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Richard K. Koelsch
University of Nebraska - Lincoln, rkoelsch1@unl.edu

Ray Massey
University of Missouri

Galen E. Erickson
University of Nebraska - Lincoln, gerickson4@unl.edu

Virgil R. Bremer
University of Nebraska - Lincoln, vbremer2@unl.edu

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Rick Koelsch, University of Nebraska, Lincoln
Ray Massey, University of Missouri
Galen Erickson, University of Nebraska, Lincoln
Virgil Bremer, University of Nebraska, Lincoln

Abstract. The introduction of ASABE Standard D384.2, Manure Production and Characteristics, has created the opportunity to integrate feed management decisions and animal performance measures into nutrient planning processes. This paper introduces a software tool that integrates estimates of nutrient excretion based on the new standard with estimates of land need, labor and equipment time allocation, and economic cost and benefit for manure application. This tool will be used to evaluate the economic implications for two scenarios using beef cattle examples as a means of illustrating tool application. The first scenario will look at the impact of feeding ethanol co-products on the economics of manure application. Labor and equipment time requirements, land access needs and economic cost all increase significantly with greater inclusion rates of co-product in the diet. However, the value of the additional nutrients is potentially greater than economic cost. The second scenario explores the impact of alternative methods for determining application rate (nitrogen vs. phosphorus based application rate). For the situation evaluated, the increase in land needs was substantial but the increased time and economic costs were modest when transitioning from an N-based to a four year P-based rate. However, applying manure to supply a single year P-based rate substantially increased the equipment and labor requirements as well as the overall manure application costs.

Keywords: manure, nutrients, economic costs and benefits, value of manure, land application.

Introduction

Implementation of comprehensive nutrient management plans (CNMP) can incur significant time and expense on the part of the animal feeding operation (AFO). Feed management, one of the six components of a CNMP, is typically ignored or by-passed in current planning processes. As such, one important opportunity for improving the environmental performance or impacting costs on many AFOs is commonly neglected. In addition, many CNMP include large errors in the estimate of manure nutrients and the land area necessary for managing those nutrients.

The purpose of this paper is to introduce a software tool designed to integrate the animal feeding program into nutrient planning and economic decisions. The new ASABE manure production and characteristics standard improves our ability to provide accurate and farm-specific estimates of nutrient excretion and integrate that information into a more comprehensive evaluation of the costs and benefits associated with manure application. Integration of this new tool for estimating excretion with existing procedures for estimating land requirements and evaluating economic factors provides a unique opportunity for integrating feed management decisions into the CNMP process.

Literature Review

When nutrients are supplied to animals in excess of that needed for maintenance and production, the excesses are excreted. Kerr (1995) concluded that nitrogen (N) excretion in swine can be reduced by approximately 8.4% for each one-percentage unit reduction in dietary crude protein (CP). Powers et al. (2005) demonstrated that dietary reductions in CP achieved a 23% reduction in N excretion over the grow-finish phases. Similar studies were reported by Ferguson et al. (1998) for broiler chickens and Tomlinson et al. (1996) for lactating dairy cows.

Similar to N excretions, phosphorus (P) excretion can be impacted by more closely matching dietary P and animal needs. Fecal P excretion in lactating dairy cows was reduced 23% by Wu et al. (2000) and 36% by Morse et al. (1992). In non-ruminants, an industry 'rule-of-thumb' is a reduction of 25% P excreted when phytase has been fed properly and combined with reduced margins of safety in P formulation (Harper et al., 1997).

Fecal volume is a function of the digestibility of the diet as undigested feed is excreted. Montgomery, et al. (2004) reported increased volatile solids in harvested manure for feedlot cattle fed diets lower in digestibility. Bierman et al. (1999) showed that manure mass removed from a beef feedlot almost tripled when cattle were fed less digestible diets (71.4% dry matter digestibility) when compared to a more digestible (83.5% dry matter digestibility) all corn diet. This research further demonstrated significant differences in excreted and harvested manure N and volatile solids when comparing typical feedlot diets based upon 7.5% roughage, all concentrates, and wet corn gluten feed. CNMPs will need to consider diet formulation effects on manure composition and mass.

