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GRID SOIL SAMPLING FOR MANURE APPLICATION
CASE STUDY #1

DAIRY FARM #1: LIQUID MANURE

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

- Total N = 32 lbs/1000 gal
- P_2O_5 = 12 lbs/1000 gal
- K_2O = 26 lbs/1000 gal

The field for this case is 50 acres. The cropping system is four years of alfalfa followed by four years of corn for silage. Manure is knife injected for the second and third year of corn after alfalfa. This case analyzes alternative manure application strategies for the **third** year of corn.

CROP NUTRIENT NEEDS AND MANURE NUTRIENT AVAILAILABILITY

Crop nutrient needs for the field 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. Updates will be available at: *http://www.extension.umn.edu/nutrient-management*

Nitrogen (N): The base N need is found in the tables of the bulletin, using the N fertilizer price/crop price ratio as a guide, and then subtracting N credits for previous manure applications and legume crops. The N /crop price ratio would be clear for corn grain, but is less clear for corn as silage, since silage is fed on the farm. If we use the lowest ratio in the table (0.05), 160 lb N/acre falls near the center of the guideline range for corn after corn. The second year manure credit is 25% of manure N applied for the previous year's crop (injected dairy manure), or 44 lbs in this rotation (see Appendix 1), giving a net N guideline of 116 lb available N/acre needed. For dairy manure, knife injected, N availability is 50% the first year, so 232 lb total 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 the above-listed URL.)

Phosphorus (P): Crop P needs are determined from soil test values. A composite soil sample for the whole field (field average) is 18 ppm Bray 1-P. The broadcast recommendation (P need) would be 15 lb/acre P_2O_5 for an expected yield >150 bu/acre corn grain. First year availability of P in manure is 80%, so the manure rate would be 19 lb/acre P_2O_5 equivalent on a whole-field average basis. 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 Very Low to Very High (5-47 ppm Bray 1P). A uniform application of 15 lb/acre available P_2O_5 would likely result in a yield penalty in the Low and Very Low P testing areas.

Potassium (K): Crop K needs are also determined from soil test values. The whole field average soil test K is 83 ppm, which results in an application guideline of 80lb/acre available K_2O for the expected yield range 175-199 bu/acre. First year availability of K in manure is 90%, so the K_2O manure equivalent would be 89 lb/acre. Again, there is high variability across the field, ranging from Low to Very High (45-186 ppm).

COMPARING MANURE APPLICATION OPTIONS

Zonal Application

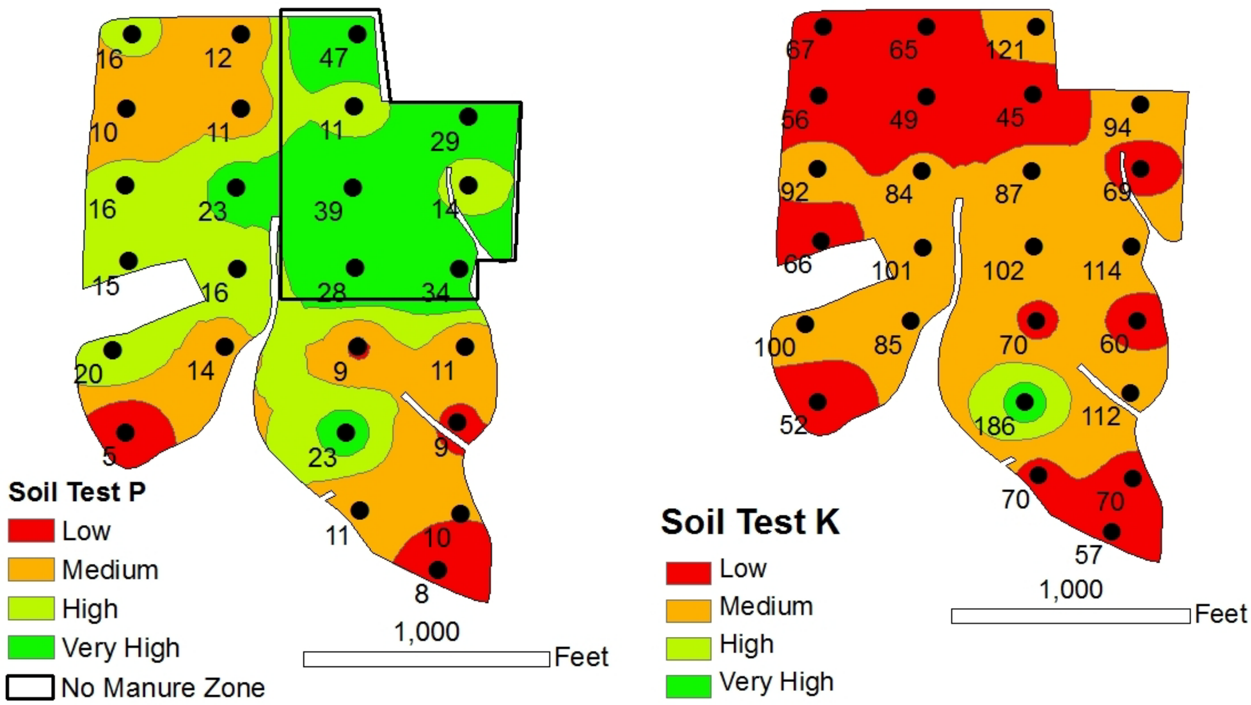

Figure 1. Soil Test P (Bray 1-P) and Soil Test K in ppm with University of Minnesota soil test classes.

