11. Precision Agriculture

Precision agriculture for crop production can be defined as a management system that:

- is information- and technology-based
- is site-specific
- uses one or more of the following sources of data for optimum profitability, sustainability and protection of the environment:
  - soils (texture, pH)
  - crop (inputs, health and growth)
  - nutrients
  - elevation/topography
  - pests
  - moisture
  - yield

(Source: U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), Precision Agriculture Technical Note, 2007).

This chapter outlines some of the basic concepts of precision agriculture as it pertains to field crop production, and is not intended to be a comprehensive overview. Precision agriculture also includes technologies being deployed in other agricultural areas, such as livestock and horticulture that will not be discussed. It is highly recommended that readers frequently check local sources of current information. Refer to Chapter 9, *Soil Fertility and Nutrient Use,* and Chapter 10, *Field Scouting,* for specific precision agriculture strategies.

Precision Tools

Real Time Kinematic (RTK) and Global Positioning Systems (GPS)

The advances made in precision agriculture started with the adoption of Real Time Kinematic (RTK) guidance and accurate elevation mapping made possible with geospatial technology that includes global positioning systems (GPS). This capability is enabling the deployment of increasingly sophisticated technology that allows fields to be managed at a spatial level never before possible. An onboard computer knows exactly where a piece of farm equipment is in space and time, and can adjust inputs (e.g., lime, fertilizer, seed population, planter depth, planter down pressure, variety, pesticide rates, tillage depth or aggressiveness) based on a prescription that is loaded into the controllers on the equipment. Precision agriculture brings together the disciplines of agronomy, engineering and geospatial analysis. Continued efforts to bridge the gap between these disciplines for producers, advisors and extension personnel will increase the ability to use these technologies more efficiently and productively.

GPS guidance systems have allowed farm equipment to be driven with automated navigation. Several key benefits are realized from this technology. One benefit is that operators are less stressed and tired from long hours in their tractor cabs. Many studies have shown significant increases in operator efficiency, comfort and improved accuracy when autopilot technology is used. The second benefit of the auto-guidance systems is efficiency in equipment operation. Larger equipment can be operated with centimetre accuracy in pass-to-pass navigation, which insures efficient use of time, fuel and inputs. Auto-steer systems allow the tractor to operate the equipment, while the operator monitors the systems and field conditions to make on-the-go adjustments without concern about where the equipment is heading.

Applications for Precision Agriculture

1. One of the first, but still vitally important, applications of precision agriculture is the yield mapping capability of harvest equipment (mainly grain combines). While yield monitors were used before the deployment of GPS technology, the amalgamation of yield monitors and GPS technology has enhanced the value of yield monitor output. Yield monitors, when calibrated, are extremely good at revealing the variability of crop yield across a field. This variability is accurately recorded so the producer can navigate to those areas to determine what factors are impacting the significant yield differences at those precise locations.

   Yield monitors gather tremendous amounts of data, and allow the preparation of visual yield maps that quickly demonstrate where, and how much, the variability in the field is affecting the overall field productivity. While yield monitors have been around for several decades, only recently has the accuracy, connectivity to GPS and software tools that process the data been available to start maximizing the use of this technology.

2. Another advancement in precision agriculture is the use of planter row, plus dry and liquid application equipment differential shutoff systems. Since the equipment tracks where it is and where it has been, it can be programmed to stop the application of inputs on areas where it has already placed inputs. This application reduces over applying inputs of seed, fertilizer, pesticides, etc. The benefit is reduced overlap, resulting in economic savings and diminished environmental risk. The savings in inputs, and potential environmental stewardship associated with use of these technologies makes purchase of planting or application equipment with VRA options a “must-have” technology with an excellent return on investment potential.

3. Down pressure technology on planting equipment is another precision agriculture tool that is not directly linked to the use of GPS. In theory, down pressure technology should adjust planter contact with the soil to ensure continuous optimum seed placement. There are two options for this:

   - air and hydraulic systems that control the whole planter
   - similar systems that control individual row units across the planter

   Continuous monitoring of planting equipment performance, seeding depth, quality of the seed trench, etc., is difficult to accomplish for most producers, but can be done by down pressure technology. Producers have reported mixed results based on their expectation of what the system should deliver. Some feel it is enough that the system take into account the general field conditions and adjust down pressure at a field level. Others have expectations that the system should react quickly to the range of topography and variable soil conditions experienced in the field, and quickly adjust down pressure to optimize continuous planting performance. The use of this technology does not exclude the operator from occasionally checking on the performance of the planter, by digging up planted seed in all rows to ensure depth, compaction, spacing and population accuracy.

