UNIVERSITY OF FLORIDA

IFAS EXTENSION

Managing Dairy Manure Accountably: Worksheets for Nutrient Budgeting [1]

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Manure is well recognized for its fertilizer value but we don't often calculate that value. Too often in the past it has been assumed that recovery costs were greater than value and manure nutrients were not fully utilized. However, unused manure N or P may leak to surface or groundwaters. Thus, environmental concerns mandate manure utilization regardless of costs. The plan for utilization needs to use manure resource value to pay for its implementation to the fullest extent possible.

This circular is directed to producers to help them develop manure nutrient management plans. Dairy advisors also are expected users. The worksheets are designed for use as a computer spreadsheet to invite easy recalculation to look at alternative plans. Background information can be found in University of Florida Cooperative Extension Circular 1016.

Abbreviations: N = nitrogen, P = phosphorus, K = potassium, DM = dry matter, DMI = DM intake, OM = organic matter, TDN = total digestible nutrients.

Unit conversions: P = 43.6% of P_2O_5; multiply P by 2.29 to convert to P_2O_5 equivalent; K = 83% of K_2O; multiply K by 1.20 to convert to K_2O; 1 gallon water = 8.346 lbs; 1 cubic foot = 7.48 gallons; 1 acre-inch = 27,152 gallons.

Objectives

1. To show you and, perhaps, your urban neighbors what happens to manure and manure nutrients on your farm. It helps to document that you are not polluting or to identify needed improvements.
2. To predict crop production (acreage and yields) needed to recycle manure nutrients and limit losses to waters and atmosphere to environmentally acceptable amounts.
3. To identify dollar value of manure nutrients recovered that help pay for costs to manage manure in an environmentally acceptable manner.
4. To determine if or how many manure nutrients must be exported off-farm.

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Worksheet 1: How much N, P, K, and DM are excreted?

The examples in Worksheet 1 (in Table 1) show calculations for herds averaging 100 milking cows and provide a column for calculations for your herd. Example 1 is for a herd which has 100% of the manure collected. Example 2 is for a part-time grazing herd which has 40% of the manure collected in the milking parlor and an adjacent feeding barn. Discussion of the 60% of the manure deposited on pasture is included in a section near the end on pasture budgets.

If you wish to obtain excretion estimates for dry cows, make calculations with zero milk yield and determine their DMI and diet composition. Recall that dry cows eat only about half the DM of high-producing lactating cows. If your feeding program is not already based on DM, you must determine the DM content of the diet to determine DMI. For illustration, if the Example 1 dairy producer (Worksheet 1 in Table 1) gets his cows to eat 9300 lb daily of wet-weight feed (after refusals are subtracted from that delivered) which is 52% DM, the average DMI is 48 lb/day (9300 multiplied by .52 then divided by 100 cows).

Some key conversion factors necessary for later calculations are: diet protein is 16% N, milk protein 15.5% N, milk contains .10% P and .15% K, and body weight gain contains 1.2% N, .70% P, and .20% K. If an estimate of DM excreted in manure is desired, an estimate of diet DM digestibility is needed. The example uses 65% (.65), which is roughly equivalent to TDN of 70%. The TDN is about 5 percentage units higher because TDN multiplies digested fat by 2.25. Thus, feces DM excreted is 35% of DMI (1 minus digestibility) and we estimate that urine DM excreted is 5% of DMI. If organic matter content of manure is desired, our data show original DM excretion of dairy cow manure to be about 83% organic matter, however, this decreases with time after excretion as organic matter decays in storage or is digested in a lagoon.

What percent of time do cows spend in the manure management system being evaluated?

This is a very important number for use when cows split their time between pastures or pasture lots and areas from which manure is collected and managed, for example holding pens, milking parlor area, and feed barns. Available data suggest that manure flow through the digestive tract is relatively steady throughout the day. Therefore, we estimate that cows distribute their manure equal to the percent of time they spend in an area.

Worksheet 2: How much of the excreted nutrients do you recover for fertilizer?

A key measure needed to help evaluate your manure management is the amount of N and P recovered in the manure you recycle. Also, you need nutrient quantities to fertilize crops correctly and to determine the dollar value you realize when you fertilize your crops with manure. It is necessary to both estimate amount by weighing enough loads of manure hauled to the fields and analyze enough samples to predict N, P, and K composition. Nutrient recoveries are obtained by multiplying concentrations by load weights and number. If an irrigation system is used to distribute wastewater from a lagoon or holding pond, wastewater analyses are needed to go with the volume of wastewater distributed. Volume meters on irrigation pumps are important; if not available, gallons pumped must be estimated by hours pumped and the estimated gallons/min listed in the pump specifications. See Table 2 .