With a grid soil P map the operator can exclude one or more field zones from manure application because of high soil P levels. In this case we demonstrate the effects on economic returns of excluding a zone composed of the seven northeast grids of this field from manure application, and supplementing with variable rate fertilizer application. Although there are some Very High testing grid cells outside this manure exclusion zone and two Medium testing zones within it, this provides an easily defined field division. Excluding the high P zone, the average P test for the remaining 36 acres is 13 ppm. For the 36 acres where manure would be applied, the P need is 45 lb/acre P_2O_5 equivalent, or 56 lb/acre manure P_2O_5 equivalent with 80% availability. The partial field average soil test K for the same 36 acres is 80 ppm, giving 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 rates are substantially higher than those on a whole field average, and would likely increase 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. The P-based whole-field option is not compared in this case because it would use only 1600 gallons of manure per acre and deliver only 32 lbs/acre of available N. It would also likely cause a yield reduction in the Low P testing areas of the field.

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.

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 a specific application rate and method. (For additional information used to complete the spreadsheet, see Appendix 2.)

Results

A comparison of results for the three rate alternatives is found 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, thus reducing the value of the manure as a fertilizer replacement, and would leave the least amount of manure for application to other fields where it might have more value.

The highest real net value of manure per 1000 gallons is the P-based zonal manure application. However, the per 1000 gallon value of manure for the N-based zonal manure application method (highlighted in Table 1) is only three dollars less than that for the zonal P-application method. Given that supplemental N would not be required for the zonal N-based application (except for some optional starter), and that the small amount of excess P and K would be used by the following year corn crop, this would likely be the most desirable approach.

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)	50	36	36
Crop Nutrient Need N - P_2O_5 - K_2O (lbs/acre)	116-15-80	116-45-135	116-45-135
Manure Application Required/Acre (gal/acre)	7300	7300	4700
Manure to be Applied (gal/acre)	7500	7500	5000
Manure-Available Nutrients Applied (lbs/acre)	120-72-176	120-72-176	80-48-117
Net Value of Manure ($/acre)	109	139	103
Net Value of Manure ($/1000 gal)	15	18	21
Manure Remaining After Spreading (gal)	375,000	480,000	570,000

Value of Grid Soil Sampling

The spreadsheet analysis above does not account for the cost of grid soil sampling. At $10.25 per acre for 2.5 acre grids, the field-total cost of sampling is $513. Comparing the N-based whole-field with N-based zonal application shows an increase in the value of the manure by $3 per 1000 gallons, or $810 for the 270,000 gallons of manure to be applied with the zonal application. The increase in value of $297 over sampling costs does not include the much more significant value of the increased yield expected from targeted higher application rates of manure P and K in lower testing areas of the field, or the value of manure conserved for other fields. One grid soil sampling can serve multiple years of manure applications, reducing the cost substantially on a per-year basis.

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 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 P 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. This is especially important on farms where silage is harvested and there is little crop residue to protect the soil from erosion and reduce runoff.

Appendix 1: The manure N credit is calculated as follows for the third year corn after alfalfa, assuming no manure applied the first year corn after alfalfa and the final alfalfa stand had been 4 plants per ft^2:

1. **Calculate the manure application rate for the second year corn after alfalfa. The total N requirement is approximately 160 lb/acre for corn after corn as described in the case study.**
2. **The second year alfalfa N credit = 75 lb/acre. (Table 6, Fertilizing Corn in Minnesota).**
3. **The remaining N requirement = 85 lbs/acre.**
4. **The manure N application rate for second year corn after alfalfa, given 50% N availability = 170 lb/acre.**
5. **The manure N credit for third year corn after alfalfa is 25% of previous manure N application, or approximately 44 lb N/acre.**

Appendix 2: 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 when manure covers N need: \$5.00 for N-based strategies.
Dry P_2O_5 and K_2O fertilizer application cost avoided/acre: \$7.50 for N-based strategies.
Additional value of micro-nutrients in manure: \$0.00 assumed.
Second year nutrient credits/acre for valuation:

- **Full credit taken for N but approximately half credit taken for P_2O_5 and K_2O**
- **N-based, whole field = 60-15-48**
- **N-based, zonal = 60-13-20**
- **P-based, zonal = 40-0-0**

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