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GRID SOIL SAMPLING FOR MANURE APPLICATION
CASE STUDY #2

DAIRY FARM #2: LIQUID MANURE & COMPLEX FIELD

Situation: This dairy operation in southeast Minnesota has 1,750,000 gallons of liquid slurry available annually, with an analysis of:

- Total N = 14 lbs/1000 gal
- P_2O_5 = 6 lbs/1000 gal
- K_2O = 18 lbs/1000 gal

The field for this case study is 95 acres with slopes of 1-12%. The cropping system is four years of alfalfa followed by four years of corn silage. Manure is knife injected the first and fourth year of corn after alfalfa. This case analyzes alternative manure application strategies for the **fourth** year of corn silage.

CROP NUTRIENT NEEDS AND MANURE NUTRIENT AVAILAILABILITY

Crop nutrient needs were determined 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 (N): The nitrogen rate range is determined by the N price/crop value ratio. If we use the lowest N Price/Crop Value ratio in the table (0.05), 160 lb N/acre falls near the center of the guideline range for corn after corn. Since there are no N credits for previous legumes or manure applications in this fourth year of corn silage, the N guideline remains at 160 lb N/acre. For dairy manure, knife injected, N availability is 50% the first year, so 320 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.)

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, 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 (7-94 ppm Bray 1-P). A large percentage (56%) of the acres fall in the Medium to Low category, where a P application would be recommended. No application would likely result in a yield limitation in these areas.

Potassium (K): Crop K needs are also determined from soil test values. The whole field average soil test K is 84 ppm, giving a need for 80lb/acre available K_2O for the expected yield range 175-199 bu/acre. First year availability is 90% for K, so the manure K_2O equivalent would be 89 lb/acre. Again, there is high variability across the field (Figure 1), ranging from Low to Very High (50-258 ppm).