With relatively hard data in hand on nutrient excretion and nutrient recovery for fertilizer use, calculating the difference provides a good estimate of nutrient losses in the manure management system. For example, in Worksheet 2 (in Table 2) it was estimated that 43.6% of excreted N, 92.1% of P, and 81.9% of K were recovered in the manure and wastewater spread on cropland.

Volatilization losses of 50% or more of N are expected unless manure is moved to fields very quickly after excretions are collected. Losses up to 80% of excreted N are not uncommon.

Recoveries of P and K should be high, 90% or more for P and close to that for K because P and K are not lost to the air. Losses of P should be explored if they were large, for example, greater than 30%. If anaerobic lagoons are utilized, the sludge at the bottom of the lagoon may be a place where P is accumulating. That P will need to be budgeted and managed sometime later when sludge is emptied from your lagoon. Large holding ponds also are a reservoir for P.

Estimating nutrient recovery percentages if amounts and composition have not been measured.

For dairy cows, about half of the original N excretion is urea (from urine) or other easily degraded N compounds in feces that yield ammonia. If you have not measured (Worksheet 2, in Table 2) what you are recovering and applying, some suggested estimates to use are:

- With quick application and incorporation, for example, irrigation of flushed manure within 5 days after excretion to crops grown under sprayfield, N recovery 65%
- Application of wastewaters from anaerobic lagoon with a 21-day or longer holding time, N recovery20 to 30%
- An average recovery for N40%
- For P, estimate recovery of 90% or more unless you use an anaerobic lagoon and discount for what likely remains in the sludge in bottom of the lagoon. That could be as much as 50% in lagoons with 21-day or more average retention time.
- For K, estimate recovery of 80 to 90%.

For Example 2 in Table 4 , Worksheet 3, a scenario was chosen assuming manure is collected in holding, milking, and feeding areas 40% of the time and stored in an anaerobic lagoon an average of 21 days before the effluent is distributed to cropland. It was estimated that 30% of the N from the 40% collected was recovered for fertilizer use. The estimated P% recovered was discounted to 50% because of assumed retention in lagoon sludge that will have to be managed separately sometime in the future when the lagoon is cleaned out.

Worksheet 3: Budgeting use of recovered manure nutrients.

After estimating total manure nutrient excretion and accounting for losses in the manure management system, the next step is to utilize the remaining nutrients on your farm or find a place to export them.

If sufficient acreage and crop production potential exists, it is likely that the optimum use of the fertilizer value in the manures will be to develop budgets based on P and, thus, manure N will be supplemented with additional N from commercial fertilizer. Optimum crops probably will be high-energy crops that are conducive to high per animal milk production rather than maximum DM yields. If acreage is short and soil storage of excess P is permitted, multiple-cropping with forages and maximum application of N will be required. Irrigation is almost essential for consistent maximum production and nutrient utilization per acre in most regions. If land or water resources make irrigation unsuitable, lower fertility, less intensive systems should be used. If excess nutrients exist after cropping system needs are met, they will have to be exported off-farm.

To start acreage calculations, let's assume that you have potential to produce corn for silage and some of the other crops listed in Table 3 . If your expected yields and N and P compositions differ appreciably from those listed, change to your yield or your advised fertilizer application rate when you calculate your nutrient application rate.

A key question is, what fertilizer application rates are needed to achieve the N and P harvests in those crops? Obviously, it will be greater than that harvested unless your soils have high fertility stores of N and P. In Table 3 examples, N removals were multiplied by 1.3 which allows 20% more than crop removals for denitrification and volatilization and 10% for losses to ground and surface waters. For P and K, crop removals were multiplied by 1.1 which allows for 10% more than crop removal for losses to surface waters.

An alternative to calculating your own nutrient application rates is to use accepted agronomic recommendations for commercial fertilizer applications in your area.

