APPLICATION OF THE CORNELL NUTRIENT MANAGEMENT PLANNING SYSTEM: PREDICTING CROP REQUIREMENTS AND OPTIMUM MANURE MANAGEMENT

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E-Z Acres Farm is a dairy operation owned and managed by the McMahon family in Scott, NY. This farm has recently consolidated its milking herd to a modern freestall barn and has constructed new dry cow and heifer facilities. With this modernization of the milking and animal housing facilities, the farm is in a competitive position for sustaining a profitable dairy farm into the next century. However; in addition to the management skills and facilities needed for maintaining a profitable dairy, managers must also address environmental issues. Most of these environmental issues relate to animal waste management. This paper will examine some of the environmental, economic and management issues dairy farmers must address to utilize nutrients in manure and fertilizer efficiently to increase profitability, while reducing losses to the environment. EZ-Acres farm will be used as a case study to demonstrate the Cornell Nutrient Planning System (1).

E-Z ACRES FARM OVERVIEW

Animal Density

The land required for manure applications is a function of the nutrient requirement of the cropping program, the nutrient content of the manure, the number of animals and their manure production (2). Animal density guidelines are used in the nutrient management planning process to predict appropriate animal to land ratios. These ratios compare the number of 1000-pound animal units with the acreage in the farm's cropping program. Animal density guidelines have been developed for New York and Pennsylvania by Klausner (3) and Beegle (4). These guidelines are intended to prevent over applications of manure, while increasing the quantity of on-farm forage produced. Proper use of the guidelines requires good management skills on the part of the farmer.

EZ-Acres farm has 550 adult dairy animals with an average weight of 1450 pounds and 430 youngstock with an average weight of 680 pounds. There are a total of 1075 crop acres with 43% in corn silage production and 57% in hay crop silage production. The hay acreage is approximately 50% alfalfa and 50% perennial forage grasses. The animal units per tillable acres is 1.01.

Soils, Topography and Hydrologic Risks

EZ-Acres farm is composed of a mix of level well-drained soils and moderately well drained sloping soils. The well-drained soils are used for corn silage and alfalfa rotations. These fields lie over the Homer-Preble Aquifer, the sole source of drinking water for the city of Cortland. Many of these fields also border Factory Brook, a trout stream, which travels through the farm. The sloping fields are composed of heavier textured soils that have a low water leaching potential but a high run off potential. Run-off from these fields can enter tributaries to Factory Brook.

Nutrient Deficiencies and Excesses

Corn silage and grass forages have a high nitrogen (N) requirement. Manure N is not adequate to meet all of the nitrogen demand of this cropping program, so additional N fertilizer is purchased. Phosphorus (P) and potassium (K) in manure collected annually exceed the annual crop requirement for P and K. Table 1 lists the total annual N, P and K collected in manure compared with the crop requirement.

Table 1. Estimated manure N, P and K collected annually and total crop nutrient requirements

Nutrient	Total Collected	Total Crop Requirement	Surplus or (Deficit)
		(lbs)	
Total N	199,900	80,400	119,500
Available N			
N^a	148,800	80,400	68,400
N^b	55,400	80,400	(25,000)
Total P	77,400	18,700	56,700
Total K	125,900	15,900	110,000

N^a = Available N with NH_3 conservation. N^b = Available N without NH_3 conservation.

The amount of available N with or without ammonia conservation is presented in Table 1. Manure is composed of approximately 50% ammonium N and 50% organic N. Ammonia N is easily lost by volatilization if it is not immediately incorporated into the soil within 24 hours. About 55% of the organic N is mineralized to a plant available form when the organic N during the year of application is added to the organic N mineralized from previous year's applications. This example shows that without ammonia conservation, there is not enough manure N to meet the crop requirements. A surplus of P and K is produced in manure compared to the annual crop nutrient requirement.

Manure applied to meet the crop's N requirement often results in excessive applications of P and K applications and excessive soil test levels of these nutrients. Fertilizer P and K application rates should be determined by soil testing with recommendations based on regional crop response research.

Manure and Fertilizer Management Practices

EZ-Acres fertilizer program consists of a corn starter fertilizer with 20 pounds per acre of N and P and no K. Soil testing, using the Cornell Nutrient Analysis Laboratory showed high levels of both P and K. Because the soils in NY are often cold and wet in the early spring, nutrients are not readily crop available. Therefore, a starter fertilizer containing a small amount of N, P and K is recommended unless the soil test levels are very high.

