Putting Theory into Practice: A Nutrient Management Planning Case Study

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Take Home Messages:

1. Basic components of a manure nutrient management plan include soil testing, fertilizer recommendations, quantity of manure, nutrient content of manure, *Agricultural Operation Practices Act* (AOPA) requirements, and record keeping.
2. Nutrient availability in manure is not known exactly and can only be estimated based on certain assumptions. This represents a major practical limitation to nutrient management planning.
3. Applying the AOPA nitrogen limits may result in over application of nitrogen relative to crop requirements, which poses a potential risk to environmental quality. It is preferable to apply nutrients based on crop requirements.
4. Phosphorus-based application of manure requires a much larger land area compared to nitrogen-based application. This is because the N to P ratio in manure is different than the ratio required by the crop. This has special significance to producers operating on a limited land base.

Introduction

Many of the concepts and principles presented elsewhere in these proceedings will be applied in the form of a case-study farm. The case study is based on information from a farm located in south-central Alberta. Basic nutrient management practices, such as soil testing, fertilizer recommendations, and measuring or estimating the nutrient content and nutrient availability in manure will be used. Three approaches are presented. In the first approach, manure application rates are determined using the nitrogen limits in the *Agricultural Operation Practices Act* (2004). The second and third approaches use nutrient balancing, one based on crop requirement for nitrogen and the other based on crop requirement for phosphorus.

CASE-STUDY FARM

Farm Description

The farm used in this case study is located in south-central Alberta. The farm has three sections of land, which is 777 hectares (ha) (Figure 1). A large portion of the land is under forage production, with some annual cropland. The farm has a 4,000-head feedlot and a 300-head cow-calf operation.

Basic Soil Information

It is always a good idea to understand the types of soils your farm is located on. In fact, some soil information is needed when using the nitrogen limits in the AOPA. Soil survey information can provide some basic information (Figure 2). This farm is located within the Black Soil Zone. The main soil series include Academy, Rockyview, and Delacour, which are all Orthic Black Chernozemic soils. Minor soil series include Kathryn, which is a Gleyed Black Chernozemic soil; Beddington, which is a Black Solodized Solonetz soil, and miscellaneous Gleysolic soils. The surface texture ranges form loam to silty clay loam, surface pH ranges from 5.7 to 7.5, and surface organic matter content ranges from 4 to 8 percent.

Identify the Land Base for Manure Application

The farm has 305 (ha) of annual cropland, 194 ha of native grassland, and 215 ha of tame forage (Figure 3). A number and letter system is used to identify fields. There are 33 individual fields in the case-study farm. The fields range in size from 4 ha (fields A1 and A2) to 85 ha (field M-crop). For the purpose of this exercise, fields B3 (10.1 ha; forage), C (40.5 ha; barley), E (80.9 ha; barley), F2 (12.1 ha; forage), and M-crop (85 ha; barley) have been identified for manure application. The total land-base area of these five fields is 228.6 ha.

Manure Quantity

Knowing the amount of manure your livestock operation produces each year is very important in planning manure application strategies. Book values can be used to estimate manure production, or attempts can be made to measure actual amounts produced, which can be done by weighing each load of manure, or by weighing a few loads of manure and count the number of loads. The actual amount of manure produced was measured for the case-study farm. The feedlot produces 10,000 megagrams (Mg)[1] of wet manure per year. No manure is collected from the cow-calf operation. From year to year, the actual amount of manure produced will depend on number of animals, diet, and climate. Climate will influence the moisture content of manure and the amount of bedding required in a given year.

Book values, such as the values in the *Agricultural Operation Practices Act* (AOPA) estimates that each feedlot animal will produce 1.39 to 2.16 Mg/yr. Therefore, a 4,000-head feedlot will produce about 5,560 to 8,640 Mg/yr. In this case the book values underestimate manure production. Book values are useful for initial estimates and planning, but if possible, it is better to determine actual values for your own operation.

[1] 1 megagram (Mg) = 1000 kilograms (kg) = 1 tonne.