If those are greater than determined in Table 3 , use those. There should be no risk in applying manure nutrients up to those levels (certainly no more risk than with commercial fertilizers). Most non-ammonia manure N is stable organic N from the feces which requires extra time to decompose and become available and may not be available for the first crop grown after application. The degradation rates are somewhat climate- and region-dependent and, therefore, the extra amount should be determined based on appropriate factors determined for your situation by agronomists experienced in manure utilization. While the N in dry feces scraped from an unpaved dry lot may be only 40% available during the first month or two after application (depending upon climate and soil type, as noted), N in lagoon or holding pond effluent is often 90+% inorganic (depending upon the amount of sludge pumped) and essentially as available as commercial sources. However, this N may also be somewhat less effective than expected for one or two seasons as the addition of water and organic matter may stimulate denitrification and other soil microbial changes that require time to equilibrate.

Many dairy farmers apply manure at established per-acre rates year after year and the amount of carryover averages out so that it is less important for budget calculations. Also, this likely will be the case if you are starting a manure budgeting plan on land which has had routine manure applications in the past. However, for the first year of manure application, especially when manure is solid or semi-solid, it is important to discount the availability of the organic N and assume, for example, that about 30% of that will not be available during the first year. Thus, some extra N from commercial fertilizer during the first year may be needed.

It should be kept in mind that the N budgeting application rates assume good production conditions or the availability of supplemental irrigation. A weather-related crop failure will (assuming drought rather than flood) result in nutrient carryover to the next crop. This will require downward adjustment in the application rate for the next crop in order to assure that soil nitrate does not leach to groundwater. If all your acreage is required to utilize manure and drought is a common occurrence, an irrigation system is almost essential for near optimum manure nutrient management.

Analyzing Your N, P, and K Accounting using the Worksheets.

The worksheets 1, 2, and 3 (Table 1 , Table 2 , and Table 4), provide calculations for two example dairies with several cropping system scenarios considered to show variation in acreages needed with the different assumptions. Corn silage was included as a single crop example because yields and feed quality are high. However, as a single crop system, it will not use nutrients enough of the year to meet most dairy producers' manure management needs. Therefore, multiple crop systems or sod-based systems are usually advised in order to assure that active roots are present in the soil year-round to intercept N, especially.

Example 1 was based on 100 cows producing an average of 60 lb milk/day all year in a confined system permitting 100% of the manure to be accounted for within one system. **Example 2** is a partial grazing dairy (cows in pastures 60% of time) where 40% of the manure is collected in holding, milking, and feeding areas. Note the assumed Nutrient Recovery Percentages (Line numbers 72 to 74, (Table 4), Worksheet 3, Example 2) are representative of what might be expected with an anaerobic lagoon designed for 21-day or more average holding time, 30% for N, 50% for P, and 80% for K. Remember with this system, the P in the lagoon will have to be managed at a later time when the lagoon is cleaned out.

Although only examples, several points can be made. Note in Example 1 (lines 96 to 113, Worksheet 3, Table 4), approximately three times as many acres were needed for manure application when manure applications were based on P as compared with N-based applications; acreages based on K fell in between..

In Example 2, where appreciable P was removed from the waste stream and stored in lagoon sludge, K was expected to remain soluble and flow with lagoon effluent. This is the only type of system where K budgets might require more acreage than P budgets. However, K almost always will be over-applied when manure is applied based on N. Repeated over-application of K leads to high-K forages because most forages will luxury-consume K. Dairy producers wish to avoid high-K forages for their dry cows.

With an N budget with triple-cropping (System 4, Worksheet 3), 25.8 acres of cropland were needed producing 22 tons/acre of wet-weight corn silage, 2.3 tons of bermudagrass hay, and 7.0 tons of rye haylage (yields from Table 3). Applying manure based on a P budget would have required 80.1 acres.

In Example 2, P budgets were much closer to N budgets. There are two major reasons for this: 1) dietary P was reduced to .41% versus .50% in Example 1; 2) the long storage time of wastewater in an anaerobic lagoon led to the estimate that 50% of the entering P remained in sludge in the lagoon. Additionally, DMI was lower in the grazing example. Keep in mind that Example 2 budgets are for the manure collected in the holding, milking, and feeding areas only and not for the 60% dropped in the pastures.

If sufficient land is available to apply manure based on a P budget, more fertilizer value will be utilized.

For Example 1 (Worksheet 3, Table 4), about 30% more value was recovered if manure was applied to crop-producing acreage that utilized all of the P than if applied based on a N budget ($12,774 versus $9,873 per 100 cows).

