Manure Distribution Patterns, Operator Decisions, and Nutrient Management Plans

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Introduction

The various forms of environmental degradation from agriculture have been well documented across widely varying spatial and temporal scales (Green et al., 2004; Waltner-Toews and Lang, 2000). The emergence of the science underlying precision agriculture approximately two decades ago offered the potential to address this situation, but the resulting environmental record has proven to be largely rhetorical as most research in this arena has been on narrow production issues. Yet the potential remains salient as current commercial agriculture can be characterized as a "leaky system" (Groffman, 1997) due to the lack of congruency between production practices and underlying biophysical settings. Precision conservation holds the potential to manage the interface between management decisions and natural processes at spatial and temporal scales not addressed in conventional commercial agriculture (Berry et al., 2003). In essence, precision conservation offers the potential to achieve the fundamental principle of resource management --- to use the land according to its capabilities.

Manure Management

Manure management is a topic that is ideal for exploring the capabilities of a precision agriculture approach for a variety of reasons. First, manure is an agricultural constituent that has had three different meanings placed on it, and this shifting definition has resulting in significant diversity in how it is managed. Manure at one time was viewed as an integral part of any agricultural system providing crop nutrients while enhancing soil quality. This first view of manure saw agriculture as being sustainable only with manure being an integral part of the system. In the middle of the 20th century the meaning placed on manure changed to one of being a waste or externality to the production system (Nowak et al., 1998). As commercial nutrients began to become widely available, producers were encouraged to dispose of manure in a timely and convenient fashion. That is, manure was viewed as a waste and treated accordingly. More recently, manure has again changed in meaning to one where it is now viewed as an environmental pollutant. Animal operations today are being challenged to manage manure in a fashion that meets environmental air and water standards. All three views of manure are found in the agricultural systems of today making this a situation that should be ideal for an application of precision agriculture.

The second reason why manure management is ideal for a precision agriculture analysis is due to the significant variability in manure relative to its form and nutrient content. Unlike commercial nutrients that have a guaranteed nutrient analysis and come in standard formats, manure is a much more variable constituent as an output from the animal production system. Manure is highly variable, unlike other standardized agricultural technologies, making it ideal for testing the capabilities of a precision agriculture approach.

Third, many of the techniques and machinery used to distribute manure on the landscape have changed little across the years. For example, the box spreader that is used by a majority of small to medium sized animal feeding operations (AFOs) in the Midwest and Great Lakes regions has changed little in basic design from when this implement was pulled by horses. Other techniques and machinery are a carry-over from when manure was considered a waste, and yet are still being used to address the challenge of achieving environmental objectives. Again, this variability in machinery function and distributional capabilities makes it an ideal test for a precision agriculture analysis.

Finally, producers of AFOs are now being asked to address environmental issues through the use of nutrient management plans. These nutrient management plans are intended to rationally allocate the distribution of manure across the farm landscape in a manner so as to reduce environmental damages. The rationale underlying these plans is a simple mass balance approach. The amount of manure generated is "balanced" against the total crop needs determined by crop acres and crop rotation. The plan is to rationally distribute the manure to the fields that need manure nutrients. These plans are based on field-scale maps that should illustrate sensitive areas, identify current and planned crop rotations, and then develop a nutrient budget that guides the distribution of manure to these fields. Yet this effectiveness of this policy approach may be questioned when using the technologies and techniques of conventional agriculture. At issue is whether conventional technologies can account for and manage all the source of variation just discussed. This question is investigated by applying a precision agriculture approach to manure management on a Wisconsin dairy farm.

The Setting

The study (see Figure 1) was conducted in a south-central Wisconsin watershed where the AFOs in operation are similar to those found in Wisconsin and possibly the Midwest Lake States. This watershed is located in a county that is currently at 25-50% of its assimilative capacity for P (Gollehon et al., 2001). The study area is located on well-drained agricultural Mollisols, typical of the glaciated region of southern Wisconsin. Soil series, in order of dominance, are St. Charles (Typic Hapludolls), Batavia (Mollic Hapludolls), Dodge (Typic Hapludolls), McHenry (Typic Hapludolls), Kidder (Typic Hapludolls), Radford (Fluvaquentic Hapludolls), Troxel (Pachic Argiudolls), and Wacousta (Typic Endoaquolls). Topography is flat to rolling, with slopes ranging from 2 to 20%. Agricultural operations in the proximity to the study farm are involved in dairy, beef, and swine production, with associated cropping systems of alfalfa [Medicago sativa (L.)], corn [Zea Mays (L.)], soybean [Glycine max], and wheat [Triticum aestivum].