ASAE (2004), SCS (1992), and MWPS (2000) have traditionally served as references for estimates of manure and manure component excretion. However, these estimates have become increasingly questionable as animal genetics, performance and feed programs change. The new ASABE standard (ASABE 2005) provides equations for estimating excretion specific to individual animal performance and feed intake levels (Koelsch et al., 2005).

Procedures for estimating economic costs and benefits associated with manure management have been developed by a number of authors. Sweeten et al. (1978) published time and motion studies key to estimating these economic costs associated with open lot beef cattle production. Harrigan (1997) developed a machinery system model for land application of dairy manure that varied with spreader tank volume and transport distance. Janzen et al. (1999) combined economic and ecological analyses as a method integrating ecological and economic goals. Additional authors have reported economic evaluations of manure handling systems including land application (Heilich, 1982; Holik and Lessley, 1982;Wright, 1997; Fulhage, 1994; Rausch and Sohngen, 1999; Massey et al., 2002). Lory et al. (2004) found operation size, manure handling systems, state regulations and ownership structure to affect the costs and benefits of swine manure management.

Objective

Costs of manure transport and distribution are highly dependent upon manure nutrient excretion and retention. The animal feeding program is a critical input to nutrient excretion and is assumed to be an important consideration in estimating the costs associated with land application of manure. The objective of this paper is to:

- Summarize progress for integrating the new ASABE standard for nutrient excretion with existing tools for estimated land requirements and economic costs and benefits associated with land application into a new software tool called SPREAD.
- Illustrate two applications of this model based upon variable model inputs for feeding program (degree of inclusion of distillers grains in beef cattle ration) and process used for determining manure applications rate (N vs. P-based application rate)

Procedures

The SPREAD software tool is designed to estimate: 1) land requirements for agronomic utilization of manure, 2) time requirements (labor and equipment) for land application, and 3) costs associated with land application and potential nutrient value (N and P only) of manure (Table 1). It is designed to vary these outputs based upon farm-specific estimates of excretion designed to account for feed ration and animal performance. The program is part of a suite of tools being assembled for a USDA Natural Resource Conservation Service funded project to establish procedures for technical service providers to integrate feed management decisions into a comprehensive nutrient management planning process. Other tools will determine "opportunities" for adjusting the feed program as part of a CNMP. This tool will determine economic impacts of those opportunities.

The software is laid out in four unique modules as illustrated in Figure 1. The module for estimating excretion is based upon ASABE Standard D384.2. The standard provides equation-based estimates for estimating excretion based upon animal performance and feed ration inputs. The beef, swine, and poultry work groups used an animal mass balance approach where excretion is estimated as a difference between intake and retention in body mass or animal products (eggs or meat). Dry matter excretion was based upon estimates of feed dry matter digestibility with adjustments based upon research literature for solids in urine. The dairy and horse work groups used existing data sets to perform multi-variable regression analysis (Nennich et al., 2003; Lawrence et al., 2003). The dairy work group proposed equations for lactating cows, dry cows and heifers. The horse work group chose to publish separate equations for exercised and sedentary horses.

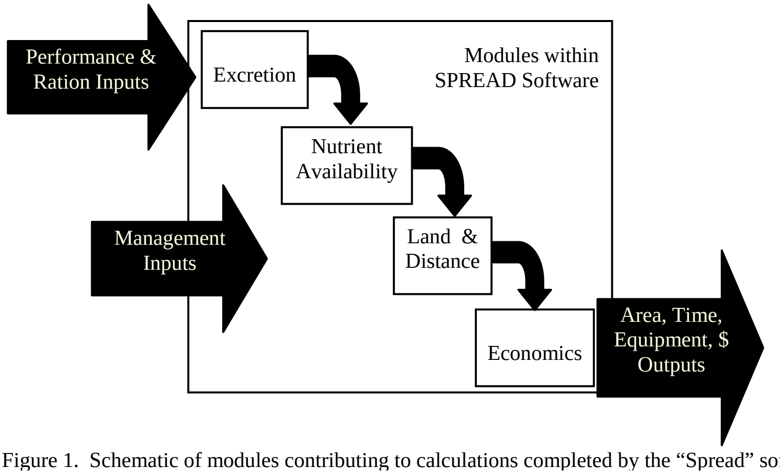

Figure 1. Schematic of modules contributing to calculations completed by the "Spread" software.

