GIS Applications in Agriculture: Nutrient Management for Energy Efficiency

John Nowatzki – Agricultural Machine System Specialist
North Dakota State University

Introduction

Precision manure application uses the global positioning system (GPS) and electronic control systems to monitor manure application rate, avoid misses or overlaps, vary application rates and record information about the application process. Computer-generated maps installed in the in-cab controller prescribe the desired manure application rate at each location across fields. Precision liquid manure application more effective that precision application of solid manure.

Why Precision Application of Manure?

Precision manure application using GIS and GPS can reduce energy reqirements by allowing producers to avoid overlappping or missing applications areas. Other advantages to precision manure application include avoiding application in environmentally sensitive areas, turning the applicator off when traveling outside field boundary areas and varying the application rate based on projected crop nutrient needs at different locations across fields. Manure application requires specific management practices similar to commercial fertilizer. Manure has significant value as a field crop input and that value is easily diminished by improper applications. Missing areas of fields during manure application can result in crop nutrient deficiencies causing lower crop yields. Overlapping manure application can also reduce crop yields because of too much vegetative growth resulting in increased crop diseases or lodging. Geospatial technologies can enhance implementation of efficient manure management practices including determining the optimum amount of manure to apply at specific locations in fields for specific crops and yield goals, applying prescribed rates, and recording where and when manure was applied.

Basics of Precision Manure Application

GPS Applications in Precision Manure Application

Precision manure application can be as simple as using a vehicle GPS guidance system to avoid overlapping or missing areas or using more involved technology that incorporates variable rate application.

Variable rate manure application involves using both geographic information system (GIS) computer programs and GPS. GIS computer programs manage and present data that is linked to locations and are used in personal computers to develop field zone maps and precision manure application maps. Zone maps divide fields into areas that require unique management practices. Precision manure application maps are geo-referenced, digital maps used in variable rate controllers to prescribe the correct amount of manure at each field management zone. In-cab computer controllers used with GPS on manure application equipment send signals to flow control valves on manure applicators to change the application rate as the equipment moves from

one management zone to the next. The computer controller also creates a digital "as-applied" map that records the time and rate of manure application at each point in the field.

Management Zones

Management zones used with variable-rate fertilization assign a unique yield goal to each zone in a field. The fertilizer application equipment used for variable-rate fertilization is capable of changing application rates during field operation. Variable-rate fertilization uses a global positioning system integrated with a computer in the tractor cab to signal the fertilizer application equipment to change rates as it moves from one zone to another.

Zone maps are made using a GIS computer program capable of combining field variability information to delineate field areas based on productivity levels. Several factors contribute to field variability including topography, soil physical and chemical properties, cropping history, remotely sensed images of previous years' vegetative growth, historical crop yield data, soil survey information and grower knowledge of the field.

Figure 1 Management Zones

Producers have several options to develop zone maps and fertilizer application maps. The major farm equipment companies and several GIS companies market computer programs capable of combining the various layers of information to make field zone maps. Farmers also hire crop consultants or agricultural computer consultants to prepare zone maps.

Web-based zone map developing tools are available that allow users to develop field management zones online. ZoneMap (http://zonemap.umac.org/) is a zone mapping tool available for use without charge that is capable of developing both management zone maps and fertilizer application maps. ZoneMap allows users to build zone maps from historical vegetative growth patterns and also allows users to upload and incorporate their own geo-referenced field information to help delineate field variability to develop management zones.

Both zone and application maps are digital computer files and therefore have unique digital formats. Users need to be cognizant of the file format required by the in-cab controller and export and save them in the appropriate format from the GIS program.

Although zone maps are usable for more than one fertilizer application, it is important to refine the zone boundaries to incorporate additional field variability knowledge garnered from each year's crop yield data and soil test analysis data.

Application Maps

Manure application maps indicate the desired manure application rate for each field management zone. Application maps are generally created in a GIS program on an office computer and exported in the digital format usable in in-cab controller. The controller uses GPS to provide vehicle real-time location in order to signal rate changes to the application equipment for each field management zone.

The size of the individual variable rate zones on the application map needs to correlate with the applicator width and the time needed to change the application rate. For practical equipment operation the smallest area requiring a manure application rate change should be at least twice the width of the applicator and long enough to allow the rate changing technology to function.

As-Applied Maps

Digital as-applied maps are created in in-cab controllers as the applicator equipment operates in the field. The controller records the application rate and time of the manure application and saves the data on a geo-referenced map file. The maps provide the operator assurance that the manure was applied as planned. After crops are harvested, as-applied manure application maps can be correlates to crop yield data to validate and improve field management zones. As-applied maps can also serve as an historical record of application including showing field setback distances and environmentally sensitive areas.

Required Equipment and Procedures

GPS Antenna and Receiver

Variable rate fertilization relies on GPS to maintain constant equipment positions allowing the in-cab computer to signal rate changes as the equipment moves from one field management zone to the next. Since fertilizer application equipment is normally much wider than the horizontal error of even uncorrected GPS signals, any GPS signal accuracy usable for vehicle guidance will function for variable rate fertilization.