The study farm manages 113.4 ha, and is milking 150 cows with another 100 young stock on site. This translates into 233 animal units, and an animal density (AU/ha) ratio of 2.05. The operation has a concrete pit with approximately 14 day storage capacity. The fields on this farm were geographically mapped using Trimble® global positioning system technology. Field boundaries were georeferenced in the Lambert Conformal Conic projection and stored in a geographic information system (GIS) (ESRI®, Redlands, CA).

Figure 1: Study Site

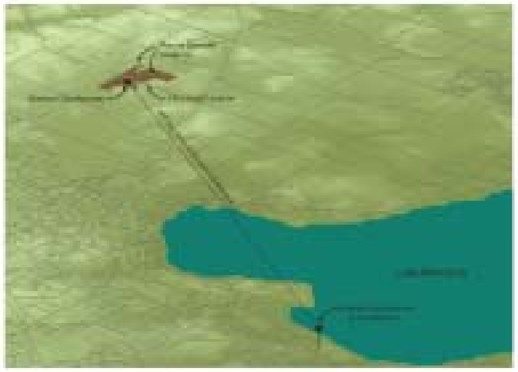


Figure 1. Precision manure management study location in Wisconsin.

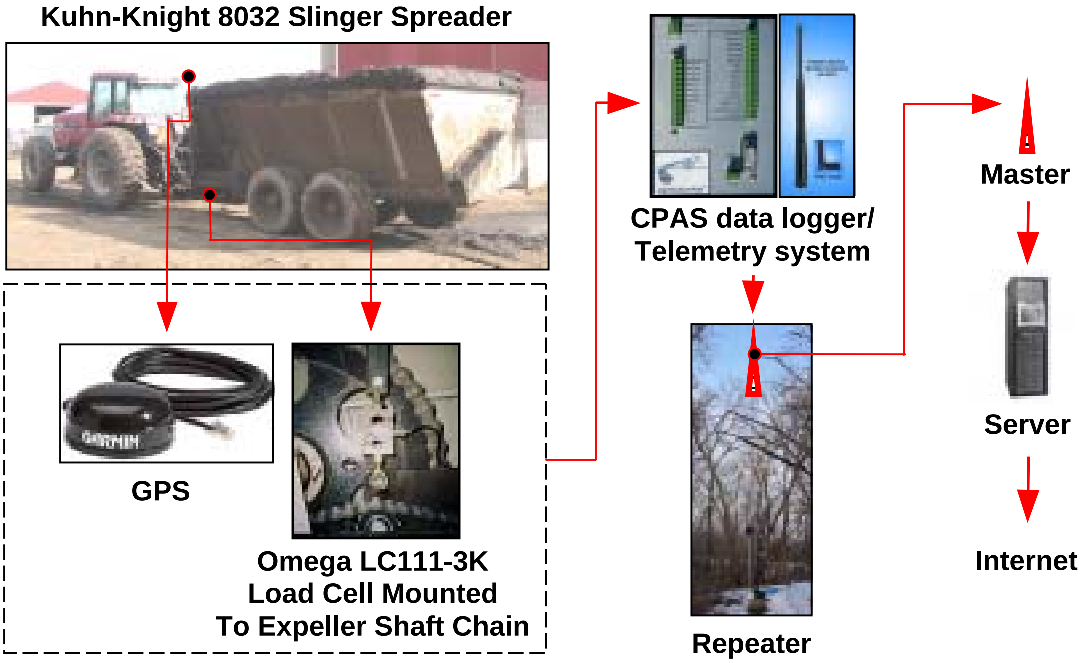
Soil sampling was performed on all fields managed by the study farm in order to assess the nutrient loss risk. Sample points were located using FarmGPS® software (Red Hen Systems, Inc., Ft. Collins, CO) and an unaligned systematic sampling protocol recommended by Wollenhaupt et al. (1994). Soil samples were collected in September and October, 2000. The analysis was based on samples that were collected every 1-ha (2½-acres) across all fields. One out of every five sample points served as the base for a stratified transect sample. The primary transect direction was randomly selected from the four principal points of the compass (north, east, west, south), and samples were taken at 5, 10, 20, and 40 m from the base. A second transect was then swiveled at 60° clockwise from the base transect, about the same origin, forming a V shape. The purpose of extending the transects in two directions was to capture spatial variability at small scales, thereby preventing samples with extremely high localized STP levels from biasing the mean STP value for the field. Each sample consisted of eight cores that were collected within a circle (1.5 m radius) centered on each sample point. The samples were taken at a depth of 5 cm to represent the effective depth of runoff-soil interaction from which most P is delivered (Sharpley et al., 1996). The soil was then air-dried and analyzed for extractable P using the Bray-P1 method (Bray and Kurtz, 1945), commonly used in Wisconsin for agronomic and soil testing guidelines (Kelling et al., 1998).