The nutrient availability module estimates crop available nutrients and manure mass. It includes adjustments to nutrient excretion based upon an estimate for retention in the animal housing and manure storage and retention during land application. Animal housing and manure storage retention factors are from Chapter 11 of the Agricultural Waste Management Field Handbook (SCS, 1992). Procedures for estimating ammonia retention during land application are adapted from tabular values in the same reference. The estimate of manure organic N availability following land application was based upon procedures used in Nebraska for nutrient planning (Koelsch et al., 2004). All estimates for nutrient retention can be modified by the user to allow for regionally appropriate retention factors.

The land and distance module produces an estimate of required land application area for manure applied at a nitrogen-based rate and a phosphorus-based rate assuming one, two, or four years of phosphorus can be applied with a single manure application (user selection). Crop available nutrients estimated in the nutrient utilization module are balanced against crop removal rates for nitrogen and phosphorus. Once the land area is determined, an estimate of average and total travel distance is made. The distance estimate assumes fields and roads are organized on a grid basis. The user inputs estimates of the land area that is in crop production (as compared to forest, CRP, etc.) and crop production that is accessible to the manure from the animal feeding operation.

The economics module provides an estimate of equipment and labor time for completing manure application, fixed and variable costs associated with land application only, and approximate value of the crop available nutrients in manure. The user selects a complement of equipment that most closely resembles their own situation from a preset list of options. Opportunity is provided to change default values of such inputs as speed, swath width and prices for various inputs. Estimation of machinery and labor time and expense follows the recommendations of the North Central Farm Machinery Task Force (Lazarus and Selley, 2005). Manure supplied nutrients are valued at commercial fertilizer prices for the nutrients that are needed for crop production (e.g. nitrogen is valued for crops requiring nitrogen fertilizer but not when applied to legume crops) or modified by the user.

Table 1. Summary of key user inputs and outputs of individual modules within "Spread" software.

Module	Primary User Inputs	Module Outputs
Excretion	Ration nutrient concentration Feed intake Animal performance (e.g. weight gain, days on feed) Facility housing animals	Excreted nitrogen mass Excreted phosphorus mass Excreted solids mass and concentration
Nutrient Availability	Manure housing/storage type Nutrient retention in storage (optional) Crop availability (optional) Land application characteristics Manure moisture and ash concentrations	Crop available nitrogen Crop available phosphorus Harvested manure mass and volume (liquid systems only)
Land and Distance	Crop rotation, yield, and crops receiving manure Crop nutrient requirements (optional) and credits from non-manure sources Basis for application rate Average field size Land Availability Value of nutrients.	Manure nutrient concentration Application rate Land requirements for agronomic Average and maximum travel distance
Economics	Application and nurse tank/truck equipment Application equipment operating characteristics Operating costs (optional)	Application time for spreading equipment and nurse tank/truck Total annual costs for manure application Nutrient value of manure Net costs of manure application

Results

To illustrate the potential role of the Spread software tool, two example scenarios will be evaluated:

- Alternative inclusion rates of ethanol co-products in the ration of beef finishing cattle.
- Alternative manure application rates based upon N-based and P-based limitations to nutrient application.

<u>Impact of Feeding Ethanol Co-Products</u>

One role for the SPREAD tool would be for situations where multiple feed program options are available to the producer. For example, the rapid growth of ethanol production has resulted in ethanol co-products being fed to several livestock species as a substitute for corn and possibly protein supplements. For the beef cattle industry, this feed will influence the amount of nutrients excreted and the costs of land application. The SPREAD tool provides a means of quantifying the manure management costs associated with these ration options.

A comparison is made of three beef finishing rations based upon three inclusion rates of ethanol co-products (Table 2). Increased inclusion of distillers grains with solubles (DGS) increases the rations protein and phosphorus concentration resulting in significantly greater nitrogen and phosphorus excretion. To manage the phosphorus will require land access to increase from 2,340 to 4,480 ha and an average haul distance to increase from 3.2 to 4.7 km. To spread manure over a larger area will require greater equipment operating time and labor requirements, approximately 350 hours for this situation. Most of this increase in time requirements is a result of greater field time for applying manure. Finally, the total costs associated with land application of manure are anticipated to increase by about $24,000. Thus, the impact of the dietary change can be quantified in terms of change to land to which this AFO will need access, labor and equipment operating time, and land application costs.

