chapter
eight

Developing an Overall Farm Nutrient Inventory, Needs, and Budget

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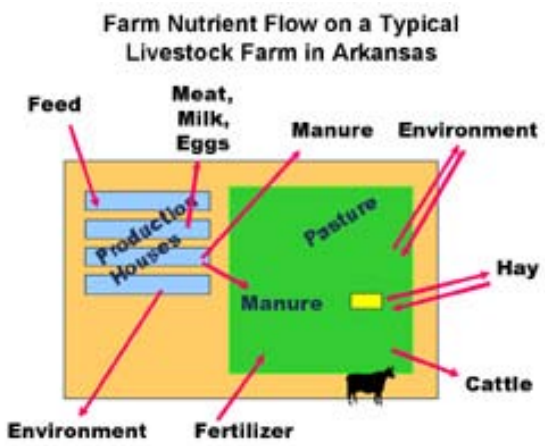
Sound nutrient management is a cornerstone to sustaining both profitable production and environmental stewardship where animal manures are utilized as fertilizer. An important underlying principle is achieving a sustainable nutrient balance for the farm. A nutrient balance considers all the import, export, and on-farm changes in nutrient storage such as build up of nutrients in soils (Figure 8-1). The goal of any operation should be to balance nutrient imports and exports to avoid nutrient accumulation on the farm.

Figure 8-1. Nutrient mass flow on a typical livestock farm in Arkansas that does not harvest grain.



In practice, achieving a nutrient balance is difficult especially on farms that do not harvest and export grain or hay. Under continual grazing of permanent pastures, nutrients are mostly recycled rather than exported, which can lead to accumulation, especially for phosphorus. The determination of a "true" nutrient balance is practically impossible since some nutrient imports and exports are difficult to measure and quantify. Nonetheless constructing an overall farm nutrient budget can be critical in achieving a nutrient balance on the farm.

To construct a nutrient budget, the following steps should be followed:

1. Determine total nutrients derived from manure production
2. Determine whole farm nutrient needs
3. Determine any Nutrient Deficits/Excesses.

Determining Total Nutrients Derived from Manure Production

Historically, the most economical use of generated animal manures is to spread it as fertilizer on adjacent crop or pasture land. An important aspect of achieving a nutrient balance on farm is to inventory the amount of nutrients contained in the manure that is produced. To do so, the following steps should be followed:

1. Estimate the total amount of manure or litter produced.
2. Determine the nutrient concentration of manure or litter.
3. Multiply the total manure (Litter) produced by the nutrient concentration.

Estimating the Total Amount of Manure or Litter Produced

Manure production for various species of confined animals can be found in the NRCS Animal Waste Handbook. For poultry produced in houses, the manure is usually mixed with bedding material such as sawdust, rice hulls, wood shavings, etc., to form

litter. To estimate the litter production, the following information is needed:

1. Amount of litter produced per quantity of birds
2. The average size of bird being produced
3. The number of flocks or cycles produced per year
4. Number of birds per flock.

The amount of litter produced is usually expressed per 1000 birds (Table 8-1).

Table 8-1. The weight of litter produced per 1,000 birds for different average target weights

Average Target Weight, lbs.	Average Litter Produced, Tons per Flock
2	0.45
4	1
6	1.5
8	2

To determine the total litter production using Table 8-1, use the following equation:

*Total litter production = tons of litter/flock * # flocks * number of birds/1000* [8-1].

Example 1: Determine the litter produced from 5 flocks of 50,000 birds grown to 4 pounds.

For a target weight of 4 pounds, 1000 birds will produce 1 ton of litter/cycle. Thus:

*1 ton litter/flock*5 flocks*[50,000 birds/cycle]/ 1000 = 250 tons of litter*

Example 2: Determine the litter produced from 6 flocks of 60,000 birds grown to 2 pounds.