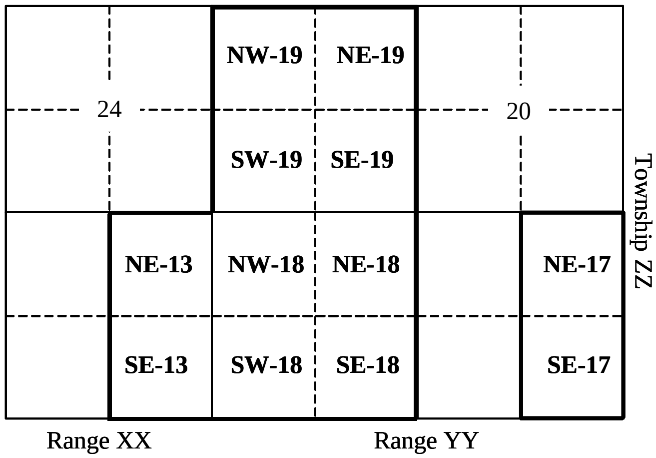

Figure 1. Layout and legal land location of case-study farm.

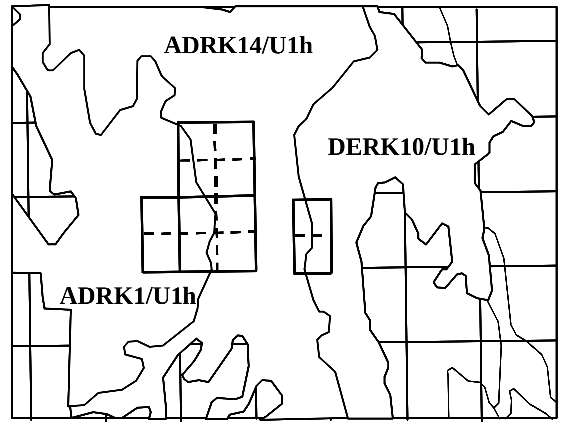

Figure 2. Case-study farm relative to soil survey information from AGRASID (CAESA Soil Inventory Project Working Group 1998).