For this situation, the negative impacts on land, time, and costs are offset by the increased nutrient value of the manure being land applied. The $24,000 increase in land application costs are more than offset by an $83,000 increase in manure value. The actual increase in manure value may be less that this value based upon willingness of neighboring land owners to pay for the full nutrient value of manure. However, the

AFO could accept a significant discounting of the manure value and still break even financially. If manure is fairly evaluated by neighboring crop producers, dietary changes that increase manure excretion may have a value equal to or greater than the increased economic costs of land application. However, the AFO must balance a possible increased manure value against the need to access and manage nutrients on a larger land base, provide additional equipment and labor for manure handling, and the increased expenses associated with land application.

Another consideration is the impact of a feed management change on animal production and profitability. For example, the average profitability of the animal is increased by $15 to $30 per finished animal using 20 to 40% distillers grains in the diet depending on inclusion level, distance from the plant, and price relative to corn grain (Vander Pol et al., 2006). Therefore, for 20,000 finished animals, the economic return for least cost formulation in this example would be $300,000 to $600,000 due to increasing distillers grains in the diet. This tool now allows for decisions related to diet changes to include the impact on nutrient excretion, and subsequent spreading costs compared to nutrient value of manure instead of only least cost formulation.

Table 2. Impact of inclusion of distillers grains with soluble (DGS) in cattle ration for 10,000 head capacity feedlot. Assumes 40% of land is accessible for manure application and crop land is in a corn (175 bu/ac) and soybean rotation (60 bu/ac).

Options:		**0% inclusion of DGS in Diet** [1]	**20% inclusion of DGS in Diet** [1]	**40% inclusion of DGS in Diet** [1]
Manure Nutrients Available				
Nitrogen				
Excreted (kg/year)		497,000	599,000	750,000
Crop Available (kg/year)		99,000	120,000	150, 000
Phosphorus (P_2O_5)				
Excreted (kg/year)		61,000	87,000	116,000
Crop Available (kg/year)		58,000	84,000	111,000
Manure Application				
Land Required (ha)		2,340	3,410	4,480
Land Required (ha/year)		640	850	1,120
Average Haul Distance (km)		3.2	4.0	4.7
Maximum Haul Distance (km)		4.8	6.0	6.9
Selected Application Rate (MT/ha)		18[2]	13	10
Portion of Land Available for Manure		40%	40%	40%
Manure Application Equipment				
Application Equipment Selected		Truck Mounted 20 ton spreader	Truck Mounted 20 ton spreader	Truck Mounted 20 ton spreader
Total Time (hours/year)		820	990	1,20
Field Time (hours/year)		460	570	720
Road Travel Time (hours/year)		210	260	300
Loading/Unloading Time (hours/yr)		160	160	160
Manure Management Economics				
Nutrient Value	Total ($/year)	$ 109,000	$ 148,000	$ 192,000
	Total ($/MT)	$ 3.90	5.20	$ 6.80
Application Cost	Total ($/year)	$ 48,000	$59,000	$ 72,000
	Total ($/MT)	$ 1.70	$ 2.10	$ 2.50
Net Value	Total($/year)	$ 61,000	$ 89,000	$ 120,000
	Total ($/MT)	$ 2.20	$ 3.20	$ 4.30

[1] Ration crude protein and phosphorus concentrations are 13% and 0.29% (0% inclusion), 15.3% and 0.39% (20% inclusion), and 18.7% and 0.49% (40% inclusion), respectively.

[2] Limited to N-based rate. P-based rate exceeded crop nitrogen requirement.

<u>Impact of N vs. P Based Application Rates</u>

The SPREAD tool will have value for evaluating impact of a variety of other manure management decisions on economic considerations. For example, with the recent implementation of a P Index risk assessment on Concentrated Animal Feeding Operations (CAFOs), fields are being identified that must receive manure at a P-based rate. P-based rates are typically lower than N based rates, requiring additional land access and time for manure applications. The SPREAD tool can be used to evaluate the economic, time, and land consequences of this decision.

For the feedlot introduced previously with 40% DGS inclusion in the diet, N and P-based rates were evaluated and those consequences summarized in Table 3. For this example, moving from an N-based rate to a 4-year P-based rate has significant land access implications. Land requirements increased from 970 to 4,800 ha. However, in any one year, the land area has not changed significantly, only the travel distance to the available fields (increased from 3.1 to 6.9 km). Labor and equipment operating time increased by about 250 hours, primarily due to additional road time. Slightly less than a $20,000 increase in land application costs was also identified. No significant change occurred in the value of manure.