4. Equipment manufacturers are collecting machinery data in near real time and are compiling and analyzing data on larger scales (e.g., farm, regional, provincial, national) to allow an evaluation of equipment performance and how this relates to crop management decisions. Partnerships between equipment, seed and agricultural input companies are forming so that data is shared and ”mined” to answer agronomic questions.

Variable Rate Application

Currently, there is an increased interest in using all the data being collected by equipment to manage fields at a sub-field level. This requires the creation of management zones across a field. Zone management is defined as areas within a field that perform similarly and consistently over time (e.g., zones with similar soil texture, topography, drainage and crop yield). Since different parts of a field often perform differently, the expectation is that by defining zones of similar performance potential, the application of varying inputs across these zones should optimize productivity. Once zones are defined, apply separate input prescriptions to each management zone for a multitude of crop inputs (e.g., fertilizer, pesticide, tillage, seed, etc.). Inputs are applied differentially across the field based on the rates allocated to each zone by the equipment controllers. This is also known as variable rate application (VRA).

The goal of VRA at the field level is to optimize crop inputs with economic yield potential. Achieving this goal often requires the application of inputs to vary significantly across a field. Compared to current practices, some portion of fields will receive fewer inputs, while other portions will receive more. The end result should optimize crop input use efficiency. The amount of crop inputs may be smaller or greater than they are now, but the geospatial application of those inputs will ensure the most efficient use. Overall, it is expected that there will be less crop inputs left in the environment than with current practices.

The delineation of management zones within the field requires input of data such as yield, soil chemistry and topography. Once zones are defined, the assignment of input prescriptions requires agronomic knowledge, to determine the rates of input that would best respond to the characteristics of the specific zones. Refer to *Defining Soil Sampling Zones,* Chapter 9 for an example of soil sampling zones created with elevation data.

Technology Challenges

Agronomists and producers are challenged to keep up with technology advancements, and a lack of standardization in technology creates difficulties using precision agriculture. Data is collected and processed using different software and hardware platforms that cannot be easily interconnected. Work is underway at several levels to address cross-communication between different systems.

One important detail missing from the VRA aspects of precision agriculture is validation of the created management zone maps and the prescriptions applied to those zones. Without a validation procedure, there is no way of knowing whether the management zones are well defined and/or if the prescription decisions made for each zone are correct. Validation requires deploying a range of rates for the target inputs into each of the zones, followed by assessment and interpretation of the results to determine the optimum rate. This must then be compared to the rate applied to the zone region as a whole. Unfortunately, like other methods of validation within crop production practices, this remains a "hindsight" exercise. But over time, the use of validation will ensure that precision agriculture is applied optimally to the field. Currently, there are some routines for validation but they are labour-intensive and time-consuming to implement and evaluate. The goal is to have validation systems that independently deploy a range of input rates at several points within each management zone. Ideally, such a system could collect, interpret and compare the data collected from these micro-plots automatically, and provide a report to the producer that outlines what rate provided the best response, based on economics of inputs and outputs. This would build the producer's knowledge-base and over time, enable targeting of the optimum level of input for each management zone in a field.

Real-Time Management

Real-time management can also be used in precision agriculture practices and to-date has generally focused on variable rate nitrogen (VRN) management for corn and wheat. Real time management typically involves employment of optical sensors mounted on application equipment that measure plant biomass and health (i.e., expressed as a vegetation index, such as the Normalized Difference Vegetative Index or NDVI). The vegetation index numbers are then used in calculations to automatically determine the amount of nitrogen to apply in real time (Figure 11–1).

Figure 11–1. Real-time Variable Rate Nitrogen application using optical sensors mounted on a y-drop fertilizer applicator. Greenseeker™ sensors circled in red on the boom for both wheat and corn

Equipment Credits: Hensall Co-op (left) and Claussen Farms (right).

Remote Sensing

Both handheld and equipment mounted optical sensors are used for scouting. The most common are optical sensors that determine NVDI.

Moving forward, there will likely be increased use of thermal and other types of sensors to determine plant stress and other factors that currently remain invisible to the human eye. These sensors will allow scouts and producers to determine if disease occurrence is imminent and if so, ensure better timing of technologies such as "protectant fungicides," where application occurs before symptoms are visible. These types of sensors may be deployed as handheld devices, equipment mounted, or on Unmanned Aerial Vehicles (UAVs) or satellite platforms.

