Economics of Beef Feedlot Manure Management from a Whole-Farm Planning Perspective

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Introduction

Manure management is a priority concern of the beef feedlot industry. Specialized livestock production often separates manure from the cropland it has been traditionally associated with. Therefore, manure management is often considered in this same context. Manure management, however, need not be discussed exclusively in the context of a feedlot operation. A whole farm planning approach offers significant potential for manure management when the production of beef feedlot cattle and crops occurs at the same site.

Integration of crop and livestock production offers benefits to the operation that are not readily available to specialized operations producing strictly crops *or* livestock. Cropland can provide feed to the livestock portion of the enterprise and a place to apply the manure produced by the cattle. Manure supplies nutrients to cropland that would otherwise have to be purchased from off-farm sources. Therefore, what would be a cost of disposal to an operation producing strictly livestock may become an economical way to supply nutrients to crop production on an integrated crop-livestock operation.

Manure management and utilization can be addressed at several stages of agricultural production from livestock ration decisions through to land application and crop choice. Dietary manipulation and composting offer potential to reduce the amount and constituents of manure. Growing crops with high nutrient demands allows more nutrients to be recycled on a fixed amount of cropland. Wang and Sparling (1995) demonstrated that it was possible for irrigated land producing hay, grain corn and silage corn within a 10 mile radius of an area of highly concentrated feedlots to absorb more than twice the manure produced by feedlots when the manure was applied at agronomic rates. Growing crops such as potatoes, sugar beets, or other crops to be exported out of a region presents yet another opportunity for long-term manure management. These crops grown for export break the cycle of applying manure to cropland, feeding the crop to livestock, and applying the subsequent manure on the same land.

Stonehouse and Narayanan (1984) found that commercial livestock-crop operations managing their manure resources in an effective manner were in a position to supply nutrients to a specified set of crops at a lower cost than those farmers entirely reliant on purchased chemical fertilizers. The addition of manure or compost to soil provides many positive attributes beyond the addition of nutrients. Addition of livestock manure can provide benefits of increased organic matter, improved water infiltration, improved soil condition for plant growth and reduced power requirements for tillage of the soil (Sommerfeldt and Chang 1985,1986). Manure and compost can also improve the productivity of eroded soils by substituting organic matter for lost topsoil (Larney and Janzen, 1996; Dormaar, Lindwall and Kozub, 1988).

The Western Beef Feedlot Linear Programming Model has been designed to explore this interaction in an integrated crop and livestock production system. It incorporates research regarding diet manipulation, composting, transportation, crop nutrient requirements, and crops that can potentially be transported out of the region into a single whole-farm economic optimization model. This framework allows for determination of optimal combinations of livestock feeding, crop choice and manure management alternatives given the set of conditions faced by a producer. Due to the fact that the model is designed to assist crop and livestock producers, parameter values can be changed to adapt the model to producer specific situations.

Model Structure

The Western Beef Feedlot Manure LP Model is a linear programming (LP) model designed to maximize net returns to an integrated beef feedlot-crop producing operation through optimal use of resources available to the operator. Activities in the model are crop and livestock production, management and composting of manure, and the buying and selling of inputs and outputs respectively. These activities are constrained by the resources available to the operation including manure, fertilizer, cropland and pen space for feeding cattle.

Production of beef can be accomplished by choosing one of three diets. Beef cattle diets in the model include barley-barley silage (BBS), barley-corn silage (BCS), and barley-barley silage with an added enzyme (BBSENZ) to reduce feed consumption and the associated manure output. All diets include a protein supplement that also serves as a carrier for minerals and feed additives and are designed to provide the nutrients necessary to feed a 800 pound feeder steer to a 1250 pound finished weight in 114 days. Manure output per animal over the feeding period is fixed with its respective feeding program. Changes to cattle feeding and manure production are accomplished by varying the number of cattle fed on each diet and not by varying diet constituents. The model will select the optimal diet based on cost of the diet, manure production associated with a particular diet, and the costs and benefits related to the manure at a whole farm level.

Four different manure management options are available to the operator. How the model handles manure depends on which method(s) are economically optimal in conjunction with crop and livestock production decisions. Manure can be applied directly from the feedlot to the cropland; or composted and applied to cropland; or composted and sold at the farm gate. A further option emulates a practice occurring in the Texas High Plains region in which producers dispose of manure by stockpiling (Johnson and Segarra, 1996). Any combination of these manure management options is available to the producer.

Crop choices in the model include the production of barley silage, corn silage, potatoes and sugar beets. These options assume fixed yields and fixed nutrient requirements necessary to achieve those yields. Cropping activities are optimized in the model by varying the number of hectares allocated to the production of a given crop. Factors determining selection of an optimal crop mix will include costs of production, crop yield and price, and nutrient requirements of the crop. Differing crop nutrient requirements equate to different capacities for the application of manure or compost. A crop that will consume large amounts of the nutrients created in the feeding portion of the operation will add to net returns if the cost of supplying manure nutrients to the crop is less than the cost of disposing of the manure and purchasing commercial fertilizer. Such interactions determine optimum levels of manure application, composting and disposal as well as the optimal choices of crops and beef cattle diets.

Other activities for the model to choose from include buying or selling silage if optimal to do so and the sale of crops produced on the operation. The sale of compost offers another potential source of revenue to the operation. This is assuming that there is a market for the compost and that all compost can be sold at the farm gate.