For a target weight of 2 lbs., 1000 birds will produce 0.45 ton of litter /cycle. Thus:

0.45 ton litter/flock*6 flocks*[60,000 birds/cycle]/ 1000 = 162 tons of litter

Determining The Nutrient Concentration of Manure or Litter

All animal manures contain nutrients that can be recycled by applying to land to meet plant nutritional needs. The concentration of N-P_2O_5-K_2O can be determined by manure testing, however, careful attention should be paid to manure sampling recommendations to ensure the accuracy of the results (See Chapter 5). When manure testing is not an option, then the NRCS design numbers can be used (Table 8-2). Nutrients in poultry litter are usually expressed as pounds of nutrients per ton of litter. Usually the macronutrients are expressed in terms of N-P_2O_5-K_2O to match soil test recommendations and fertilizer grades.

To determine the total N-P_2O_5-K_2O nutrients available in manure, simply multiply litter amount by the nutrient concentration. During storage, handling and spreading of manure, appreciable amounts of Nitrogen can be lost due to volatilization. To account for this loss, the NRCS uses a design loss number of 40 percent. However, volatilization loss rates are highly variable as they are dependent on variable climatic, geographical, and soil conditions.

Determining Whole Farm Nutrient Needs

The total amount of nutrients needed to optimize crop production for the entire farm is dependent on many factors including total land area, type of crop, nature of harvest, yield goals, soil nutrient levels, etc. Since individual pastures can vary in these factors, total whole farm nutrient needs are determined by summing the needs of individual fields. Since manure or litter is the primary source of nutrients for pastureland on many confined livestock operations in Arkansas and litter application rates may be restricted by the P-Index, the best approach is to determine the liter application rates allowed by the P-Index. From these rates, the amount of N-P_2O_5-K_2O added as manure can be determined. Total crop needs for each field can be determined by utilizing soil test recommendations. From this information, it can be determined if there are any nutrient deficits and whether commercial fertilizer is needed. This process is known as nutrient budgeting.

Table 8-2. Nutrient content of various poultry litters in lbs of nutrient per ton of litter. Nitrogen can be loss as litter is handled after cleanout as reflected in the table.

In-House	N (In-House)	N after Losses from Handling	P_2O_5	K_2O
Broiler Litter	56	34	54	40
Turkey Litter	55	33	69	43
Pullet Litter	41	26	53	40
Breeder Hen Litter	42	26	62	42

Example 1: Determine the amount of N-P_2O_5-K_2O contained in 250 tons of litter. For nitrogen calculate both the in-house amount and the amount after N losses.

From Table 8-2, the N-P_2O_5-K_2O concentration in litter as found in the house is 56-54-40 lbs/ton. Total nutrients would be:

*Total N = 56 lbs/ton *250 tons =* ***14,000 lbs of N in house***

Total N after losses would be:

*Total N = 34 lbs./ton*250 tons =* ***8,500 lbs of N after losses***

*Total P_2O_5 = 54 lbs./ton*250 tons =* ***13,500 lbs of P_2O_5***

*Total K_2O = 40 lbs./ton*250 tons =* ***10,000 lbs of K_2O***

Example 2: Determine the lbs of N-P_2O_5-K_2O after N losses in broiler litter from 5 flocks of 60,000 birds grown to 4 lbs.

Step 1 – Determine litter production:

For a target weight of 4 lbs., 1000 birds will produce 1 ton of litter /cycle. Thus:

*1 ton litter/flock*5 flocks*[60,000 birds/cycle]/1000 =* ***300 tons of litter***

Step 2 – Use nutrient concentrations to determine N-P_2O_5-K_2O in lbs.

Total N after losses would be:

*Total N = 34 lbs./ton*300 tons =* ***10,200 lbs of N after losses***

*Total P_2O_5 = 54 lbs./ton*300 tons =* ***16,200 lbs of P_2O_5***

*Total K_2O = 40 lbs./ton*300 tons =* ***12,000 lbs of K_2O***

Determining Appropriate Nutrient Application Rates for Individual Pastures

Central to the concept of nutrient management planning is determining nutrient application rates that meet crop needs without harm to the environment. Determining the appropriate fertilizer to meet both criteria can be challenging especially when using animal manure as a fertilizer source.