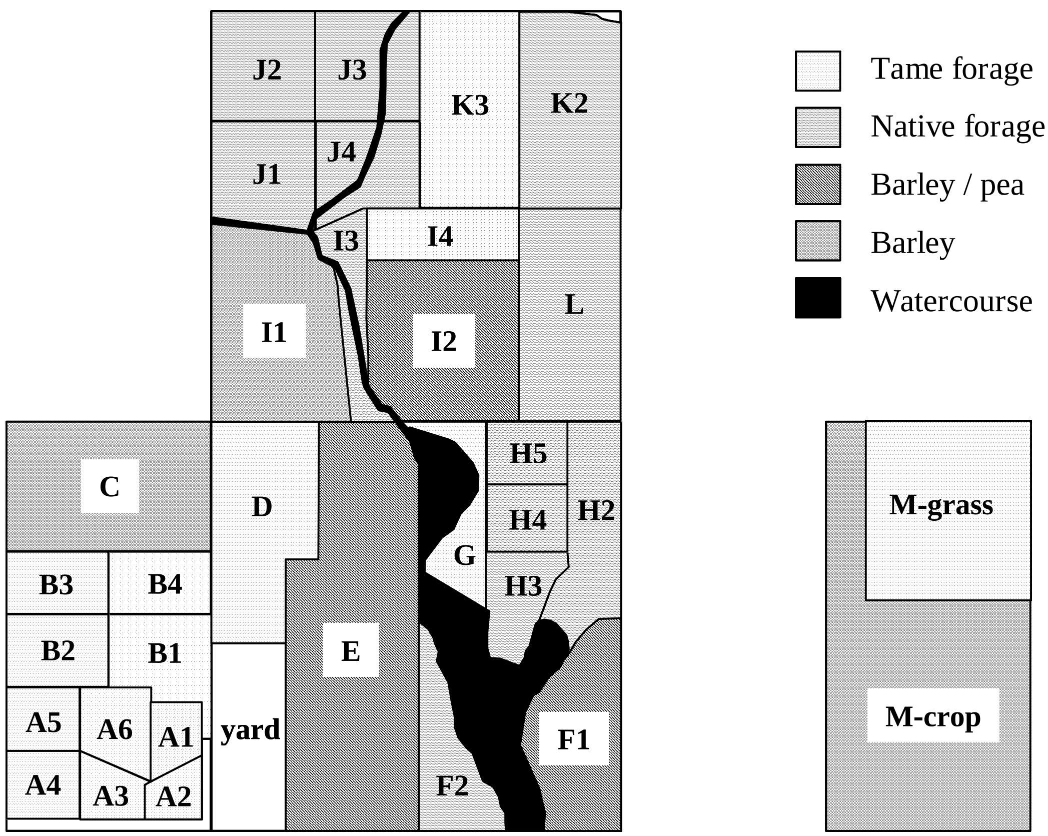

Figure 3. Case-study farm field arrangement, identification, and crop types.

Nutrient Content of Manure

In addition to the amount of manure produced, the nutrient content of manure is also important information. Nutrient content of manure can either be estimated using book values or determined by submitting samples to a laboratory for chemical analysis. Minimum parameters that should be analysed include total nitrogen (N), total phosphorus (P), ammonium-nitrogen (NH_4-N), and moisture. Laboratories can measure additional parameters upon request.

For the case-study farm, manure samples were not sent to a laboratory. Therefore, book nutrient content values listed in the 2001 version of the AOPA were used. Values used are 10 kg/Mg total N, 2.4 kg/Mg total P, and 2.6 kg/Mg NH_4-N. These values are on a wet-weight basis with a moisture content of 50 percent.

Book values can provide initial estimates, but it is recommended that producers obtain actual nutrient content values by sending manure samples to a laboratory for analysis. Nutrient content of manure can vary widely. Submitting samples for several years will generate a database of manure nutrient content. You may find that your measured average values may be similar, higher, or lower than book values. As an example, Table 1 shows results from an eight-year field study of manure analysis compared to the AOPA values. The results show a wide range between minimum and maximum values. However, the total N and moisture average values are similar to the AOPA values, whereas NH_4-N average values are less than the AOPA value and total P average values are greater than the AOPA value.

Table 1. Total N, NH_4-N, total P, and moisture minimum, maximum, and average (in parentheses) values from an eight-year field study (Olson et al. 2003) compared to values in the AOPA.

	Total N[z] (kg/Mg)	NH_4-N[z] (kg/Mg)	Total P[z] (kg/Mg)	Moisture[z] (%)
Site 1	7.1-15.5 (10.8)	0.6-2.9 (1.4)	1.7-5.4 (3.7)	24.6-59.6 (47.3)
Site 2	8.4-15.8 (11.5)	0.4-2.4 (1.3)	2.3-5.6 (3.7)	21.5-63.1 (50.5)
AOPA[y]	10.0	2.6	2.4	50

[z] Values expressed on a wet-weight basis.
[y] *Agricultural Operation Practices Act* (Province of Alberta 2001).

Soil Testing and Fertilizer Recommendations

Results of soil testing for the five fields are shown in Table 2, and fertilizer recommendations are shown in Table 3. Soil-test results are often given in parts per million (ppm) by laboratories. To convert from ppm to kg/ha, multiply ppm by 2 if the soil depth is 15 cm, or multiply by 4 if the soil depth is 30 cm. These conversion factors are not exact, but they will provide good estimates. Also, be careful with how phosphorus (P or P_2O_5) and potassium (K or K_2O) are expressed. Multiply P values by 2.29 to obtain P_2O_5 values, and multiply K values by 1.2 to obtain K_2O values.

All five fields required additional nitrogen ranging from 62 to 118 kg/ha (Table 3). Most of the fields have adequate phosphorus and potassium. Four of the five fields required added sulfur. Fields B3, C, and E have moderately elevated phosphorus levels.

Agricultural Operation Practices Act Requirements

In AOPA there are two soil chemical parameters that need to be considered: electrical conductivity in the top 15 cm, and nitrate-nitrogen (NO_3-N) in the top 60 cm. Electrical conductivity is a measure of soil salinity. The regulations state that no manure can be applied when electrical conductivity is greater than 4 dS/m. Surface soil electrical conductivity at the case-study farm range from 0.2 to 1.7 dS/m, which is well below the 4 dS/m limit. Therefore, soil electrical conductivity is not a restriction at this farm.