COMPARING MANURE APPLICATION OPTIONS

Zonal Application

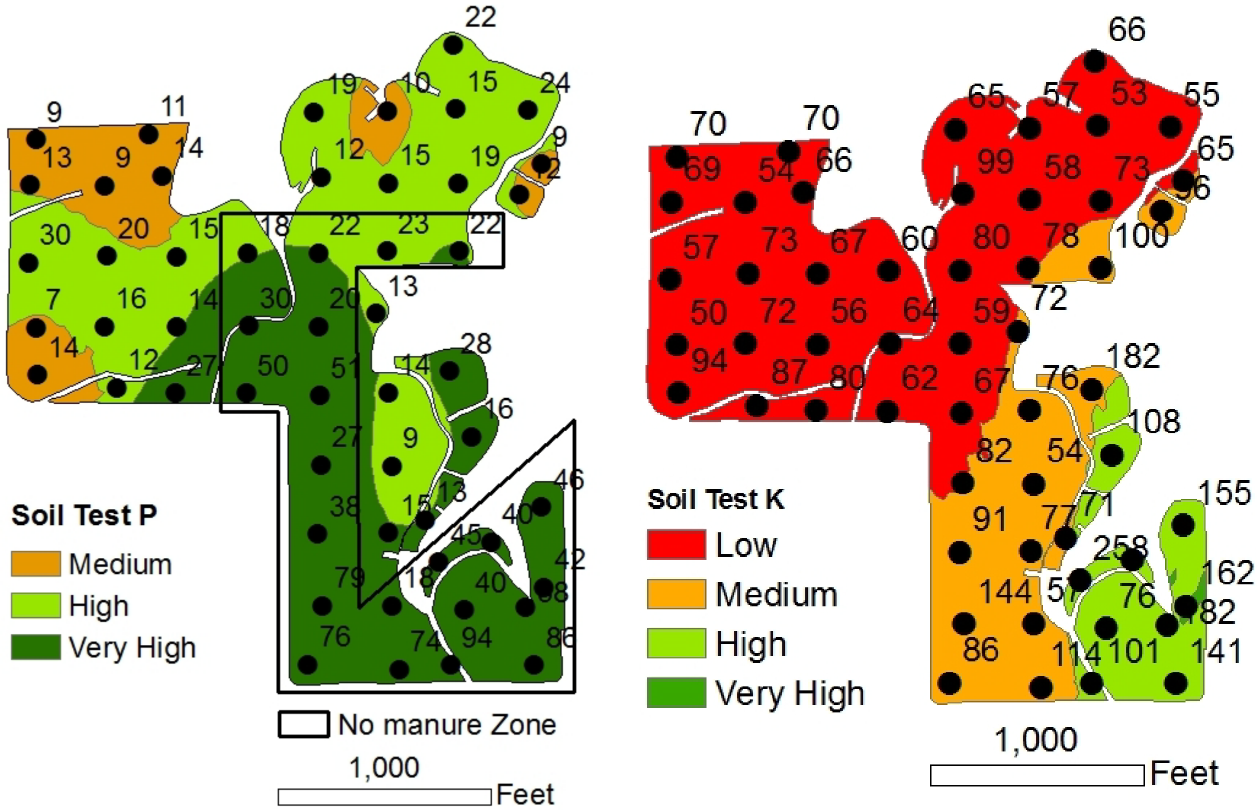

Figure 1. Soil Test P (Bray 1-P) and Soil Test K in ppm with University of Minnesota soil test classes.

With a grid soil P map the livestock producer can exclude one or more field zones from manure application because of already high P levels. In this case we demonstrate the effects on economic returns of excluding a 39 acre zone (see soil test P map) composed of 22 High to Very High P grids of this field from manure application, and supplementing with variable rate fertilizer application. Excluding the high P zone, the average P test for the remaining 31 grids is 15 ppm. For these 56 acres where manure would be applied, the P need is 45 lb/acre P_2O_5 for broadcast application, or 56 lb/acre manure P_2O_5 equivalent with 80% availability. The partial field average soil test K for the same 31 grids is 74 ppm, given a crop need of 135 lb K_2O per acre for the 175-199 bu/acre expected yield range, or 150 lb manure K_2O equivalent at 90% availability. These manure application rates are substantially higher than if the producer was using a whole-field soil test P or K average, likely increasing yields in the low P and K areas of the field while avoiding application in areas where these nutrients are not needed.

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. Note that a whole-field P-based rate of manure application would be zero since the whole-field P soil test value is above 21 ppm Bray P-1.

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

Photo: UM Extension

The economic comparisons are made using the spreadsheet “What’s Manure Worth?” MANURWKST.XLS, available at http://z.umn.edu/manureworth . A comparison of results for the three rate alternatives is found in Table 1. (For additional information to complete the spreadsheet, see Appendix 1.) The manure available is sufficient to cover only 88 of the field total of 95 acres at the whole-field N-based rate. The highest net value of manure per 1000 gallons is the P- based Zonal application with the N-based Zonal strategy second. Only the P-based Zonal application has a net positive value of manure above application cost because of the relatively low N content of this manure. Even at 20,000 gal/acre we do not meet the N requirements of the crop so some N fertilizer is required. The following year crop is alfalfa, which does not need N, so we do not have a second year manure N credit to add to the valuation of this manure application. However, the extra P and K would be used by the following alfalfa crop and is credited (conservatively at half the expected amount). 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.

Both the field and the manure exclusion zone in the example above are irregular in shape, leaving three separate zones for manure application. While the economic analysis (Table 1) is optimized with this manure exclusion zone, the producer may find it necessary to define larger and more rectangular zones for application, recognizing a reduced fertilizer replacement value for the manure. If alternative manure application sites are limited, then applying manure at P removal rates (amount of P removed in the crop) is another option that would use more of the manure on this field than the P-fertilizer based rate listed above. (See **Nutrient Removal by Major Crops**, UM Extension: Minnesota Crop News, George Rehm, 2001.) With this approach, reduction of the in-field P variability and reduction of P in runoff should be addressed by excluding the highest P testing areas (southern-most 14 acres of the field) from manure application. P replacement rate application is analyzed in more detail in Case Studies 5 and 6.