Animal manures contain appreciable amounts of nitrogen (N), phosphorus (P), and potassium (K), all essential nutrients of plant growth. Plants require these nutrients in differing amounts. Unlike commercial fertilizers where the N-P_2O_5-K_2O ratio can be easily tailored to meet the crop needs, the N-P_2O_5-K_2O ratio in manures is not easily manipulated and can lead to over application of some nutrients and under application of others depending on the application rate. Secondly, the plant nutrients in commercial fertilizer are readily soluble and available to plants whereas a large proportion of nutrients in manure must undergo transformations dependent on weather, soil and other environmental factors before they are readily soluble and plant available. The lower solubility of nutrients in manure also means the nutrients are less likely to become soluble in runoff water than nutrients from commercial fertilizers.

These fundamental differences between commercial fertilizer and animal manures exemplify the difficulty in properly managing nutrients derived from animal manure in crop and forage production. This fact has contributed to increased environmental concerns over utilizing animal manures as fertilizer sources. Nutrient management planning is the most accepted practice to ensure that animal manures are properly applied to cropland to receive as much benefit as possible from the manure.

Phosphorus-Based Application Rates

Historically, application rates in nutrient management plans have been based on nitrogen since forage crops need much more nitrogen than P (Table 8-3). In nitrogen-based plans, the long-term use of animal manure as fertilizer on forages that are continually grazed has led to the build up of soil P since poultry litter contains nearly as much P as Nitrogen (Table 8-2). Due to the sensitivity of water quality to P inputs and the excessive P applications in nitrogen-based plans, nutrient management plans

EXAMPLE: Compare N vs P_2O_5 Based Litter Applications *for a broiler farm consisting of four houses that places a nominal 20,000 four-pound birds per house and averages five flocks per year. The litter produced will be applied to produce 4 tons of fescue per acre with the following assumptions:*

- *Litter is produced at a rate of 1 ton per 1,000 birds per flock.*
- *The litter contains 60 lbs N/ton and 55 lbs P_2O_5/ton.*
- *The fescue produced will contain 36 lbs N/ton and 14 lbs P_2O_5/ton.*
- *25% of the N is lost during litter application to volatilization.*
- *No other mineralization, denitrification or leaching losses for N or P_2O_5 are considered.*

Litter Nutrient Information

- *400 tons litter/year*
- *18,000 lbs N available/year*
- *22,000 lbs P_2O_5 available/year*

Fescue Nutrient Information

- *4 tons fescue/A*
- *144 lbs N required/A*
- *56 lbs P_2O_5 required/A*

Application Comparisons N Based vs. P_2O_5 Based

- *125 A required • 393 A required*
- *3.2 tons litter/A • 1 ton litter/A*
- *144 lbs N applied/A • 46 lbs N applied/A*
- *176 lbs P2O5 applied/A • 56 lbs P_2O_5 applied/A*
- *N needs met • 98 lbs N deficit/A*
- *120 lbs P2O5 surplus/A • P_2O_5 needs met*

Comment

A P_2O_5 surplus of 120 lbs/A does not imply that the STP will increase by 120 lbs/A. Due to soil chemical reactions,significant amounts of the surplus P will become bound in the soil and unavailable for plant use. Because soil test procedures were developed to indicate plant-available Pthey will not measure bound P. For this reason, a 120 lbs/A surplus P_2O_5 will increase the STP level by significantly less than 120 lbs/A.