Table 2. Soil test results of the five fields selected for manure application.

Field	Area (ha)	Crop	Irrigated or dry	N^z (kg/ha)	P^y (kg/ha)	K^y (kg/ha)	S^z (kg/ha)
B3	10.1	forage	Dry	24	138	714	54
C	40.5	barley	Dry	81	190	1462	87
E	78.4	barley	Dry	99	244	1101	37
F2	9.5	forage	Dry	19	67	672	99
M-crop	85.0	barley	Dry	84	69	607	64

^{z} 0 to 60-cm depth.
^{y} 0 to 15-cm depth.

Table 3. Fertilizer recommendations for the five fields selected for manure application.

Field	Area (ha)	Crop	Irrigated or dry	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	S (kg/ha)
B3	10.1	forage	dry	62	0	0	40
C	40.5	barley	dry	84	0	0	16
E	78.4	barley	dry	73	0	0	20
F2	9.5	forage	dry	101	0	0	0
M-crop	85.0	barley	dry	118	11	17	11

The NO_3-N limit in the top 60 cm for this farm is 225 kg/ha, which is the limit for a medium to fined textured soil in the Black Soil Zone. All five fields are well below this limit (Table 2). As a result none of the five fields are restricted due to the nitrogen limit.

As a side note, the 225 kg/ha limit in this example is above agronomic thresholds. Soil-test values of about 115 kg/ha would result in a recommendation of no fertilizer application. It is possible, under the regulations in the AOPA, manure can be applied even though soil-test results indicate no fertilizer is required. Therefore, the nutrient management aspect of the AOPA is not strictly based on nitrogen requirements of crops, but rather on specific nitrogen limits, which are, for the most part, above agronomic thresholds.

The Act states that manure must not be applied if NO_3-N in the soil after manure application will exceed the limits. The soil NO_3-N content in the five fields ranges from 19 to 99 kg/ha.

Therefore, within the context of the regulations, NO_3-N levels could be increased by amounts ranging from 126 to 206 kg/ha, depending on the field.

The question is, how much manure is required to increase NO_3-N in the soil by these amounts? This is not easy to answer, and at best only an estimate can be made. The problem is that most of the nitrogen in manure exists as organic nitrogen or as NH_4-N, not NO_3-N. Biological processes are required to convert these forms of nitrogen to NO_3-N, and this requires time. Most of the NH_4-N will convert rapidly to NO_3-N, whereas conversion of organic nitrogen takes longer.

One approach is to estimate the amount of NO_3-N that will become available during the first growing season after application. We can assume that most of the NH_4-N and about 25 percent of the organic nitrogen will be converted to NO_3-N. Calculations are shown in Table 4 where these assumptions are applied and manure application rates determined.

Organic nitrogen content of manure is calculated by subtracting NH_4-N from total nitrogen. A portion of the NH_4-N will be lost to the atmosphere through the volatilization of ammonia (NH_3). Timely incorporation can minimize this loss. Injection of liquid manure will result in very little loss. For the case study let's assume that 15 percent is lost from fields C, E, and M-crop (i.e. 85 percent retained) and 50 percent is lost from fields B3 and F2 (i.e. 50 percent retained). Losses are greater for the latter two fields because solid manure cannot be incorporated into forage land. Losses could even be higher depending on the climatic condition at the time of application. The calculated manure application rates range from 31 to 64 Mg/ha (Table 4).

Table 4. Calculation of manure application rates using the AOPA nitrogen limits.

Col A	Col B	Col C	Col D (= Col C – Col B)	Col E	Col F	Col G (= Col E – Col F)	Col H	Col I (=Col G x 0.25)	Col J (= Col H + Col I)	Col K (= Col D – Col J)
Field	Soil-test N (kg/ha)	N limit (kg/ha)	NO_3-N increase (kg/ha)	Manure[z] total N (kg/Mg)	Manure[z] NH_4-N (kg/Mg)	Manure organic N (kg/Mg)	NH_4-N retained[y] (kg/Mg)	Converted organic N[x] (kg/Mg)	NO_3-N available (kg/Mg)	Manure rate (Mg/ha)
B3	24	225	201	10	2.6	7.4	1.3	1.85	3.15	64
C	81	225	144	10	2.6	7.4	2.21	1.85	4.06	35
E	99	225	126	10	2.6	7.4	2.21	1.85	4.06	31
F2	19	225	206	10	2.6	7.4	1.3	1.85	3.15	65
M-crop	84	225	141	10	2.6	7.4	2.21	1.85	4.06	35

