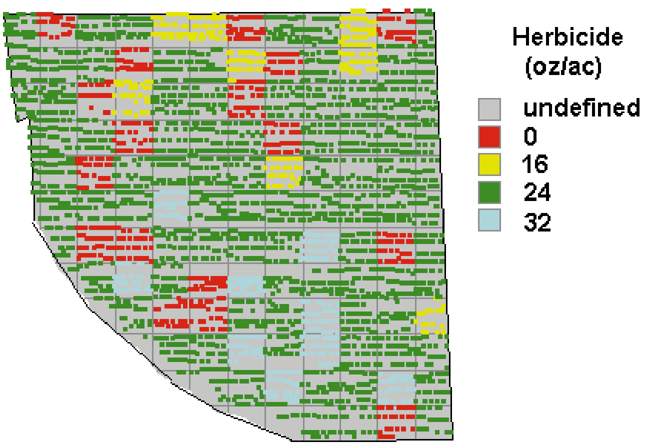

Figure 3.

Mapping software is used to handle, display and analyze data stored as a value and a position. Mapping software is available with a wide range of capabilities. Low-end packages are used primarily for creating maps or graphical images, and have little capability to process or analyze data. High-end products are known as ***Geographic Information Systems*** or GIS, and have many data processing capabilities. Because precision farming requires a relatively high level of data processing, software used for this purpose has become known generically as GIS software. Potential users should consider capabilities such as data editing, interpolation/contouring functions and statistical analysis when purchasing mapping software.

Several types of data can describe a field's characteristics. Common data types include yield, soil texture and nutrient status. Each of these is stored as a data layer. Conceptually, a field can be described by a stack of data layers. Some layers may be raw data, representing the actual measurements taken (e.g., soil pH as determined by sampling and analysis or weed densities as determined by field scouting). Other layers may be derived by mathematically processing one or more layers to generate a new layer. Figure 4 shows a data layer representing soil phosphorus levels as determined at sample points and interpolated over the field.

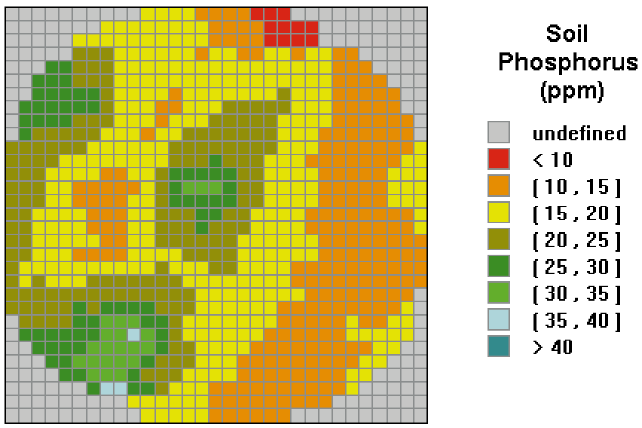

Figure 4. Soil phosphorus as determined by sampling and interpolation.

Variable Rate Technologies (VRT) describes machines that can automatically change their application rates in response to their position. VRT systems are available for applying a variety of substances including granular and liquid fertilizers, pesticides, seed and irrigation water. The most widely recognized VRT machines are large chemical applicators that control up to 11 different materials at once. VRT applicators consist of a controller that adjusts the actual material flow rate, a positioning system, and a map of the desired application rates for the field (Fig. 5). The controllers are very similar to those used on many sprayers, spreaders and other agricultural machines. On conventional machines, the operator controls the application rate by selecting the desired rate from the console panel in the cab. By integrating GPS and GIS databases into the system, application rate changes can be made automatically as the vehicle crosses the field.

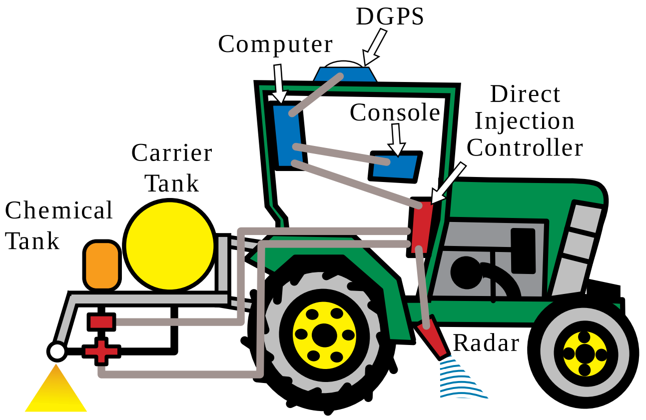

Figure 5. Schematic representation of the components of a VRT chemical applicator.

Often the data used to determine the application rates for VRT machines is gathered through grid sampling of fields. ***Grid sampling*** involves taking soil samples from the field in a fixed pattern as shown in Figure 6. Each grid square typically has an area of $2^1/2$ to 4 acres for grain crops, but more samples can be taken for higher value crops. Some producers have had success with ***targeted*** or ***zone sampling***. This method uses knowledge of field conditions to determine the sampling sites rather than a uniform spacing. Generally, the samples are located where soil or topology changes occur in the field.

The sampling data are entered into a GIS database and a map of the field's soil parameters is made.

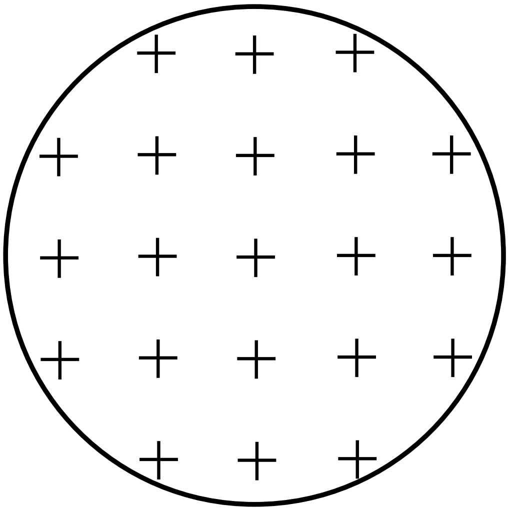

Figure 6. Each cross represents a soil sample position in a field.