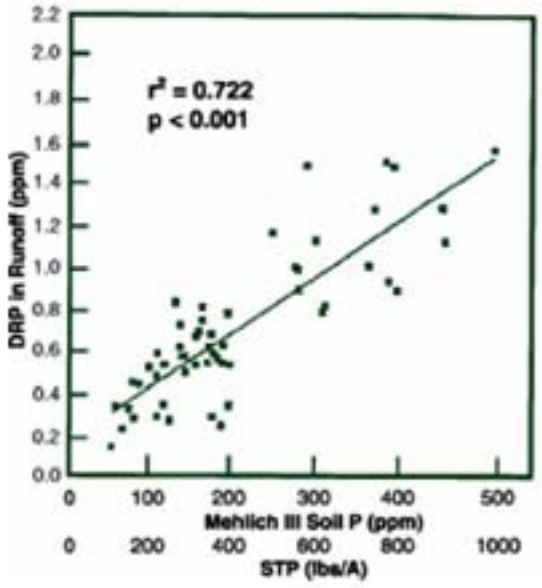
Table 8-3. Amount of fertilizer nutrients removed per ton of forage dry matter			
	N	P_2O_5	K_2O
	----------lbs removed per ton*----------		
Alfalfa	**58	14	56
Bahiagrass	31	8	34
Bermudagrass	39	12	44
Bluestems	29	13	56
Clover	**43	12	44
Dallisgrass	34	14	44
Fescue	36	14	50
Legume/grass mix	**39	12	43
Oats	44	4	37
Orchardgrass	44	15	56
Ryegrass	39	16	54
Sorghum/sudangrass	37	14	47
Wheat	36	13	40
*Average of Arkansas forage tests from 1984-96. **N comes from N fixation not from fertilizer.			

are now being written based on P as the first consideration. Under Title XXII (Section 2202.4) of the Arkansas Soil Nutrient Application and Poultry Litter Utilization Act, the State of Arkansas now requires nutrient management plans to be P-based plans developed using the Arkansas P-Index for pastures. At the federal level, both EPA and NRCS have adopted P-Based planning as their standard for nutrient management plans. The new CAFO guidelines put forth by EPA and the guidelines for a CNMP put forth by NRCS recommend three options for determining P-based application rates:

1. Application based on forage phosphorus needs determined from soil testing.
2. Application ceases at a soil P environmental threshold.
3. Application rates determined by the P-Index.

Option 1 would restrict the application of P to pastures where soil test recommendations would not warrant P fertilizer needs. The establishment and maintenance of most cool and warm season grasses grown as forage in Arkansas do not require additional P when soil test P is greater than 100 lbs/acre as determined by the University of Arkansas Soil Test Lab (Figure 8-3). This option would greatly restrict the use of manure for most forages grown in Arkansas especially where poultry litter has been used previously.

Figure 8-2. The relationship between dissolved reactive phosphorus (DRP) in runoff from pastures and soil test phosphorus. (Adapted from Pote et al., 1996)



Option 2 is based on research that indicates that the concentration of P in runoff increases with increase in soil P and at some threshold value of soil P, the concentration in runoff becomes environmentally questionable (Figure 8-2). In Arkansas, 300 to 400 lbs per acre has been the most discussed threshold. For example, if the soil P in your pasture is > 300 lbs per acre, then additional P applications would be halted. If your soil P is below this threshold, then P is applied at some pre-determined rates related to soil test. This option is not as restrictive as Option 1, but many pastures in Arkansas already exceed this threshold.

Options 1 and 2 have the potential to cause social and economic harm for producers who have legally, and without malice, applied animal manures to pastures for years. One scientific argument against options 1 and 2 is that soil test is not the only factor that influences P movement in runoff. Other factors such as runoff potential, slope, ground cover, application timing, rainfall, etc., can influence the movement of P from pastures. Option 3, the P-Index, allows the flexibility for these other factors to be accounted for in P-based plans and application rates.