Note that the relatively low nutrient analysis of this manure indicates that there might be an opportunity to reduce hauling costs by reducing water inputs to manure storage with clean water diversions, roof runoff controls, and other water management techniques.

TABLE 1. ECONOMIC ANALYSIS OF ALTERNATIVE MANURE APPLICATION STRATEGIES.

Manure Application Strategy	N-Based, Whole-Field[1]	N-Based, Zonal	P-Based, Zonal
Manure Application (Acres)	88	56	56
Crop Nutrient Need N - P_2O_5 - K_2O (lbs/acre)	160-0-80	160-45-135	160-45-135
Manure Application Required/Acre (gal/acre)	22,857	22,857	9375
Manure to be Applied (gal/acre)	20,000	20,000	10,000
Manure-Available Nutrients Applied (lbs/acre)	140-96-324	140-96-324	70-48-162
Net Value of Manure ($/acre)	-88.58	-27.45	23.56
Net Value of Manure ($/1000 gal)	-4.43	-1.37	2.36
Manure Remaining After Spreading (gal)	0	630,000	1,190,000

[1] Available manure is not sufficient to cover all 95 acres at the planned rate.

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 $974. Comparing the N-based whole-field with N-based zonal application shows an increase in the value of the manure by $3.06 per 1000 gallons or $3428 for the 56 acres where manure is to be applied with the zonal application. At the lower P-based rate the value goes up by another $3.73 per 1000 gal. This does not account for the higher value of the increased yield expected from higher application rates of manure P and K targeted where it is needed, nor for the value of the manure conserved for other fields. One grid soil sampling every 3 to 5 years can serve multiple manure applications, reducing the cost substantially on a per-application basis.

ADDITIONAL ENVIRONMENTAL CONSIDERATIONS:

Manure injection on this farm prevents surface runoff from carrying manure or soluble P from manure. However, this field has some soils with 6-12% slopes (see contour map below), susceptible to soil erosion. The dominant source of total P reaching water on these slopes with corn harvested for silage would be P attached to eroded soil particles. In addition to avoiding build-up of soil test P to excessive levels, several erosion prevention strategies could be considered:

2' Contour Lines and Aerial Photo

- Reduce the number of silage years in the rotation to reduce the frequency of soil exposure with no plant or residue cover.
- Plant a cover crop immediately after silage harvest.
- 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

The RUSLE2 predicted soil erosion reduction in changing from a fall chisel/spring field cultivate system to a no-till system for the silage corn on the steeper slopes of this field is 6.3 tons/acre/year averaged over the 4 corn years, or 4.0 tons/acre/year reduction averaged over the 8 year rotation including the alfalfa years. This assumes an 8% slope of 200 foot length. That reduction in tillage also lowers the Phosphorus Index risk class from “Medium” to “Low”, indicating that less P would reach the stream with the reduced tillage regime.

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 whole field.
3. Excluding zones of excess soil test P from manure application will:
   a. Allow more efficient use of manure on other fields and field areas, increasing the total value of the manure supply.
   b. Reduce P pollution in runoff, since soluble P in runoff is proportional to soil test P.
4. Irregular field boundaries and nutrient distribution may require modification of the shape and size of application zones to improve application efficiency.
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: \$0.00 for all strategies.
Dry P_2O_5 and K_2O fertilizer application cost avoided/acre: \$7.50 for all strategies where manure applied.
Additional value of micro-nutrients in manure: \$0.00 assumed.
Second year nutrient credits/acre for valuation:

- **No credit taken for N (alfalfa next crop) and approximately half credit taken for P_2O_5 and K_2O**
- **N-based, whole field = 0-0-122**
- **P-based, whole field = 0-0-0**
- **N-based, zonal = 0-26-95**
- **P-based, zonal = 0-0-14**

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