However, can you make good use of the feed produced if you farm all the acres needed to utilize the P? With the estimated tonnages of DM harvested (6.6 tons/acre for corn silage, 2.0 for bermudagrass after corn silage, and 2.8 tons/acre for winter rye before corn), we estimate 294 tons of DM from the 25.8 acres utilized with an N budget which will supply 16.1 lb DM/cow daily on a year-round basis. With a P budget, 937 tons of DM from the 80.1 acres required translates to 50.0 lb DM/cow daily. The DM amount with the P budget is about twice as much forage DM as most dairy producers feed their lactating cows. Therefore, you would have an excess, probably even more than could be used for heifers and dry cows. Also, many dairies do not have the .80 acre/cow of land required for crop production with this system (more if triple-cropping rye after corn silage and bermudagrass is not possible).

The acreage required for the N budget would allow most dairy producers to utilize the manure and forage produced. However, the 294 tons DM produced annually with this system, which supplies only 16.1 lb DMI/day, may not be enough. Thus, additional forage production or purchasing of forage may be needed.

Note in Table 3 that triple-cropping with conventional tillage to produce corn, sorghum, and winter rye consumed the most N, P, and K. However, sod-based triple-cropping was chosen for the example in Worksheet 3 (Table 4) because sod cover and roots should reduce runoff and leakage of N to groundwater.

What can you do if you are forced to follow a P budget?

The first and easiest step is to reduce P in the diet to NRC requirements. If diets formulated to supply required P average out at .41% of DMI, like in Example 2, recalculating Worksheet 1 (Table 1) predicts a daily P excretion of .136 lb/cow versus .179. This leads to excretion estimates of 4964 lb (versus 6519 lb) and an application of 4468 lb of P/yr if we recover 90% of P for fertilizer use. This change in diet, which would not be expected to affect performance, would change acreage needed with the triple-cropping system (Crop System 4, Line 106, Worksheet 3, Table 4) to 59.6 acres which would supply 690 tons of DM (37.8 lb DM/day to milking cows year-round). This is still 2.3 times the acreage needed for N budgeting but the forage production required is more nearly in line with needs if some of it is fed to heifers and dry cows.

Calculating value of recovered N, P, and K.

Animal nutritionists and most dairymen use and think in terms of actual N, P, and K. Agronomists and the fertilizer industry use actual N, but refer to P in terms of P_2O_5 and K in terms of K_2O. The P_2O_5 actually contains 43.6% P (.436) and K_2O is 83% K (.83). Thus, 10-10-10 fertilizer units are equivalent to 10- 4.36 - 8.3 units of actual N, P, and K.

Conversions are needed to work from actual P and K excretion calculations to fertilizer recommendations or values based on P_2O_5 and K_2O. Note that the application rates used in Worksheet 3 (Table 4) were based on actual P and K from Table 3 . Conversions often are needed for pricing as well. For example (as used in Worksheet 3, Lines 114 to 118), quotes obtained from a fertilizer dealer on a N-only fertilizer, e.g., ammonium nitrate, leading to \$.36/unit N; a phosphate, leading to \$.32/unit P_2O_5, and a K source leading to \$.15/unit K_2O calculates to values of actual N, P, and K of \$.36, \$.73, and \$.18. Divide P_2O_5 values by .436 and K_2O values by .83 for the conversion. .

If we utilize all of the recovered manure nutrients effectively, the dollar values calculated in Worksheet 3 (Lines 119 and 120) lead us to expect recovered fertilizer values of more than \$100/cow annually. These values (Example 1) are with 43.6% of the N being recovered. *How many dollars could have been saved by utilizing better N conservation management practices in manure handling?* We don't have an exact answer but, if we utilize all of the P and K, and we use a 65% N recovery in Example 1, the manure fertilizer value recovered increases to \$15,570 (\$156/cow). These examples suggest that in the future most dairies will need to reduce P excretion as much as possible and save more N, if possible, to make dairy manure nutrient management systems balance well with crop production, economics, and the environment.

How could these worksheets be used for a pasture budget?