The Process of Determining Nutrient Budgets When Using Manure as a Fertilizer

Phosphorus-based plans do not necessarily mean that application rates will be based on phosphorus instead of nitrogen. If it is determined during the planning process that the P-Index indicates that minimal environmental impact from P exists, then the application rates may well be based on nitrogen. However, if P-based application rates are recommended and animal manure is the primary source of nutrients, then the two major ramifications are 1) more acreage will be needed to spread the same amount of manure and 2) nitrogen and potassium needs from the manure itself will be insufficient to meet high production goals. Thus, for optimum forage production, a nutrient budget will need to be developed to determine the amount of commercial fertilizer needed to account for any nutrient deficiencies. To construct a nutrient budget for a given field, the following information will be needed:

- Soil Test Results and Recommendations
- Manure Application Rates as determined by the P-Index
- Nutrient Content of Manure

If commercial fertilizer is being used exclusively, such as no animal manure is being utilized, then the application rates are simply determined by the soil test recommendations. If manure is being utilized, then the nutrient budget should be constructed for each field using the following steps:

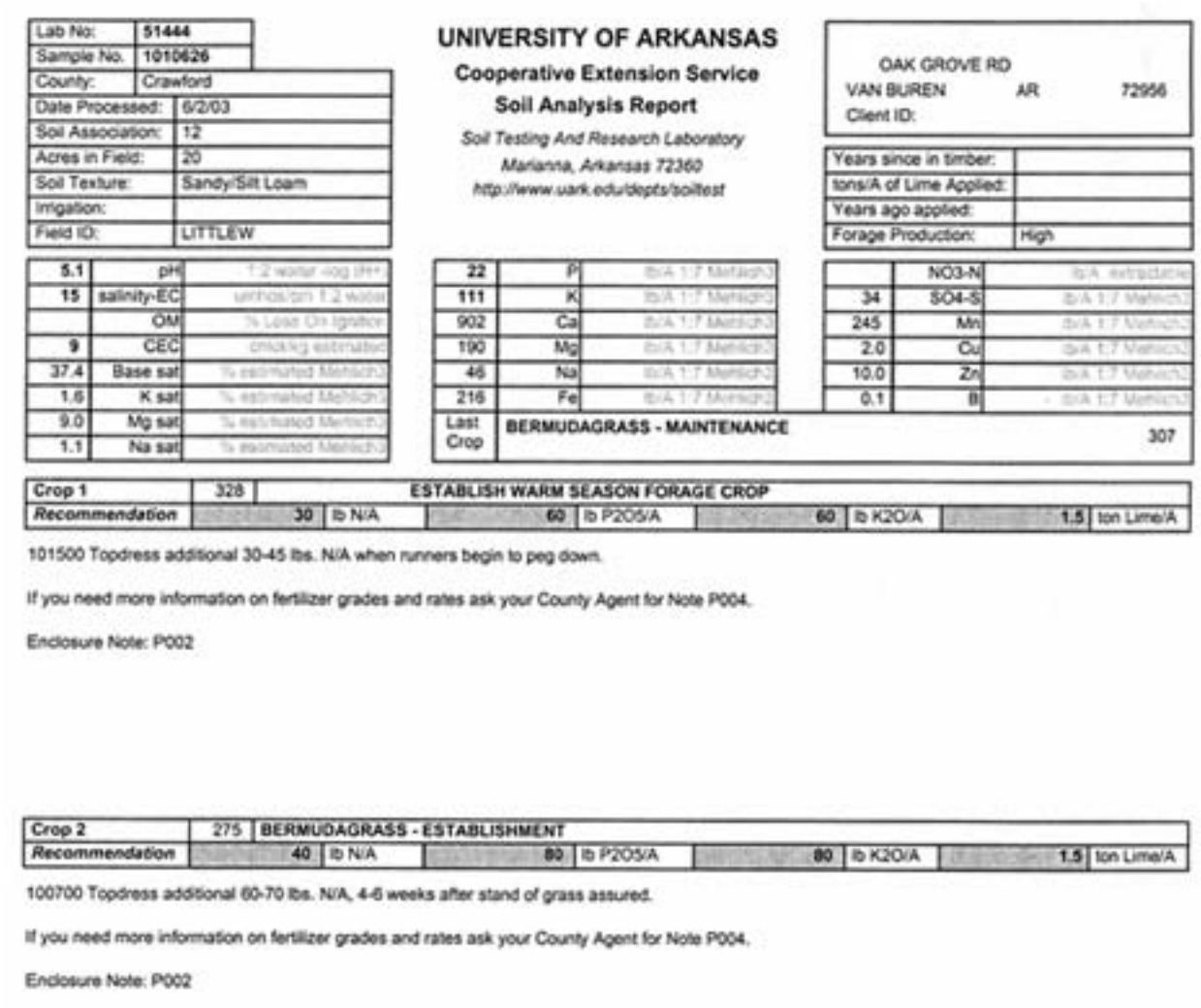
1. Determine total crop nutrient needs using soil test recommendations.
2. Determine manure application rates using the P-Index recommendations.
3. Determine total N-P_2O_5-K_2O added with manure applications.
4. Determine any nutrient deficits and commercial fertilizer needs.