[z] From the *Agricultural Operation Practices Act*.
[y] Assume that 85 percent of NH4-N is retained in the soil in fields C, E, and M-crop (i.e. annual crop land) and 50 percent is retained in fields B3 and F2 (i.e. forage land).
[x] Assume 25 percent of organic nitrogen is converted to NO_3-N within the first growing season after application.

The amount of manure used per field is shown in Table 5. However, any setback areas along common bodies of water, or watercourses, need to be removed from the land base, as outlined in the AOPA. This applies to fields E and F2 (Figure 3). A 30-m setback distance is required for surface-applied and incorporated manure. This applies to field E.

Manure cannot be incorporated on field F2 because of the forage crop. In cases where manure cannot be incorporated then slope dictates the width of the setback distance. If the slope is less than 4 percent a 30-m setback distance is used. As slope increases the setback distance also increases. No unincorporated manure may be applied on land with a slope of 12 percent or greater. To calculate the area of the setback zone multiply the setback width by the length the field that borders a common water body.

The total amount of manure used is 8,087 Mg (Table 5). This leaves an excess of 1913 Mg of manure (10,000 Mg - 8,087 Mg). Therefore, more land is required. As a rough estimate, if we assume an average manure application rate of 46 Mg/ha, which is based on the rates shown in Table 5), then about 42 ha of additional land is required (i.e. 1913 Mg ÷ 46 Mg/ha). Potentially there is ample land to accommodate the excess manure on this farm (Figure 3). The above calculations can be repeated with the addition of one or more fields.

Table 5. Calculation of setback areas and total amount of manure applied using the *Agricultural Operation Practices Act* nitrogen limits.

Col A	Col B	Col C	Col D (= Col B – Col C)	Col E	Col F (= Col D x Col E)
Field	Field size (ha)	Set-back zone (ha)	Available land (ha)	Manure rate (Mg/ha)	Total manure applied (Mg)
B3	10.1	0	10.1	64	646
C	40.5	0	40.5	35	1418
E	80.9	2.5[z]	78.4	31	2430
F2	12.1	2.6[z]	9.5	65	618
M-crop	85.0	0	85.0	35	2975
			Total amount of manure used:		8087

[z] A setback width of 30 m was used. The length was 841 m for field E and 853 m for field F2.

Nutrient Balance Approach – Nitrogen Based

The application of manure based on the AOPA nitrogen limits may not necessarily mean manure is applied based on the crop nitrogen requirements, and may in fact result in the over application of nitrogen. The better management practice is to apply nutrients based on crop requirements. The following calculations in Tables 6 and 7 are similar to the previous section, but fertilizer recommendation values for nitrogen are used instead of the AOPA nitrogen limit.

The manure application rates are lower, and as a result, less manure is applied on the five selected fields. Based on these application rates, there will be an excess of 4,769 Mg of manure (10,000 Mg – 5,231 Mg). As a rough estimate, if we assume an average manure application rate of 24 Mg/ha, which is based on the rates shown in Table 7, then about 199 ha of additional land will be required (i.e. 4,769 Mg ÷ 24 Mg/ha). Compared to the AOPA nitrogen limits approach, if manure is applied strictly based on the crop nitrogen requirements, then about 60 percent more land is required to accommodate the manure. Again, depending on the nitrogen status of the other fields, there should be enough land to accommodate the manure.

Table 6. Calculation of manure application rates using nitrogen fertilizer recommendations.