If the GPS receiver antenna is not mounted directly on the fertilizer applicator, the in-cab controller needs to be programmed to account for the separation distance between the GPS antenna and applicator to ensure the fertilizer rate is changed at the correct location as the equipment moves into a new management zone.

In-cab Computer/Controller

The central component of precision application and variable rate application equipment is the computer/controller normally mounted in the vehicle cab. The controller performs several functions including: 1) operating a software program to display the application map; 2) recording the GPS signal to recognize the vehicle real-time position on the map; 3) communicating signals with the rate control device to alter the application rate; 4) monitoring vehicle speed; and 5) recording the manure application map.

Figure 2 In-cab Computer/Controller

Unfortunately, many older controllers are not capable of performing variable rate application requiring producers interested in variable rate application to purchase new controllers. Several functions are important when choosing a controller including compatibility with other brands, compatible digital data formats, ease of interaction, ability to record and save application maps, and capabilities to perform other functions besides variable rating. Other controller functions include operating spinner fertilizer spreaders, variable rate and boom section control on sprayers, and vehicle guidance systems.

Equipment for Precision Application of Solid Manure

It is more difficult to accomplish precision application of solid manure than liquid manure and is generally less accurate. However, there are management practices that can be employed to increase the precision and accuracy of solid manure. Using GPS guidance along with solid manure spreader innovations such as horizontally mounted rear throwers, along with drive sprockets on augers and expellers that can be changed to match the consistency of the manure being spread allow for more even distribution of manure. Other new solid manure spreaders incorporate vertically-mounted rear manure throwers which spread manure more evenly than traditional spreaders.

Rate changes with solid manure application can be accomplished by either altering the operation rate of the spreader or altering the rate of travel of the spreader. Load cells can provide a continuous data stream of weight during the manure applicator discharge. Measured weight differences during unloading can be used to determine applicator discharge rate. In-cab controllers can calculate the application rate by knowing the discharge rate, application width and travel speed.

Equipment for Precision Application of Liquid Manure

Manure in liquid form is normally used for precision and variable rate application. The components needed to accomplish precision and variable rate liquid manure application are an in-cab controller, a section control switch, a liquid flow meter and a flow control valve. The controller can be used to maintain a constant application rate as travel speed varies or vary the rate based on previously defined application maps.

Variable-rate application is accomplished by varying applicator discharge rates with flow control valves. A flow control valve and an electromagnetic flow meter can be plumbed in line after the pump on liquid or slurry manure applicators to measure and change the manure flow. Flow meters and controllers automatically adjust a valve or change the pump speed to keep a constant application rate as tractor speed or topography changes. Both the flow valve and flow control valve are connected to the in-cab controller that functions to continually monitor the flow rate and signal the flow control valve to change the application rate to correspond to the rate prescribed in the manure application map.

Electromagnetic flow meters function better than turbine-type meters with liquid manure because they are not affected by solids in the stream flow. Doppler flow meters can also be used to monitor the liquid flow.

Figure 3 Flow Meter and Control Valve

Commercial Equipment Options

Commercial equipment is available to accomplish different levels of precision manure application. A flow meter plumbed inline after the pump can be used with an in-cab monitor to gauge how much manure is flowing through the applicator. Using a monitor capable of monitoring the speed of the tractor, width of the spread pattern, and flow rate allows the operator to know how much manure is being applied per acre. Connecting a GPS to the system allows the operator to produce a map of where manure was applied on the land. Finally, by adding a flow control valve inline after the flow meter, and an electronic switch, the system can vary the application rate at different field zones. Manure application equipment manufacturers to date are only marketing machines equipped with flow meters, in-cab monitors and GPS units allowing operators to monitor application rate and prepare "as-applied" manure application maps. However, some operators are modifying their equipment by incorporating the components necessary to accomplish variable rate manure application.
A hydraulic cylinder is used to change the flow rate of the flow control valve. An electric over hydraulic control switch is incorporated with the system to prevent the cylinder from operating when the manure injectors are not engaged in the ground.

Figure 4 Commercial Applicator with Variable Rate Controls

References

1. Ess, E.R., 2001. Implementing Site-Specific Management: Liquid Manure Application. SSM-1-W. Purdue University, 615 West State Street, West Lafayette, IN 47907-4773.
2. Laatsch, T. P.2008. Mapping Manure Application. Environmental Services, 7475 State Route 127, Carlyle, IL 62231 http://www.mnpork.com/producers/2008/ManureMapping2008.pdf
3. Krohne KROHNE Messtechnik GmbH & Co. KG, Ludwig-Krohne-Str. 5, D-47058, Duisburg. http://www.krohne.com/
4. Eldon C. Stutsman Inc Website: http://www.stutsmans.com/index.cfm?show=10&mid=18