GRID SOIL SAMPLING FOR MANURE APPLICATION
CASE STUDY #3

HOG FARM #1: LIQUID MANURE

Situation: This hog operation in southeast Minnesota has 1.0 million gallons of swine finishing liquid manure available annually, with an analysis of:

- Total N = 65 lbs/1000 gal
  - 31 lbs/1000 gal NH_4-N
  - 34 lbs/1000 gal organic N
- P_2O_5 = 35 lbs/1000 gal
- K_2O = 31 lbs/1000 gal

Photo: USDA-ARS

The field for this case study is 276 acres. The cropping system is two years of grain corn followed by one year of soybeans. Manure is knife injected the first and second years of corn after soybeans. This case analyzes alternative manure application strategies for the first year of corn.

CROP NUTRIENT NEEDS AND MANURE NUTRIENT AVAILABILITY

The crop nutrient needs for this field were from University of Minnesota guidelines in UM Extension bulletin 3790, **Fertilizing Corn in Minnesota**, 2006 or UM Extension bulletin 06240, **Fertilizer Guidelines for Agronomic Crops in Minnesota**, 2011. Use the most recent guidelines, since publications are updated with new research. Publications are available at: *http://www.extension.umn.edu/nutrient-management*

Nitrogen: The nitrogen (N) rate range is determined by the N price/crop value ratio. If we use the lowest N Price/Crop Value ratio (0.05), 120 lb N/acre falls near the center of the guideline range for corn after soybeans. For hog manure, knife injected, N availability is 70% the first year, so 172 lb manure N would be needed. For manure nutrient availability see **Manure Management in Minnesota**, UM Extension bulletin 03553 from 2007, and **Nitrogen Availability from Liquid Swine and Dairy Manure: Results of On-Farm Trials in Minnesota**, UM Bulletin 08583 from 2008, both available at *http://www.extension.umn.edu/nutrient-management*

Phosphorus (P): Crop P needs are determined from soil test values. A composite soil sample for the whole field (field average) is 27 ppm Bray 1-P, which is in the "Very High" range. In that range, no P applications are needed. However, since we have grid soil sample results mapped for this field (Figure 1), we can see that the P distribution is highly variable, ranging from Low to Very High (3-115 ppm Bray 1-P). A large portion (46%) of the field falls in the Medium to Low category where a P application would be recommended. No P application would likely result in a yield limitation in these Medium to Low testing areas of the field.

Potassium (K): Crop K needs are also determined from soil test values. The whole field average soil test K is 225 ppm, indicating no K would be needed. There is variability across the field, ranging from 132 to 494 ppm K_2O, following the trends of phosphorus.