Manure applications are based on the predicted N crop requirement. The Cornell Nutrient Management Planning System uses a decay series to estimate the availability of N from organic sources (manure, soil organic matter, and crop residues

such as sod crops in the rotation). The decay series is a function of climate and therefore it should be determined in the region where it is used. The N requirement of a crop is calculated by subtracting these organic N sources from the total crop N requirement. For EZ-Acres, the majority of corn acreage requires only a small amount of N in starter fertilizer.

To verify the need for additional N for corn (beyond a starter fertilizer) the Pre-Sidedress Nitrogen Test (PSNT) is used (5). The PSNT is taken when the corn is 6-12 inches tall, to determine if sufficient N is present for maximum economic yields from organic N sources such as manure and crop residues. Utilization of the PSNT on EZ-Acres corn fields has resulted in a 75 to 96% reduction in purchased sidedress-N fertilizer over the past 4 years, without a reduction in yield.

EZ-Acres farm spreads manure year round. There is 10 days of storage in the milking barn and bedded manure is spread as needed from dry cow and youngstock housing facilities. Manure is applied to corn fields with low run-off potential during the winter. Manure is spread on grass hay and then legume hay fields during the growing season. In the spring of 1997, approximately 100,000 gallons were spread on neighboring crop farms. This was required because all corn fields had manure applied and were planted and grass hay fields were within a week of harvest.

EZ-Acres is making a transition to intensive grass management for lactating cows. Research of J. Cherney [1] at Cornell has shown that intensively managed grass can be high quality dairy forage. This required frequent cuttings, 3 to 4 times a year, and up to 230 pounds per acre of N. Manure can not meet the high N demand of intensively managed grasses. Approximately half of the N demand should be supplied by N fertilizer to provide a readily plant available N source. Research by S. Klausner[2] has found significant yield responses to added N and minimal yield responses to P and K at medium soil test levels. This research also found that the K content in grasses increased with increased application rates of K fertilizer. The K content in grasses increased from 1.8 to 3.6% (dry a dry matter basis) with fertilizer application rates from 0 up to 360 pounds per acre, with no increase in yield.

Manure Applications Based N, P and K

Manure application rates based on N have similar effects on the K content in grasses. A manure application rate of 12,000 gallons to the acre over a growing season would supply 100, 195 and 325 pounds per acre of N, P and K respectively. The grasses would use most or all of the N, while the P and K applied would exceed their crop requirement. The excess P and K accumulate in the soil. High K soils lead to high K forages that are animal health problems for dry cows.

The production of intensively managed grass significantly increased the N requirement of EZ Acres' cropping program. This allows a higher animal density and higher manure rates to be applied per acre. However, P and K will continue to

[1] Personal communication. J. Cherney, Department of Soils, Crop and Atmospheric Sciences, Cornell University, Ithaca, NY

[2] Personal Communication, S. Klausner, Department of Soils, Crop and Atmospheric Sciences, Cornell University, Ithaca, NY

accumulate. Table 2 shows the required gallons of manure, over the whole farm basis, for applications based on N, P or K requirements of the crop rotation.

Table 2 shows that E-Z Acres' farm, like most dairy farms would be severely limited in the amount of manure that could be applied if spreading rates were restricted to meet P or K crop requirements. Research by Klausner (6) found similar scenarios with manure nutrients and crop nutrient requirements on New York dairy farms ranging from 45 to 500 cows.

Table 2. Manure volume collected and manure required for the total crop nutrient needs for N, P or K.

Total Manure collected	Manure volume required N	P	K
(gallons)			
4,631,026	6,008,500	408,500	412,000

Table 3 shows the average manure rates per acre that would be applied when EZ-Acres' applications are prioritized for N, P or K crop requirements. This example further illustrates the restriction in manure application rates when based on P or K. An average 5,589-gallon per acre rate of manure based on crop N requirements is reasonable.

Table 3. Average manure rates per acre with applications based on N, P and K.