Table 3. Impact on costs of manure application if manure application rate is being determined on a nitrogen or phosphorus based rate. Assumes 40% of land is accessible for manure application and crop land is in a corn (175 bu/ac) and soybean rotation (60 bu/ac).

Manure Application Rate Options:		**N-Based Rate [1]**	**4-Year P-Based Rate [1]**	**1-Year P-Based Rate [1,2]**
Manure Nutrients Available				
Nitrogen - Crop Available (kg/year)		150, 000	150, 000	150, 000
Phosphorus - Crop Available (kg/year)		110,000	110,000	110,000
Manure Application				
Land Required (ha)		970	4,500	4,800
Land Required (ha/year)		970	1,120	4,500
Average Haul Distance (km)		1.9	4.7	4.8
Maximum Haul Distance (km)		3.1	6.9	7.1
Selected Application Rate (MT/ha)		12	10	2.5
Portion of Land Available for Manure		40%	40%	40%
Manure Application Equipment				
Application Equipment Selected		Truck Mounted 20 ton spreader	Truck Mounted 20 ton spreader	Truck Mounted 20 ton spreader
Total Time (hours/year)		920	1,200	2,100
Field Time (hours/year)		640	720	1,600
Road Travel Time (hours/year)		130	300	320
Loading/Unloading Time (hours/yr)		160	160	160
Manure Management Economics				
Nutrient Value	Total ($/year)	$ 197,000	$ 192,000	$ 195,000
	Total ($/MT)	$ 7.00	$ 6.80	$ 7.00
Application Cost	Total ($/year)	$ 52,000	$ 72,000	$ 144,000
	Total ($/MT)	$ 1.90	$ 2.50	$ 5.10
Net Value	Total($/year)	$ 145,000	$ 120,000	$ 51,000
	Total ($/MT)	$ 5.10	$ 4.30	$ 1.80

[1] Ration crude protein and phosphorus concentrations are 18.7% and 0.49% (40% inclusion of DGS), respectively for a 10,000 head feedlot.

[2] Field speed of manure applicator was assumed to be 8.0 km/h for the N-based rate and 4 year P-based rates. It was assumed to increase to12.9 km/h for a 1 year P-based rate.

Application of the P-based rate to meet only a single crop seasons P needs includes additional increases in costs. The total land requirements remain similar to a 4-year P-based rate. However, for a 1-year P-based rate, all land must receive manure each year as opposed to every fourth year and application rates must be reduced (2.5 vs. 10 MT/ha). An AFO required to apply manure on a 1-year P-based rate will experience an increase in labor and equipment operating time of approximately 900 hours over the 4-year P-based rate and more than 1100 hours over the N-based rate. In addition, the AFO will experience an increase in costs of more than $70,000 and $90,000. The nutrient value of manure exceeds the costs of manure application for all situations evaluated, assuming that neighboring farms are willing to pay the full value of the nutrients in manure. A transition to a 1 year P-based rate has significantly greater costs that a 4-year P-based rate.

Conclusion

The opportunity is now available to begin integrating the consequences of the feed management decisions into a CNMP process. The SPREAD tool will allow a connection to be made between animal feeding program and land requirements for excreted nutrients, labor and equipment time for managing manure, and economic costs and benefits associated with land application. From the application of this tool to beef cattle example scenarios, the following was learned:

- Increased inclusion of distiller's grains into a beef cattle ration will produce significant increases in the land requirements, labor and equipment time, and financial costs of manure application.
- These increased financial costs have the potential of being offset by increased value of manure, possibly even producing an income greater than the increased financial costs.
- Transition from a N-based application rate to a P-based rate where manure in applied to meet 4 years of crop P requirements has only a modest impact on labor and equipment time as well as land application costs. However, it has a significant impact on land requirements.
- The transition from an N-based rate to a single year P-based application will have substantially greater impact on all costs evaluated. If a single year p-based application and a four year P-based application produce similar environmental benefits, beef cattle feedlots will experience far fewer financial and time burdens if a multi-year P-based application is allowed.

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