Materials and Methods

We used an integrated system to track the location and mass flow rate of animal manure from a Kuhn Knight Slinger™ Spreader that transmits data in near-real time via a wireless network backbone to a server connected to the Internet. The mass flow rate is measured using a patented method of measuring manure application rate developed by McFarlane (2000, 2001) in which chain tension is used to measure the torque applied to the expeller shaft of a site-discharge type spreader. The physical torque sensing system is composed of a bracket assembly affixed to an idler sprocket driven off the tension side of the chain driving the expeller shaft. The assembly adds tension to the chain and the force the chain is pulling down can by measured by integrating an “S” beam load cell into the assembly. The load cell reading is linearly related to the manure application rate.

The load cell (HBM INC Model #RSC-3K 25100) and a Garmin Model (GPS16) receiver are connected to a data logger interfaced with radio telemetry (900 MHz ISM spread spectrum frequency hopping) developed by Washington State University’s Center for Precision Agricultural Systems. The data logger is programmed to record an integrated load cell value and a GPS $GPRMC data string every second. The radio telemetry network is configured in a master-repeater-slave topology with the master residing at the University of Wisconsin connected to a server and a repeater located xx km in line-of-sight of the master and the experimental farm. The network is managed by a program operating on the server that manages and polls the telemetry network. The manure tracker system is powered through the tractor and therefore operates only when the manure spreader is connected to one of three tractors the grower uses for manure spreading. The slave unit attached to the load cell on the spreader is called every five minutes to retrieve any data that might have been collected during that time. If the spreader is out of sight of the repeater, the data will be transmitted the next time the unit is in line-of-sight. The end result is a remotely recorded data file containing 1 second records of load cell reading, time, and location coordinates for the duration of a spreading event. The relationship between these components is illustrated in Figure 2.