Col A	Col B	Col C	Col D	Col E	Col F (= Col D – Col E)	Col G	Col H (= Col F x 0.25)	Col I (= Col G + Col H)	Col J (= Col C / Col I)
Field	Soil-test N (kg/ha)	Fertilizer N recommendation (kg/ha)	Manure[z] total N (kg/Mg)	Manure[z] NH_4-N (kg/Mg)	Manure organic N (kg/Mg)	NH_4-N retained[y] (kg/Mg)	Converted organic N[x] (kg/Mg)	NO_3-N available (kg/Mg)	Manure rate (Mg/ha)
B3	24	62	10	2.6	7.4	1.3	1.85	3.15	20
C	81	84	10	2.6	7.4	2.21	1.85	4.06	21
E	99	73	10	2.6	7.4	2.21	1.85	4.06	18
F2	19	101	10	2.6	7.4	1.3	1.85	3.15	32
M-crop	84	118	10	2.6	7.4	2.21	1.85	4.06	29

[z] From the Agricultural Operation Practices Act (Province of Alberta 2001).
[y] Assume that 85 percent of NH4-N is retained in the soil in fields C, E, and M-crop (i.e. annual crop land) and 50 percent is retained in fields B3 and F2 (i.e. forage land).
[x] Assume 25 percent of organic nitrogen is converted to NO_3-N within the first growing season after application.

Table 7. Calculation of setback areas and total amount of applied manure using nitrogen fertilizer recommendations.

Col A	Col B	Col C	Col D (= Col B – Col C)	Col E	Col F (= Col D x Col E)
Field	Field size (ha)	Set-back zone (ha)	Available land (ha)	Manure rate (Mg/ha)	Total manure applied (Mg)
B3	10.1	0	10.1	20	202
C	40.5	0	40.5	21	851
E	80.9	2.5[z]	78.4	18	1411
F2	12.1	2.6[z]	9.5	32	304
M-crop	85.0	0	85.0	29	2465
			Total amount of manure used:		5233

[z] A setback width of 30 m was used. The length was 841 m for field E and 853 for field F2.

Nutrient Balance Approach – Phosphorus Based

The application of manure based on crop nitrogen requirements will result in the accumulation of excess phosphorus in surface soil. The build-up of phosphorus in surface soil is considered an environmental risk to surface water quality. The best way to prevent phosphorus build-up in soil is to apply manure based on the crop phosphorus requirements. Currently there are no phosphorus limits in the AOPA. However, proposed phosphorus limits are currently being developed (Olson 2004).

The calculations in Tables 8 and 9 show the determination of manure rates and the amount of manure used based on phosphorus requirements of crops. The calculations are more straightforward than for nitrogen, mainly because there is no gaseous loss of phosphorus and a percentage of total phosphorus in manure is taken as an estimate of the amount of plant available phosphorus during the first year after application.

The results in Table 8 show that only one of the five fields can receive manure. The field that can receive manure only requires a small amount (2.9 Mg/ha). This highlights an important challenge for phosphorus-based application of manure, particularly for solid manure for which the uniform application of low rates may be a problem.

Table 8. Calculation of manure application rates using phosphorus fertilizer recommendations.

Col A	Col B	Col C	Col D	Col E (= Col D x 0.7)	Col F (= Col E x 2.29)	Col G (= Col C/Col F)
Field	Soil-test P (kg/ha)	Fertilizer P_2O_5 recommendation (kg/ha)	Manure total P[z] (kg/Mg)	Available total P[y] (kg/Mg)	Available total P_2O_5 (kg/Mg)	Manure rate (Mg/ha)
B3	138	0	2.4	1.68	3.85	0
C	190	0	2.4	1.68	3.85	0
E	244	0	2.4	1.68	3.85	0
F2	67	0	2.4	1.68	3.85	0
Mc	69	11	2.4	1.68	3.85	2.9

[z] From the Agricultural Operation Practices Act (Province of Alberta 2001).
[y] Assume 70 percent of total phosphorus becomes plant available within the first growing season after application.

Table 9. Calculation of setback areas and total amount of applied manure using phosphorus fertilizer recommendations.

Col A	Col B	Col C	Col D (= Col B – Col C)	Col E	Col F (= Col D x Col E)
Field	Field size (ha)	Set-back zone (ha)	Available land (ha)	Manure rate (Mg/ha)	Total manure applied (Mg)
B3	10.1	0	10.1	0	0
C	40.5	0	40.5	0	0
E	80.9	2.5[z]	78.4	0	0
F2	12.1	2.6[z]	9.5	0	0
M-crop	85.0	0	85.0	2.9	247
			Total amount of manure used:		247

[z] A setback width of 30 m was used. The length was 841 m for field E and 853 for field F2.