Once the nutrient budget is determined for each field, a total farm nutrient balance and the total amount of manure-derived nutrients should be estimated to determine if there is excess manure being produced on the farm and to determine manure storage needs (See the following Chapter).

Determining Total Crop Nutrient Needs Using Soil Test Recommendations Data

Once a soil sample has been submitted through the local County Extension Office (see Chapter 5 for sampling and submission instructions), soil test results and recommendations are mailed from the County Office to the end user usually no later than two weeks from the time the lab receives the sample. The results and recommendations are reported on Extension Form (Figure 8-3). Results are reported at the top of the form while the recommended application rates of N-P_2O_5-K_2O in pounds/A. It should be noted that these recommendations are made independent of the source of nutrients. They represent the total amount of nutrients needed, and not the fertilizer rate nor the manure application rates. (See Chapter 3 to determine fertilizer spreading rates based on fertilizer grade and soil test recommendations.)

Figure 8-3. Examples of soil test results and fertilizer recommendations as reported by the University of Arkansas Soil Test Lab in Marianna.



Lab No:	51444
Sample No.	1010626
County:	Crawford
Date Processed:	6/2/03
Soil Association:	12
Acres in Field:	20
Soil Texture:	Sandy/Silt Loam
Irrigation:	
Field ID:	LITTLEW

UNIVERSITY OF ARKANSAS
Cooperative Extension Service
Soil Analysis Report
Soil Testing And Research Laboratory
Marianna, Arkansas 72360
http://www.uark.edu/depts/soiltest

OAK GROVE RD
VAN BUREN AR 72956
Client ID:

Years since in timber:	
tons/A of Lime Applied:	
Years ago applied:	
Forage Production:	High

5.1	pH	1:2 water
15	salinity-EC	mmhos/cm 1:2 water
	OM	% Loss On Ignition
9	CEC	meq/kg estimated
37.4	Base sat	% estimated Mehlich3
1.6	K sat	% estimated Mehlich3
9.0	Mg sat	% estimated Mehlich3
1.1	Na sat	% estimated Mehlich3

22	P	lb/A 1:7 Mehlich3
111	K	lb/A 1:7 Mehlich3
902	Ca	lb/A 1:7 Mehlich3
190	Mg	lb/A 1:7 Mehlich3
46	Na	lb/A 1:7 Mehlich3
216	Fe	lb/A 1:7 Mehlich3

	NO3-N	lb/A extractable
34	SO4-S	lb/A 1:7 Mehlich3
245	Mn	lb/A 1:7 Mehlich3
2.0	Cu	lb/A 1:7 Mehlich3
10.0	Zn	lb/A 1:7 Mehlich3
0.1	B	lb/A 1:7 Mehlich3

Last Crop	BERMUDAGRASS - MAINTENANCE	307

Crop 1	328	ESTABLISH WARM SEASON FORAGE CROP							
Recommendation	30	lb N/A	60	lb P2O5/A	60	lb K2O/A	1.5	ton Lime/A	

101500 Topdress additional 30-45 lbs. N/A when runners begin to peg down.

If you need more information on fertilizer grades and rates ask your County Agent for Note P004.