Unmanned Aerial Vehicles / Unmanned Aerial Systems

Unmanned aerial systems (UAS) are commonly referred to as unmanned aerial vehicles (UAV). UAVs of both fixed-winged (airplane) and rotor (helicopter) are rapidly being deployed in farming. These come in various sizes, payload capacity and flight duration. There is a wide range in cost and sophistication of the sensors mounted on the platforms. Significant restrictions exist regarding where UAVs can be used. Because UAVs share their airspace with conventional aircraft, federal authorities want to ensure that their use does not pose a risk to aircraft. Privacy issues also result in restrictions for use of UAVs. However, seeking landowner permission is a common practice in agricultural sectors before flights occur.

The various payloads available for these vehicles can collect a variety of images during a scouting operation. These include high resolution digital photography and video, modelled 3D elevation, infrared, NDVI, thermal and other sensors. This data can be made available to producers and advisors to assist in monitoring the crop within a field or whole field, or on a local, regional or national level. This technology appeals to many diverse groups interested in the status and progress of crops throughout the growing season.

While these are very valuable tools that ideally could collect, interpret and compare data; to date the technology simply identifies where field differences are occurring. From there it can direct attention to exact locations in the field to determine what is happening. On-site human interpretation of differences identified by the technology is required to establish economical management options that can address the detected differences.

Advances with remote sensing and UAV technology will likely result in ground truthing the differences identified (i.e., patterns, crop, weed or soil colours, etc.), to build the capability to detect, identify and determine the cause of differences and enable automatic management decisions. It is expected that this technology may advance to the point where management decisions can be made without having to visit the field to calibrate observations made by the sensors.

Sensors in future will detect disease, insects, drought, weeds, flooding etc. There are satellite companies currently exploring their role in agriculture and the timeliness of observations needed to benefit crop management.

Many of these new technologies will enhance the options available in precision agriculture to improve economic and environmental aspects of crop production.

Trust vs. Test

Currently, many precision agriculture software and cloud-based computing services are offered. In many cases the expectation is that the producer will upload their field data into the system for analysis (e.g., soil chemistry and yield data, etc.). A prescription map can then be downloaded from the system for variable rate application in the field. Some of these solutions are modeled results and are not always based on site-specific climate and soils information. "Test not trust" prescription maps, and implement validation strategies. For example, in Figure 11–2, *Comparing strips to blocks with nitrogen applied using variable rate technology,* entire passes or small blocks within management zones reflect the conventional uniform practices and rates that would have typically been used by the producer. Post-harvest analysis would compare the precision agriculture approach versus the results of the normal practice for that particular growing season's conditions. The goal is to determine areas of the field that were optimized, while identifying zones in the field where the prescription may require further adjustment in the years to follow.

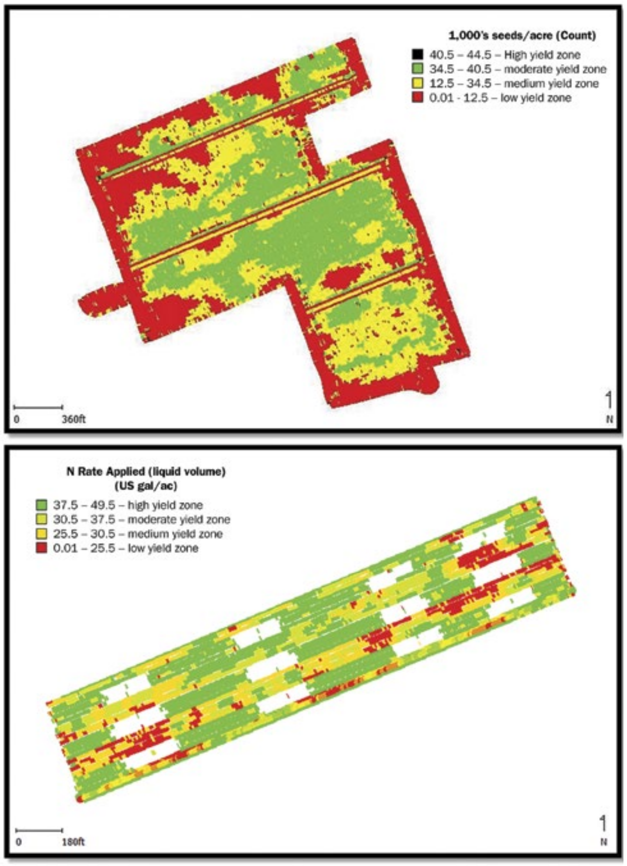

Figure 11–2. Screen captures comparing strips to blocks with nitrogen applied using variable rate technology.

In Figure 11–2, the top map illustrates a variable rate population corn map with strips of uniform population that cross all management zones. The bottom map shows results of a tractor mounted optical sensor for nitrogen application (e.g., Greenseeker™) on corn, where blank areas show no nitrogen was applied. These as-applied maps verify that the equipment performed as stipulated in the prescription maps.