COMPARING MANURE APPLICATION OPTIONS

Zonal Application

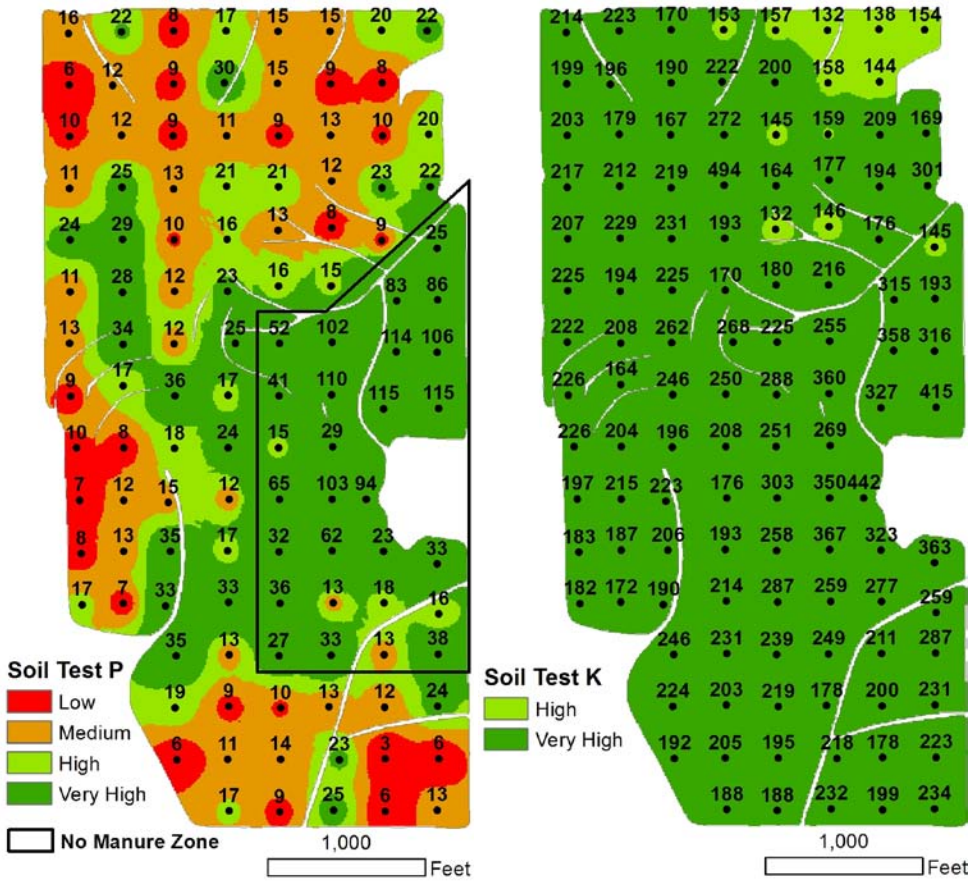

Figure 1. Soil Test P (Bray 1-P) and Soil Test K in ppm with University of Minnesota soil test classes.

Using a grid soil P map the operator can exclude one or more field zones from manure application because of already high P levels. This case study demonstrates the effects on economic returns of excluding a zone composed of 67 acres of high testing P & K grids from manure applications and supplementing with variable rate fertilizer application. Excluding the high P zone, the average P test for the remaining grids is slightly under 16 ppm. For these acres where manure would be applied, the average P need is 45 lb/acre P_2O_5 for broadcast application, or 56 lb/acre manure P_2O_5 equivalent with 80% availability. This manure rate is substantially higher than that determined by a whole-field P-based average, and would likely increase yields in the low P areas of the field while avoiding application in areas where P is not needed. The partial field average soil test K for the same grids is Very High due to past management, so little to no crop response would be expected in year 1 or 2 of corn. By avoiding continued high applications of K we will gradually bring levels down.

The manure exclusion zone in the example above is relatively regular in shape, making it easy to follow in the field. It does not, however, exclude all Very High P testing areas of the field. The producer would need to decide if the increased value of manure from avoiding a larger and more irregular area would be worth the increased management time required in manure application.

N-based vs. P-based Application

We have the option of basing manure application rates on either N or P needs of the crop if we do not exceed the crop N needs and do not over-apply P in sensitive areas. (See the bulletin "Applying Manure in Sensitive Areas", available on-line at *http://www.pca.state.mn.us/index.php/view-document.html?gid=3530*.)

We can compare the expected economic outcomes of the following three manure application rate and area alternatives. The P-based whole-field option is not available, since no P application would be recommended on a field average basis.

Whole-Field Application (no grid sampling)	**Zonal Application (with grid sampling)**
N-based manure rate	N-based manure rate in manure application zone. N and P fertilizer (variable rate P) in manure exclusion zone.
	P-based manure rate and supplemental N fertilizer in manure application zone. N and P fertilizer (variable rate P) in manure exclusion zone.

The economic comparisons are made using the spreadsheet "What's Manure Worth?" MANURWKST.XLS, available at http://z.umn.edu/manureworth. Data on the farm's manure type, amount, analysis, spreading method and spreading costs, application rates, and nutrient availability, as well as fertilizer costs, crop nutrient needs, acres for spreading, expected yield boost from use of manure instead of fertilizer, and second year nutrient credits are entered to determine the value of manure (total, per acre, and per gallon) under the a specific application rate and method. Additional data for the spreadsheet calculations are shown in Appendix 1.

Results

A comparison of results for the three rate alternatives is found in Table 1. The highest net values of manure per 1000 gallons are the P-based Zonal and N-based Zonal applications. Note that supplemental N would not be required for the Zonal N-based application, except for some starter if desired, and that the extra P would be used by the following year corn crop. Results of the Zonal N application analysis are highlighted in Table 1. The N-based whole-field uniform application would over-apply P in the Very High and High soil test areas of the field, reducing the value of the manure as a fertilizer replacement. Also, this would leave the least amount of manure for application to other fields where it might have more value by being placed where a yield response to P would be more likely and loss of P in runoff less likely.

TABLE 1. ECONOMIC ANALYSIS OF ALTERNATIVE MANURE APPLICATION STRATEGIES.

Manure Application Strategy	N-Based, Whole-Field	N-Based, Zonal	P-Based, Zonal
Manure Application (Acres)	276	209	209
Crop Nutrient Need N - P_2O_5 - K_2O (lbs/acre)	120-0-0	120-45-0	120-45-0
Manure Application Required/Acre (gal/acre)	2700	2700	1600
Manure to be Applied (gal/acre)	3000	3000	2000
Manure-Available Nutrients Applied (lbs/acre)	137-84-84	137-84-84	91-56-56
Net Value of Manure ($/acre)	72	108	82
Net Value of Manure ($/1000 gal)	24	36	41
Manure Remaining After Spreading (gal)	172,000	373,000	582,000

Value of Grid Soil Sampling

The spreadsheet analysis does not account for the increased cost of grid soil sampling. At $10.25 per acre for approximately 2 acre grids, the field-total cost is $2,829. Comparing the N-based whole-field with N-based zonal application shows an increase in the value of the manure by $12 per 1000 gal or $7524 for the 209 acres where manure is to be applied with the zonal application. This does not account for the higher value of the increased yield expected from targeted application of manure P, nor for the value of the remaining manure available for other fields where P and K need may be higher. One grid soil sampling every 3 to 5 years can serve multiple manure applications, reducing the cost substantially on a per-application basis.