If in Example 2 (in the worksheets) we were interested in some analysis of the pasture budget, we could recalculate the worksheets with a change in the percent of time in the manure collection area (Line 40, Worksheet 1) to 60%, the amount of time the cows were on the pastures. Additionally, let's assume our pasture system is described by the bermudagrass and rye pasture data in Table 3 . This would be managed as bermudagrass overseeded with rye in the fall, thus, double-cropping. The total calculated application rates per acre for these two crops (from Table 3) is 450 lb N, 39 lb P, and 242 lb K. For this example, it was assumed that 40% of N, 90% of P, and 80% of K dropped on those pastures was recovered as fertilizer. Putting those application rates and recovery percentages into Worksheet 3, (Table 4), in place of one of the six systems illustrated gives 17.4 acres (N basis), 61.8 acres (P basis) or 31.1 acres (K basis) of pasture needed.

Obviously 17.4 acres based on N is not enough acres to feed 100 cows. How many acres do you need? If we assumed that we had pasture to graze 90% of the year and that cows ate 15 lb DM from pasture per day, that computes to 4900 lb DM/cow yearly. Table 3 assumptions for those pastures were for 6 tons DM grazed/acre (12,000 lb). Dividing 12,000 lb/acre by 4900 lb per cow gives 2.45 cows per acre as an average stocking rate or 100 cows divided by 2.45 cows/acre equals 40.8 acres. If you choose your acres to have in pasture based on estimated DM consumption, you can estimate relative N, P, and K availability from the ratios of calculated acreages to acreage needed. For example for N, 17.4/40.8 = 43%, which is an estimate that manure would supply only 43% of the total N fertilizer needed for 40.8 acres. The ratio for P of 61.8/40.8 = 1.49 indicates that manure would be supplying about 1.5 times as much P as recommended. Thus, soil P storage amounts would be expected to increase. The K ratio, 31.1/40.8 is about .76 which indicates little K application should be needed.

This pasture example helps support some general conclusions about pasture budgets. First, if pastures are truly grazed and not simply used as a sodded dry lot, additional N from commercial fertilizer generally will be needed beyond that supplied by manure N. Second, additional P from commercial fertilizer will not be needed unless soil P storage previous to current grazing year was below soil fertility recommendations based on soil tests. Third, soil tests are recommended to help decide if K fertilization is needed.

How many, if any, nutrients should be exported off-farm?

This calculation can be approximated from the worksheets. For example, if you don't have the acreage needed for your selected crop production system, the ratio of acreage you have to that needed is the fraction of the total manure nutrients that you can utilize. The remaining fraction may have to be exported if you can't intensify crop production to utilize more nutrients on the acres that you have.

Summary

- Nutrient excretions by lactating dairy cows, especially N and P, are easily estimated accurately when DMI, nutrient composition of the diet, and milk yields are known.

- Dairy producers must quantify manure nutrients recovered from the waste management system to accurately develop a whole-farm nutrient budget. That means weighing loads of manure, measuring gallons of wastewaters used in irrigation, and having samples analyzed for nutrient composition.

- Losses of more than 50% of the excreted N are common. If an average recovery must be used for preliminary calculations, we suggest that 40% be used, i.e., 60% lost. Losses of P should be less than 10%, and losses of K should be less than 20%.

- Manure nutrient applications for fertilizer are usually of less risk to the environment than equal nutrient applications of commercial fertilizer because enough of the recovered manure N is in organic form to lessen risk of leaching.

- Most dairy manure budgets find enough P to fertilize two to three times as many acres of crop production based on P as can be fertilized appropriately with manure N.

- Pasture budgets will almost always show need for supplemental N from commercial fertilizer N with no supplemental P needed from commercial fertilizer.

- Practical goals to realize the most value from dairy manure usually include: 1) reducing dietary P to NRC requirements to reduce diet cost and manure P excretion; 2) applying manure based on P budgets; and 3) applying manure to growing crops as soon as possible after excretion to minimize N volatilization losses.

Table 1.