The application of manure based on phosphorus will result in the under application of nitrogen. For fields B3, C, E, and F2, all nitrogen requirements will have to be met by using inorganic nitrogen commercial fertilizers. However, a portion of the required nitrogen for field M-crop is provided by manure application. The calculations in Table 10 shows the amount of nitrogen provided by manure and the amount of additional nitrogen fertilizer that is required.

The amount of manure applied on the five selected fields is 247 Mg, based on crop phosphorus requirements (Table 9). Therefore, most of the manure (9,753 Mg = 10,000 Mg – 247 Mg) still requires land application. Based on the 2.9 Mg/ha rate, 3,363 ha (9,753 Mg ÷ 2.9 Mg/ha) would be required to accommodate the excess manure. However, the remaining 28 fields on the farm have a combined area of only about 485 ha. Additional soil testing would be required to determine if any of these fields could benefit from added phosphorus. If the first five fields are any indications, it may be a challenge for this farm to apply manure based on phosphorus requirement of crops.

Table 10. Additional nitrogen requirements after phosphorus-based application of manure.

Col A	Col B	Col C	Col D	Col E (= Col C x Col D)	Col F (= Col B - Col E)
Field	N fertilization recommendation (kg/ha)	Manure rate [z] (Mg/ha)	Available N from manure [y] (kg/Mg)	Available N applied with manure (kg/ha)	Additional N required as fertilizer (kg/ha)
B3	62	0	3.15	0	62
C	84	0	4.06	0	84
E	73	0	4.06	0	73
F2	101	0	3.15	0	101
M-crop	118	2.9	4.06	12	106

[z] From column G in Table 8.
[y] From column J in Table 4.

The application of 2.9 Mg/ha of solid manure most likely is physically impractical with existing application equipment. One option would be to apply two to four years worth of phosphorus-based manure and then not apply manure again for that length of time. For example, in this case study, a four-year application rate is nearly 12 Mg/ha. Once applied, then manure would not be applied again until four years later. Any nitrogen requirements could be managed with commercial inorganic fertilizers.

Manure Management Planner Software

The above example is fairly straightforward in terms of making the calculations by hand or using a computer spreadsheet program. However, for more complicated situations or when several different scenarios are explored, and repeated each year, the calculations can become difficult, tedious, and prone to errors. To assist with these calculations, computer software programs have been developed for on-farm nutrient management. Alberta recently adopted a manure management program called Manure Management Planner (MMP), which was developed by Purdue University (West Lafayette, Indiana). The MMP program has been adopted by 28 states in the United States. Several more states are in the process of adopting MMP. Alberta is the only Canadian province to adopt MMP.

A copy of the Alberta Manure Management Planner (AMMP) program can be downloaded from Alberta Agriculture, Food and Rural Development's Ropin' the Web site at the following address:

http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/epw8834

Summary and Conclusions

The example used in this case study represents the condition of one farm. There is almost an endless number of combinations of factors used to prepare a nutrient manage plan, including available land, nutrient status of soil, cropping strategies, livestock numbers and types, management style and experience, economic pressures, and climatic conditions. Each farm operation is unique. The preparation of effective nutrient management plans requires significant effort to gather the proper information. This effort is necessary to insure that today's farm operations are managed in a sustainable manner in terms of the environment and economics.

During the course of preparing nutrient management plans, through the process of gathering information, making decisions, and carrying out the plan, it is important to keep records, which will always be useful for future reference.

The farm example used in this case study raises a concern that the nitrogen limits in the AOPA can allow over application of nitrogen and, in part, are not based on the crop requirements for nitrogen. The strict nutrient balance approach for nitrogen may mean that more land is required to accommodate manure compared to using the nitrogen limits in the AOPA. However, the magnitude of this difference will depend on specific characteristics of each farm operation. This case study clearly showed that of the three approaches, the strict nutrient balance approach for phosphorus requires the largest land base for manure application.

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