Nutrient	Average manure rate per acre (gallons)
N	5600
P	380
K	380

Minimizing Environmental Risks

In addition to calculating application rates of manure based on crop nutrient requirements, the timing of applications are determined to minimize the risk of surface run-off. Risk assessments have been developed for New York by Klausner (3) and are used in the Cornell Nutrient Management Planning System. These risk assessments take into consideration leaching and runoff potential, slope gradient and length, areas of concentrated water flow, winter access and closeness to neighbors in estimating risk levels to each field. Once each field is assigned a risk level, timings for manure applications are suggested. The risk levels 1 and 2 allow winter spreading (Tables 4a and 4b). Risk level 3 restricts spreading to the growing season to minimize runoff from manure applications. Spring runoff from melting snow and precipitation can transport manure nutrients and pathogens from fields that have a high runoff potential. Risk level 4 recommends no spreading in fields that have potential neighbor problems.

These risk assessments can be used to predict the need for manure storage systems. If a farm has insufficient fields for winter spreading (risk level 1 and 2); considerations should be given to installing a manure storage system.

EZ-Acres has enough flat well drained fields to allow winter spreading. Most of the level fields can be classified as being in risk levels 1 or 2. Research is currently being conducted at Cornell to more accurately predict risks associated manure spreading with different field characteristics. Moderately well drained sloping fields are targeted for summer spreading on grass. Since this farm currently purchases dry cow hay, K accumulation in grass forage is not a major concern.

Table 4a. Estimated risk level to minimize impact on surface water quality.

Field Characteristic	Risk Level 1	Risk Level 2	Risk Level 3	Risk Level 4
A. Slope gradient: Annual crops perennial crops	0-5% 0-8%	6-10% 9-15%	10+% 15+%	not applicable not applicable
B. Slope length	0-300 ft.	300-500 ft.	500+ ft.	not applicable
B. Flooding Frequency	None or rare	Occasional	Frequent	not applicable
D. Drainage class	Well drained to Excessively drained	Moderately Well drained	Somewhat poorly to very poorly drained	not applicable
E. Areas of Concentrate water flow	No	No	Yes	not applicable
F. Winter access	Unlimited	Sometimes limited	Usually limited	not applicable
G. Closeness to Neighbors, etc.	No problem	no problem	no problem	a problem

Source: R. Halbohm, Natural Resources Conservation Service, Walton, N.Y.

Table 4b. Risk levels used to estimate timing of manure applications.

Risk level 1 :
Year-round spreading.
Risk Level 2:
Primary-April through December
Secondary-January through December (if not enough Risk Level 1 fields available).
Risk Level 3:
May through October. No winter spreading
Risk Level 4:
Restricted. No spreading.

The long- term implications of P and K accumulations in soils are not well known. There have not been water quality risks identified from K entering water bodies. N can be both a ground and surface water pollutant. Nitrate-N is subject to leaching and ammonium and organic-N is subject to run-off. The primary impact of P on water quality is eutrophication. This problem limits water use for fisheries, recreation, industry or drinking, due to increased growth of undesirable algae and aquatic weeds. Oxygen shortages are caused by their senescence and decomposition and some algae and aquatic weeds can be harmful to livestock and humans (7).

Manure P applied to soils is rapidly immobilized into slowly available or unavailable forms. Runoff is the primary transport mechanism of P to surface waters. Once P enters water it can become biologically available. Therefore erosion control is the primary means to avoid P transport. However, sandy or gravely soils with a shallow depth to the water table and high P levels have been found to leach P. P has also been found to move through soils by preferential flow through macropores and earthworm holes.

Researchers are developing soil P testing procedures that estimate environmental risks rather than agronomic P requirements (7,8,9,10). In addition P indexes have been proposed that nutrient management planners can use to analyze site characteristics to obtain an assessment for P vulnerability to loss (11).

For EZ-Acres Farm, alternating manure applications with N fertilizer can reduce P and K accumulations in soils where grass hay is produced. Manure applications rates to corn fields with high N requirement accumulate soil P and K, rotating to alfalfa can remove much of the K and some of the P.

Best management practices should be implemented in critical areas, such as fields adjacent to streams to reduce the risk of manure nutrients, sediments and pathogens entering the stream. Vegetative buffer strips along stream borders have been evaluated as means to minimize the transport of pollutants to streams. Research by Chaubey et al (12) found that a 21-meter vegetative filter strip reduced organic N, ammonium N, and total phosphorus in swine manure entering a stream by 87, 99, and 92%, respectively. This study, conducted in Arkansas, used simulated rainfall on a sloped field with manure applied to the upper 3 meters of vegetative filter strips composed of tall fescue. This research also found that the vegetative filter strips were not effective in reducing NO_3 or coliform bacteria. These pollutants can move through the subsurface in soil solution. Evaluations of on-farm vegetative filter strips by Dillaha et al (13) found that the filter strips were less effective in hilly fields and more effective in flatter fields in the filtration of pollutants, but were effective in all situations in controlling erosion.