Table 1. Worksheet 1. Accounting of manure N, P, and K excretion and percent collected in managment area.				
Line number	Example 1	Units	Your herd[1]	Example 2
Herd information (yearly averages)				
1. Average number milking cows/d (d=day)	100	lb/d		100
2. Average DMI/d (DMI = dry matter intake)	48.0	%CP		42.0
3. Average diet CP% (DM basis) (CP = crude protein)	17.0	% N		17.0
4. Average diet N% = CP% X .16 =	2.72	% P		2.72
5. Average diet P% (DM basis)	0.50	% K		0.41
6. Average diet K% (DM basis)	1.20	lb/d		1.20
7. Milk yield/d (milking cows)	60	lb/d		50
8. Milk protein percentage	3.2	%		3.2
9. Milk N% = protein % X .155 =	0.496	% N		.496
10. Milk phosphorus (P)%	0.10	% P	0.10	0.10
11. Milk potassium (K)%	0.15	% K	0.15	0.15
12. Average net body weight gain/day	0.20	lb/d		0
13. Average N% of weight gain	1.20	% N	1.20	1.20
14. Average P% of weight gain	0.70	% P	0.70	0.70
15. Average K% of weight gain	0.20	% K	0.20	0.20
16. Average diet DM digestibility %	65	%		62
Daily balances per cow:				
Nitrogen (N):				
17. Input: lb DMI x diet N%/100 =	1.306	lb N/d		1.142
18. Export: Milk yield/d x milk N%/100 =	0.298	lb N/d		0.248
19. Export: Average gain/d x gain N%/100 =	0.002	lb N/d		0
20. Difference (manure estimate) = Input - export =	1.006	lb N/d		0.894
21. Yearly manure N = cows x difference x 365 =	36,704	lb N/yr		32,646
Phosphorus (P):				
22. Input: lb DMI x diet P%/100 =	0.240	lb P/d		0.172
23. Export: lb milk x milk P%/100 =	0.060	lb P/d		0.050
24. Export: lb gain x gain P%/100 =	0.001	lb P/d		0
25. Difference (manure estimate) = input - export =	0.179	lb P/d		0.122
26. Yearly manure P = cows x difference x 365 =	6.519	lb P/yr		4.460
Potassium (K):				
27. Input: lb DMI x diet K%/100 =	0.576	lb K/d		0.504
28. Export: lb milk x milk P%/100 =	0.090	lb K/d		0.075
29. Export: lb gain x gain K%/100 =	0.0004	lb K/d		0

Table 1.

30. Difference (manure estimate) = input - export =	0.486	lb K/d		0.429
31. Yearly manure K = cows x difference x 365 =	17,724	lb K/d		15,659
Dry matter (DM):				
32. Input: lb DMI (from line 2)	48.0	lb DMI		42.0
33. Output (feces) = lb DMI - (dig. X DMI) =	16.8	lb DMI		16.0
34. Output (urine): = 0.05 x DMI	2.4	lb DMI		2.1
35. Total DM output/d = feces + urine =	19.2	lb DMI		18.1
36. Manure DM output, % of input = (line 35/line 32)	40.0	%		43.0
37. Manure DM/yr = cows x output DM/d x 365d =	700,800	lb/yr		659,190
38. Manure organic matter/yr = DM x 0.83 =	581,664	lb/yr		547,128
39. Wet manure/yr @ 14% DM = DM/0.14 =	5,005,714	lb/yr		4,708,500
40. **% manure collected (% of time in area)**	100	%		40
41. Cubic ft wet manure stored/day	220	cu ft		83
42. Gallons water used/cow/day to wastewater	175	gallons		100
43. Cubic ft wastewater stored/day	2,340	cu ft		1,337
44. Number days storage needed	14	days		21
45. Cubic ft storage needed	35,830	cu ft		29,811
46. **Lb N collected (line 40 x line 21)**	36,704	lb/yr		13,058
47. **Lb P collected (line 40 x line 26)**	6,519	lb/yr		1,784
48. **Lb K collected (line 40 x line 31)**	17,724	lb/yr		6,263

[1] Boxes require input data specific for your farm. Data for other lines are calculated.

Table 2.

Table 2. Worksheet 2. Accounting of manure N, P, and K recovered for fertilizer use.

Line number	Example 1	Units	Your herd[1]	Example 2
Manure utilized/yr (manure spread):				
49. Number loads/yr	200			Data not
50. Average weight/load	10,000	lb		collected for
51. Average DM% of loads	25.0	% DM		Example 2
52. Average N% of manure DM	2.00	% N		
53. Average P% of manure DM	0.80	% P		
54. Average K% of manure DM	1.8	% K		
55. Manure DM = loads x lb/load x % DM/100 =	500,000	lb DM/yr		
56. N recovered = DM lb x N%/100	10,000	lb N/yr		
57. P recovered = DM lb x P%/100	4,000	lb P/yr		
58. K recovered = DM lb x K%/100	9,000	lb K/yr		

Table 2.