Additional Application Considerations

A frequent approach to manure application when land is limiting, is to apply manure at crop P removal rates. This results in higher manure application rates in areas where soil test P would indicate low or no fertilizer P application would be needed but where the crop would remove the added P. This approach would not reduce the in-field P variability or reduce loss of P in runoff unless the highest P testing areas were excluded from manure application. Crop P removal rates are acceptable but may result in lower economic value of the manure. Another frequent approach is to apply manure once at P rates sufficient for two successive years of crops. This is also acceptable, however availability of P in the second year may differ among soil types and be more difficult to predict.

Photo: Stearns SWCD

ADDITIONAL ENVIRONMENTAL CONSIDERATIONS

In addition to reducing areas of excessive soil test P, other strategies to reduce runoff loss of nutrients should be considered. Manure injection on this farm already reduces the risk of manure and dissolved P in surface runoff.

Nitrogen loss in the nitrate form can also be a risk with liquid swine manure because a high percentage is in the inorganic (ammonium) form. If applied in the fall before soil temperatures drop below 50 degrees F., ammonium can be converted to nitrate and subsequently lost to drainage tile or groundwater the following spring before crops are established. Delaying fall manure or N fertilizer application until soil temperatures fall below 50 degrees F. will conserve the N.

2' Contour Lines and Aerial Image

Most of the soils in this field are on slopes of 0-6%, however there are some slopes of 6-12% and 12-18%, and areas of concentrated flow (see contour map, left). The dominant source of total P reaching water on these slopes with a corn-corn-soybean rotation would be P attached to eroded soil particles. Crop rotations and tillage practices that minimize soil erosion are essential to reducing P pollution of water. Several strategies should be considered:

- Minimize tillage intensity as much as possible.
- Consider structural controls such as terraces, sediment control basins, and filter strips.

The local NRCS/SWCD office and some crop consultants can provide a predicted erosion rate for any combination of slope, crop rotation, and tillage practices using the RUSLE2 model. It is also part of the Minnesota Phosphorus Index available at http://www.mnpi.umn.edu

As an example with the steeper slopes in the northern part of the field, if tillage were fall chisel and spring field cultivate all three years of the corn-corn-soybean rotation, the predicted erosion rates would average 6.1 tons per acre per year assuming 8% slope and 200 foot slope length. Converting to no-till soybeans, spring field cultivate before first year corn, and fall chisel/spring field cultivate before second year corn would reduce rotation average erosion to 4.0 tons per acre per year while maintaining yields, reducing fuel use, and reducing P loss to water.

CONCLUSIONS:

1. Grid soil sampling allows the livestock producer to identify and treat zones of excess and deficiencies for P and K, which may have developed with a history of non-uniform manure applications.
2. Targeting manure and perhaps supplemental fertilizer P and K applications to lower soil test P and K areas of the field will likely result in higher average yields compared to uniform rate applications based on the average soil test value for the field.
3. Excluding zones of excess soil test P from manure application will allow more efficient use of manure on other fields and field areas, increasing the total value of the manure supply.
4. Excluding zones of excess soil test P from manure application will reduce P pollution in runoff, since P in runoff is proportional to soil test P.
5. The choice of crop rotation, manure application method, and tillage practices have a strong influence on loss of P to water.

Appendix 1: Additional information used to calculate the value of manure with the spreadsheet "What's Manure Worth?":

Fertilizer nutrient prices/lb.: N = $0.59, P_2O_5 = $0.54, K_2O = $0.54
Cost of purchased micronutrients/acre: $2.50
N fertilizer application cost avoided: $10.00 for the N-based application strategies.
Dry P_2O_5 and K_2O fertilizer application cost avoided/acre: $5.50 for all strategies where manure applied.
Additional value of micro-nutrients in manure: $0.00 assumed.
Second year nutrient credits/acre for valuation:

- **N-based, whole field = 29-0-0**
- **N-based, Zonal = 29-20-0**
- **P-based, Zonal = 20-5-0**

Manure yield boost value/acre over fertilizer alone: $20.00
Tillage effect of manure application: $0.00
Manure application cost/gallon: $0.015

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