Since the fields that border Factory Brook on EZ-Acres farm are relatively level, vegetative filter strips would most likely be effective in reducing manure inputs to the stream. Since applications to hill fields are made in the summer on growing grass, the probability of runoff is reduced. However, major precipitation events can cause runoff, especially in the winter, and reduce the effectiveness of vegetative buffer strips.

Another approach to limiting nutrient accumulations on dairy farms is to reduce the amount of nutrients entering the farm in feed. Evaluations by Klausner (6) found

that the majority of N, P and K entering dairy farms is from purchased feed. Therefore, production of high quality forages and proper ration balancing is vital to prevent unnecessary feed purchases. Animal nutrition management programs such as the Cornell Net Carbohydrate and Protein System (CNPS) are useful in reducing imported nutrients in feed (14). Fox (15) and Klausner (16) found that 30 to 40% of the N, P and K excreted in manure could be reduced by adjusting the feed ration in two Central New York dairy farms.

CONCLUSION

The utilization of the Cornell Nutrient Planning System has been effective in helping EZ-Acres utilize manure nutrients for crop production. The management steps that EZ-Acres and other New York dairy farms can be summarized by the following strategy developed by Klausner (3):

Determine Animal Density: As EZ-Acres and other dairy farms add animals it is important to maintain an appropriate animal to land ratio. This can prevent excessive manure application rates and maximize on-farm forage production.

Determine quantity of manure collected: Estimates of the quantity produced or collected will estimate the quantity that needs to be managed.

Analyze manure to determine nutrient content: Manure nutrient analyses will estimate the amount of N, P and K and dry matter content. The amount of nutrients collected in manure can then be compared with crop nutrient requirements.

Soil test to determine crop nutrient requirements: A good soil testing program will estimate the plant available nutrients in the soil and determine the need for supplemental nutrients from manure or fertilizer.

Estimate the nutrient availability in manure: Manure nutrients can not be substituted on a pound to pound basis with those in fertilizer. Regional field research is needed to estimate manure nutrient availability to crops.

Hydrologic evaluation: Determine field by field hydrologic risks by evaluating flooding, leaching and runoff potentials. Determine the best time of year to apply manure to individual fields,

Manure application: Use manure as the primary nutrient source and supplement with fertilizer if required, based on soil testing. Apply at a time to maximize crop nutrient availability and minimize loss.

Fertilizer management: Use fertilizer after accounting for all other sources of crop nutrients. The rate, timing and placement should maximize crop response.

Storage requirement: Storage helps manure management on many farms, especially farms with limited fields that manure may be applied to in the winter. There are risks and advantages with both storage and daily spread manure management systems. However, the management skills applied to either system are the most important factor.

Crop management: Crop management practices such as selection of crops, hybrids and varieties, tillage, rotations, pest management, planting dates and harvest schedules influence dry matter yields and quality. These practices need to be individualized to farm soils and topography, herd dry matter requirements and farm production goals. If crop management practices are optimized there is more efficient utilization of crop nutrients and improved forage quality. This can reduce requirements for off farm feed nutrients that can add to the farm's nutrient surplus.

Soil and water conservation: Producers should work with their local Soil and Water Conservation Districts and Natural Resource Conservation Service to plan and implement conservation practices that prevent runoff and protect soil and water resources.

Management: The key to implementing a nutrient management plan successfully is management. Farm managers have a challenge to integrate nutrient management into their whole farm plan. Labor management, equipment maintenance, manure application system selection, and proper land application practices are all important elements of a nutrient management plan. When this is added to animal nutrient management and herd management, the management challenge becomes increasingly complex.

EZ-Acres has made excellent progress in implementing their nutrient management plan. For dairy farms to sustain themselves, profitability needs be linked to environmental stewardship. Community and neighborhood relationships can not be ignored. Implementing nutrient management plans often involve storing manure and applying it to fields that may have note received manure in the past. This often brings new odors to neighborhoods and associated complaints, Dairy farmers and other livestock producers need to be increasingly proactive in maintaining good community relations. These relationships need to be considered in the planning and implementation of nutrient management. Nutrient management planning is one strategy dairy and livestock producers can use to help position themselves for the future.

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