Wastewater utilized/yr:				
59. Gallons for irrigation (gal = gallons)	6,000,000	gallons		
60. Average N ppm (ppm = parts per million)	120	ppm		
61. Average P ppm	40	ppm		
62. Average K ppm	110	ppm		
63. N recovered = gal x 8.35 lb/gal x N ppm/1,000,000	6,012	lb N/yr		
64. P recovered = gal x 8.35 lb/gal x P ppm/1,000,000	2,004	lb P/yr		
65. K recovered = gal x 8.35 lb/gal x K ppm/1,000,000	5,511	lb K/yr		
Total N, P, and K recovered/yr:				
66. N recovered = solids spread + irrigation =	16,012	lb N/yr		
67. % recovered of collected N excreted =	43.6	%		
68. P recovered = solids + irrigation =	6,004	lb P/yr		
69. % recovered of collected P excreted =	92.1	%		
70. K recovered = solids + irrigation =	14,511	lb K/yr		
71. % recovered of collected K excreted =	81.9	%		

[1] Boxes require input data specific to your farm. Data from other lines are calculated.

Table 3.

Table 3. Estimating N,P and K application rates to use or compare with other agronomic rate recommendations.

Crop	Wet tons per acre	DM%	DM tons per acre	Composition, % of DM				Crop removals, lb/acre			A calculated application rate [1]				
				CP%	N%	P%	K%	N	P	K	N	P	K	P_2O_5 [1]	K_2O [2]
Corn silage	22.0	30	6.6	10.0	1.60	.30	1.2	211	37	158	270	40	174	90	210
Rye or wheat haylage	7.0	40	2.8	20.0	3.20	.36	1.0	179	20	56	230	22	62	50	70
Perennial peanut haylage	15.0	40	6.0	16.0	2.56	.30	1.9	307	36	228	400	40	251	90	300
Pernnial peanut hay after no-til corn for silage	2.3	86	2.0	16.0	2.56	.30	1.9	102	12	76	130	13	84	30	100
Bermudagrass hay	7.0	86	6.0	14.0	2.24	.30	1.5	269	36	180	350	40	198	90	240
Bermudagrass hay after no-til corn for silage	2.3	86	2.0	14.0	2.24	.30	1.5	90	12	60	120	13	66	30	80
Stargrass hay	8.0	86	6.9	12.0	1.92	.30	1.5	265	41	207	340	45	228	100	270
Forage sorghum silage (after com)	20.0	28	5.6	9.0	1.44	.30	1.2	161	34	134	210	37	147	80	180
Bermudagrass pasture	20.0	20	4.0	16.0	2.56	.30	2.0	205	24	160	270	26	176	70	210
Rye pasture	13.3	15	2.0	22.0	3.52	.30	1.5	141	12	60	180	13	66	30	80
Multiple-crop totals:															
Corn silage-bermudagrass hay-rye silage	28.3		11.4					480	69	274	620	75	302	170	360
Corn silage-perennial peanut hay	24.3		8.6					313	49	234	400	53	258	120	310
Corn silage-forage sorghum-rye silage	49.0		15.0					551	91	348	710	99	464	240	550
Corn silage-bermudagrass hay	24.3		8.6					301	49	218	390	53	240	120	290

Table 3.

Calculations for farm or other crops:																		

[1] Calculated application rates (rounded to nearest 10 lb for N_1 P_2O_5 , and K_2O) are developed from crop removals plus losses to expected groundwater and surface runoff that are within environmental standards, plus expected change in soil storage which I assurred to be 0 in this table, plus, for N_1 expected losses to denitrification and volatilization of ammonia. For N_1, removals were multiplied by 1.3 which allows 20% more than crop removals for denitrification and volatilization and 10% for losses to ground and surface waters. For P and K, crop removals were multiplied by 1.1 which allows for 10% more than crop removal for losses to surface waters.

[2] Application rates rounded to nearest 10 lb. For P_2O_5 are actual P rates divided by .436 unit P/unit P_2O_5; K_2O application rates are K rates divided by .83 unit K/unit K_2O.

Table 4.