Enclosure Note: P002

Crop 2	275	BERMUDAGRASS - ESTABLISHMENT							
Recommendation	40	lb N/A	80	lb P2O5/A	80	lb K2O/A	1.5	ton Lime/A	

100700 Topdress additional 60-70 lbs. N/A, 4-6 weeks after stand of grass assured.

If you need more information on fertilizer grades and rates ask your County Agent for Note P004.

Enclosure Note: P002

Determining Manure Application Rates Using the P-Index Recommendations

When developing P-based plans, the Arkansas P-Index for pastures is used to determine the appropriate manure application rate. To initiate the P-Index calculation, a desired manure application rate as it relates to the soluble P content of the manure must be input with other parameters to determine the P-Index value for the given manure application rate. As a general rule, it is usually assumed that there is 1 pound soluble P per ton of poultry litter such that a two-ton per acre litter application results in the addition 2 pounds of soluble P per acre. Thus 2 pounds would be the input value into the source term of the P-Index calculation. It should be strongly noted that this assumption may be violated in the real world. Preliminary studies indicate that the soluble P content in litter can vary significantly among litter samples. To avoid the violation of this assumption, litter should be tested for its soluble P content as it may be affected by several factors including management.

If the P-Index value is calculated and the resulting P-Index value is unacceptable, then the soluble P input must be lowered by lowering the target manure application rate on a trial and error basis until an

EXAMPLE: Determine the total N-P_2O_5-K_2O applied in pounds/A to a pasture receiving 2 tons of broiler litter using the NRCS design numbers in Table 8-2.

N – *There are 56 pounds of N per ton of broiler litter as collected in house, thus:*

*2 tons/A of litter * 56 lbs of N/ton = 112 lbs N/A could potentially be applied;*

however, volatilization losses need to be accounted for. Using the NRCS loss assumption of 40 percent, the actual N applied is:

*N lost due to volatilization = 112 lbs N/A * 0.4, or 45 lbs N/A*

Total N applied = 112 lbs N/A – 45 lbs N/A = ***67 lbs N/A***

P_2O_5 *– There are 54 lbs of P_2O_5 in a ton of broiler litter, thus*

*2 tons/A of litter * 54 lbs of P_2O_5/ton =* ***108 lbs P_2O_5/A***

K_2O *– There are 40 lbs of K_2O in a ton of broiler litter, thus*

*2 tons/A of litter * 40 lbs of K_2O/ton =* ***80 lbs K_2O/A***

acceptable P-Index value is obtained. Once the desired P-Index value is achieved, then the appropriate application rate is the rate associated with the soluble P content used to achieve the acceptable P-Index value.

Determining Total N-P_2O_5-K_2O Added With Manure Applications

The total amount of nutrients (N-P_2O_5-K_2O) added as manure is calculated by multiplying the manure application rate by the nutrient content of the manure. The manure application rate is determined from the P-Index (See the Section above) while the content of N-P_2O_5-K_2O can be determined by manure testing; however, careful attention should be paid to manure sampling recommendations to ensure the accuracy of the results (see Chapter 5). When manure testing is not an option, then most planners utilize the NRCS design nutrient content values (Table 8-2). It should be noted that actual nutrient content values may vary significantly from these design numbers. For instance, the University of Arkansas Diagnostic Lab has summarized all manure samples submitted for testing to look at the variability of results.

During storage, handling and spreading of manure, appreciable amounts of Nitrogen can be lost due to volatilization. To account for this loss, the NRCS uses a design loss number of 40 percent. However, volatilization loss rates are highly variable as they are dependent on variable climatic, geographical, and soil conditions.

Determining Nutrient Deficits and Commercial Fertilizer Needs.

Once the total nutrients applied with manure is known, then these values can simply be subtracted from the soil test recommendations to determine if there are nutrient deficits or not. If there are nutrient deficits, then they can be made up using commercial fertilizer.