Because data is available for only a few points in the field, the values for other locations are estimated based on the values of the nearby sample points. This technique is most frequently used to determine fertilizer application rates. The required nutrient levels are determined, based on expected yield. Then nutrients are analyzed for each sample point and credit is given for these residual nutrients in each part of the field. The overall profitability of this approach to fertilization varies by region and crop, but experiences in Texas and other states have shown that, for granular fertilizer applications on high yielding corn, costs can be reduced by $5 to 15 per acre.

Yield mapping is another important technique in precision farming. Yield maps show the variability in yield within a field. A yield mapping system measures and records the amount of grain being harvested at any point in the field, along with the position of the harvester. To produce a yield map, the harvester must be equipped with a GPS receiver and a yield monitor. A yield monitor can be a flow meter or a scale. In harvesting most grains, a sensor is placed in the flow of the grain as it passes through the harvester. This type of system measures the flow rate and moisture content of the grain, shifts the data in time to match the position where the grain was cut and divides the flow rate by the machine's harvested area to achieve a yield per unit of area (e.g., bushels per acre). For non-grain crops such as potatoes or sugar beets, scales are used to continuously weigh the produce to achieve the same results. The yield data are sent to the onboard computer where measured yield is matched with its appropriate field position and the data are stored in a memory card. The data stored on this card can be transfered to a computer equipped with mapping software to produce a yield map. Figure 7 is a yield map for a highly variable corn field in North Texas.

Yield maps can provide useful information to the producer. The maps identify areas of high and low

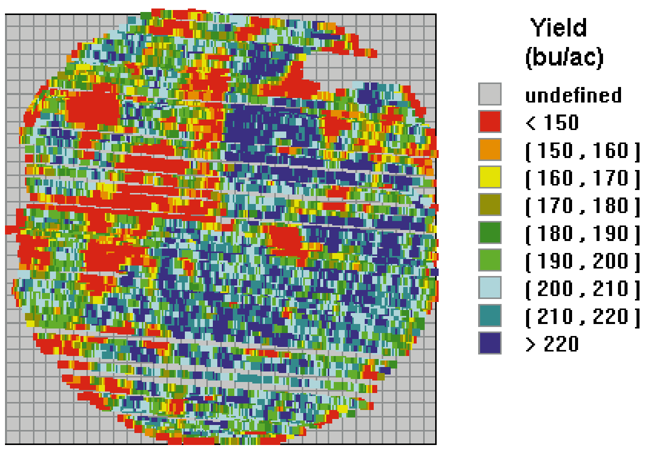

Figure 7. Corn yield in an irrigated field in the Texas Panhandle.

yields so that inputs can be adjusted to maximize the productivity of a field. Yield maps document both natural and man-made sources of variability. Natural variability is caused by weather within a growing season and from year to year. To correct for this, a producer may need to obtain several year's data to determine consistent yield trends that can be related to soils or field topology. However, man-made variability may be easily identified and corrected with a single year's data. Examples of man-made variability include poor distribution of irrigation water and the effects of past production practices.

The way harvesting machinery is operated can influence the accuracy of the resulting yield maps. For example, in irregularly shaped fields, the harvester may end up harvesting grain over a partial width of the machine. This will cause the yield sensors to indicate a lower yield than was actually obtained. Operators must understand how yield monitors record yield data. Most combine yield mapping systems are designed so that data recording is halted when the header is lifted. This makes it easy for the operator to stop recording data when traveling. However, if turns are made with the header in the down position, data points are added that show a zero yield. Another manmade error occurs when the yield sensors have not been properly calibrated. Poor sensor calibration can lead to inaccurate yield calculations.

The profitability of precision farming is as variable as field conditions. In highly uniform fields, better knowledge of soil and plant parameters is not as likely to result in greater economic return as it is in fields with variable conditions. Producers who use site-specific management must recognize that information becomes another input to the system, and that it has a cost. With soil, weed, fertility and yield maps for a particular field, the producer can know more about the field's yield potential and determine which areas of a field are creating the largest profit, as well as which areas are not capable of producing as well as others (Fig. 8). The profitability of adding more fertilizer or decreasing a pesticide rate at a specific site in the field can be determined. Precision farming technology brings increased efficiency to crop production. By closely matching application rates with crop needs, profit potential can be increased and possible environmental impacts can be minimized.

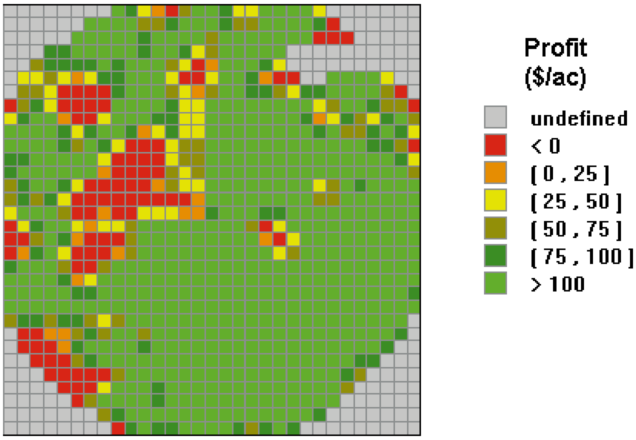

Figure 8. Estimated profit margin in the field in Figure 7 (dollars/acre).

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