Figure 2: Calibrated Spreader, Data Logger and Telemetry System

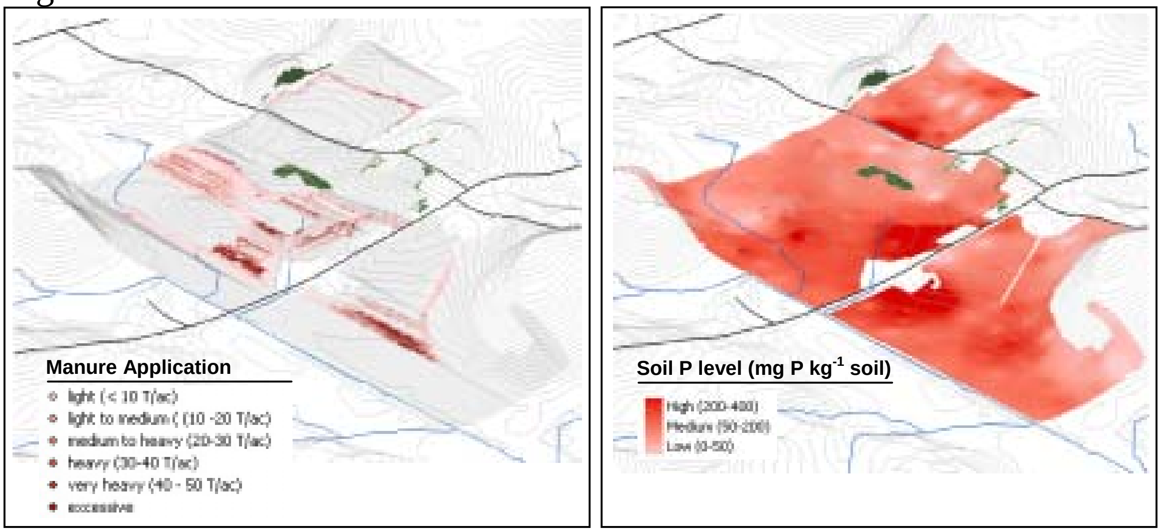


Results

Initial results are illustrated in Figure 3. Manure application patterns by location within fields are contrasted with soil test P levels. This study farm had had two 590 nutrient management plans developed prior to the distribution patterns illustrated in Figure 3. The first plan was developed by a crop consultant who used standard soil sampling protocols to develop recommended manure application rates. A year prior to the distribution pattern illustrated in Figure 3, the 1 ha soil sampling data collected as part of this project was given to the farmer and crop consultant. A second 590 nutrient management plan was then developed based on the more dense soil sampling data generated by this project.

The manure distribution patterns measured with the monitoring equipment represents the farmer decisions based on this most recent plan.

Figure 3: Manure distribution and soil test levels



A simple visual comparison of the data represented by Figure 3 indicates that the farmer was making manure distribution decisions based on more traditional criteria. In particular, crop rotations, access to fields, and convenience seemed to determine where manure would be spread on a regular basis.

Besides a visual analysis of the congruency, or lack thereof, between soil test levels and distribution patterns, a more fine grained analysis is in the process of being conducted. At 33 locations within two fields the soil test levels were correlated with the rate of manure being applied. The results from this analysis are in Figure 4.

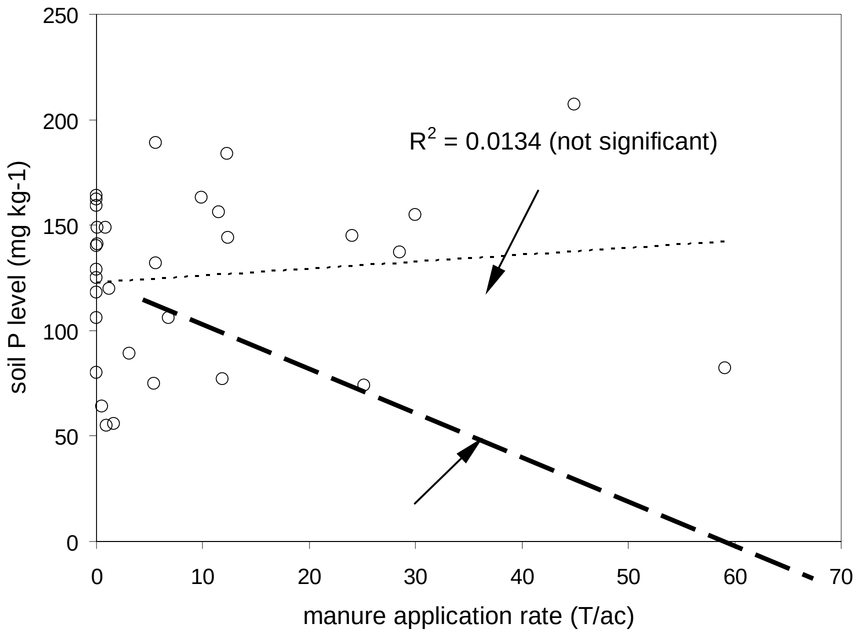
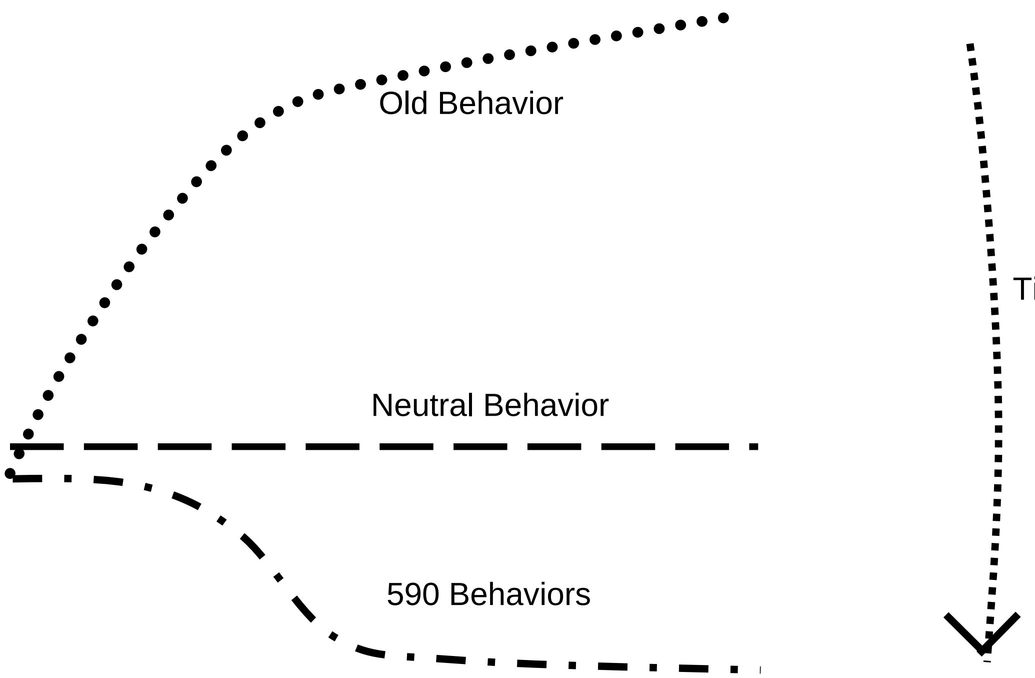