Table 4. Worksheet 3. Budget accounts for recovered N, P, and K.				
Line Number	Example 1	Units	Your farm[1]	Example 2
Nutrient recoveries (%):				
72. N recovered (from Worksheet 2 or estimated)	43.6	%		30.0
73. P recovered (from Worksheet 2 or estimated)	92.1	%		50.0
74. K recovered (from Worksheet 2 or estimated)	81.9	%		80.0
Nutrient recoveries (lb):				
75. N recovered (line 72 x line 46)	16,003	lb/yr		3,917
76. P recovered (line 73 x line 47)	6,004	lb/yr		892
77. K recovered (line 74 x line 48)	14,516	lb/yr		5,011
Crop application rates:				
78. Crop system 1 (corn silage) N:	270	lb N/acre		270
79. Crop system 1 (corn silage) P:	40	lb P/acre		40
80. Crop system 1 (corn silage) K:	174	lb K/acre		174
81. Crop system 2 (bermudagrass hay) N:	350	lb N/acre		350
82. Crop system 2 (bermudagrass hay) P:	40	lb P/acre		40
83. Crop system 2 (bermudagrass hay) K:	198	lb K/acre		198
84. Crop system 3 (corn, bermudagrass after corn) N:	390	lb N/acre		390
85. Crop system 3 (corn, bermudagrass after corn) P:	53	lb P/acre		53
86. Crop system 3 (corn, bermudagrass after corn) K:	240	lb K/acre		240
87. Crop system 4 (corn, bermudagrass, rye) N:	620	lb N/acre		620
88. Crop system 4 (corn, bermudagrass, rye) P:	75	lb P/acre		75
89. Crop system 4 (corn, bermudagrass, rye) K:	302	lb K/acre		302
90. Crop system 5 (perennial peanut) N:	400	lb N/acre		400
91. Crop system 5 (perennial peanut) P:	40	lb P/acre		40
92. Crop system 5 (perennial peanut) K:	251	lb K/acre		251
93. Crop system 6 (corn sil., perennial peanut) N:	400	lb N/acre		400
94. Crop system 6 (corn sil., perennial peanut) P:	53	lb P/acre		53
95. Crop system 6 (corn sil., perennial peanut) K:	258	lb K/acre		258
Calculated acreage needed for crop system examples:				
96. Crop system 1 (corn silage) N:	59.3	acres		14.5
97. Crop system 1 (corn silage) P:	150.1	acres		22.3
98. Crop system 1 (corn silage) K:	83.4	acres		28.8
99. Crop system 2 (bermudagrass hay) N:	45.7	acres		11.2
100. Crop system 2 (bermudagrass hay) P:	150.1	acres		22.3

Table 4.

101. Crop system 2 (bermudagrass hay) K:	73.3	acres		25.3
102. Crop system 3 (corn sil., bermudagrass after corn) N:	41.0	acres		10.0
103. Crop system 3 (corn sil., bermudagrass after corn) P:	113.3	acres		16.8
104. Crop system 3 (corn sil., bermudagrass after corn) K:	60.5	acres		20.9
105. Crop system 4 (corn, bermudagrass, rye) N:	25.8	acres		6.3
106. Crop system 4 (corn, bermudagrass, rye) P:	80.1	acres		12.2
107. Crop system 4 (corn, bermudagrass, rye) K:	48.1	acres		16.6
108. Crop system 5 (perennial peanut) N:	40.0	acres		9.8
109. Crop system 5 (perennial peanut) P:	150.1	acres		22.3
110. Crop system 5 (perennial peanut) K:	57.8	acres		20.0
111. Crop system 6 (corn sil., perennial peanut) N:	40.0	acres		9.8
112. Crop system 6 (corn sil., perennial peanut) P:	113.3	acres		16.8
113. Crop system 6 (corn sil., perennial peanut) K:	56.3	acres		19.4
Commercial fertilizer values:				
114. Value/lb N:	$0.36	$/lb N		$0.36
115. Value/lb P_2O_5:	$0.32	$/lb P_2O_5		$0.32
116. Value/lb P (2.29 x P_2O_5):	$0.73	$/lb P		$0.73
117. Value/lb K_2O:	$0.15	$/lb K_2O		$0.15
118. Value/lb K (1.20 x K_2O):	$0.18	$/lb K		$0.18
Manure fertilizer values recovered /yr:				
119. With P budget (all recovered N, P, K used)	$12,774	$/yr		$2,966
120. With N budget (all recovered N used, 40% of P, 90% of K)	$9,873	$/yr		$2,484

[1] Boxes require input data specific to your farm. Data from other lines are calculated.