Figure 4: Hypothesized relation with 590 Nutrient Planning

Figure 5: Probable Outcomes of Management Decisions Across Time



References

Berry J.K., J.A. Delgado, and F. Pierce. 2003. Precision conservation for environmental sustainability. ournal of Soil and Water Conservation 58:6; 332-339.

Green, R. E., S.J. Cornell, J.P.W. Scharlemann and A. Balmford. 2004. Farming and the fate of wild nature. Science Express. December 1-10.

Groffman, P.M. 1997. Ecological Constraints on the Ability of Precision Agriculture to Improve the Environmental Performance of Agricultural Production Systems. In "Precision Agriculture: Spatial and Temporal Variability of Environmental Quality" (J.V. Lake, G.R. Bock, and J.A. Goode), pp. 52-64. John Wiley & Sons, New York.

Kelling, K. A., L.G. Bundy, S.M. Combs, and J. B. Peters. 1998. Soil test recommendations for field, vegetable and fruit crops, UWEX.

McFarlane, Claude L. [inventor]. 2000. Discharge apparatus for discharging materials. U.S. Patent 6,024,305, February 15, 2000.

McFarlane, Claude L. [inventor]. 2001. Discharge apparatus for discharging materials. U.S. Patent 6,206,306, March 27, 2001.

Nowak, P. F. Madison and R. Shepard. 1998. "Farmers and manure management: A critical analysis." Pp. 1-32 in J. Hatfield and B. Stewart (Eds.) Animal Waste Utilization: Effective Use of Manure as a Soil Resource, Ann Arbor Press, Chelesa, MI.

Sharpley, A. N., T.C. Daniel, J.T. Sims, and D.H. Pote. 1996. Determining environmentally sound soil phosphorus levels. J. Soil and Water Cons. 51: 160-166.

Waltner-Toews, D., Lang, T. 2000. A new conceptual base for food and agricultureal policy: the emerging links between agriculture, food, health, environment and society. Global Change & Human Health 1(2): 116-130.

Wollenhaupt, N. C., R.P Wolkowski, and M.K. Clayton. 1994. Mapping soil test phosphorus and potassium for variable-rate fertilizer application. J. Prod. Agric. 7: 441-448.