The rows of the LP model deal with constraints on resources, supply-demand balances, and transfer activities within the model. Constraints on resources are the capacity of the feedlot and the number of hectares of irrigated cropland to which manure can be applied. Supply-demand balance rows ensure that all animals produced are sold; all manure produced in the feedlot is removed from the feedlot in some form and that crop nutrient requirements are met from either manure or chemical fertilizer sources. Other balance constraints force all crops produced to be sold or used in the operation and ensure that purchased inputs such as feed and fertilizer are used in the production process. Finally, transfer rows allow the model to transfer outputs in one part of the model to use as inputs in other parts of the model. Manure can be transferred from a manure production activity to use by crops, transformation into compost or disposal by stockpiling. Barley and corn silage crops can be transferred to feeding activities or selling activities. The transfer processes enable the model to simulate the joint activities of a livestock feeding-crop enterprise.

Revenue in the model is made up of receipts from crop, livestock and compost sales. Expenses in the model include cost of buying and finishing feeder steers, cost of utilizing (compost or raw form) or disposing of the manure created in the livestock feeding enterprise, costs of crop and livestock production, and purchasing fertilizer for crop production or diet ingredients for beef production. Costs of production, selling prices, crop yields and transportation distances can be altered to suit the specific situation faced by the feedlot-farm operator.

Simulations and Results

Two pairs of simulations are conducted to examine how the increased fertilizer prices of Spring 2001 change optimal manure management decisions made by a feedlot farm operator. Such a demonstration provides an example of how the WBFM LP model can be applied to common decisions faced by feedlot-farm operators. The feedlot-farm operation in question is assumed to have a one-time capacity of 5000 head of cattle and control a land base of 1036 hectares (2560 acres). Cropland on which manure is currently applied is assumed to lie within a 2 kilometer average distance of the feedlot but this assumption will be relaxed when examining maximum economically optimal manure hauling distances.

The primary question regarding the effects of changing fertilizer prices addressed here is "Given the substantial increase in the cost of nitrogen fertilizer, how will manure management strategies be affected?" The answer to this question is not a simple one and must consider the effects of the price change on how manure is handled, what crops are grown and if changes to choice of livestock diets are warranted. The question of how far manure can be hauled must also be re-addressed in response to changes in the price of an input as significant as fertilizer.

The first pair of simulations examine optimal decisions based on the year 2000 fertilizer prices. Initially, the 2000 base model (2 kilometer manure hauling distance) is run and results are produced. Once the optimal choices for the 2000 base model are determined, the hauling distance is increased to the point at which purchased inorganic fertilizer is substituted for manure. The prices per kilogram of nitrogen and phosphate fertilizer are $0.62 and $0.81 respectively. Table 1 on the following page provides the results of these two simulations.

In the base 2000 simulation, feedlot farm profit is $43,806.00. Sixteen thousand head of cattle are finished on the barley grain-corn silage diet creating 34,856 tonnes of manure. All manure is applied to cropland producing corn silage while 71 and 15 tonnes of actual nitrogen and phosphate respectively must be purchased in the form of inorganic fertilizer to meet crop nutrient demands not satisfied by manure. Even though fertilizer must be purchased, the shadow value of manure (the value that one more tonne would contribute to profit) is -$1.00 and can be interpreted to mean that each additional tonne of manure produce by the feedlot portion of the operation will decrease profit by $1.00. This indicates that applying manure to land is the cheapest means of disposing of the manure and not the cheapest way to supply crop nutrients. The shadow values of land and cattle indicate that one more hectare of land would contribute $811 to profit while livestock capacity of one additional head would contribute $75 to the feedlot-farm profit.

Table 1. Base simulation and maximum economic manure hauling distance simulation for year 2000 fertilizer prices.

	2000 Fertilizer Prices

	Units	Haul Manure 2 km (BASE)	Haul Manure 9 km
Feedlot-Farm Profit	$	$43,806	-$8,534
Cattle Fed on Barley Grain-Corn Silage Diet	Head	16,009	16,009
Tonnes of Barley Grain Purchased	Tonnes	18,931	18,931
Tonnes of Supplement Purchased	Tonnes	821	821
Corn Silage Cropland	Hectares	1,036	1,036
Corn Silage Sold	Tonnes	39,364	39,364
Manure Produced	Tonnes	34,856	34,856
Manure Applied to Corn Silage	Tonnes	34,856	0
Compost Produced and sold	Tonnes	0	12,381
Nitrogen Fertilizer Purchased	kg	70,586	174,109
Phosphate Fertilizer Purchased	kg	14,867	69,644

The second simulation of the pair based on year 2000 fertilizer prices is shown above in the right hand column of Table 1. The distance that manure was hauled for field application was increased until manure was replaced by commercial inorganic fertilizer as a crop nutrient source in order to determine the maximum economically optimal hauling distance for manure based on the 2000 fertilizer prices. This was done in order to facilitate comparison with the same results based on year 2001 fertilizer prices. Fertilizer replaced manure at a 9 km hauling distance. The manure was composted and sold as a means managing the manure produced by the cattle feeding operation. As could be expected, profit decreased with increased hauling distance and more nitrogen and phosphate fertilizer had to be purchased. Optimal livestock diet and crop choice remained unchanged.

The pair of simulations corresponding to the year 2001 fertilizer prices of $0.99 and $0.79 per kg of actual nitrogen and phosphate fertilizer respectively are very similar to their counterparts in the pair of simulations based on year 2000 prices. Activity levels for the 2 kilometer hauling distances based on 2000 and 2001 fertilizer prices are the same. This is not surprising because, given the set of crops, and the type of livestock produced in a given geographic area, agricultural production is likely to be relatively inflexible to change over the short run. The profit, however, is lower in the 2 kilometer hauling distance simulation based on the 2001 fertilizer prices due to the increase in the price of nitrogen. Table 2 displays activity levels for the simulations based on the 2001 fertilizer prices.

A particularly interesting portion of the output related to the increased cost of nitrogen fertilizer lies in the shadow value of manure. The shadow value of one more tonne of manure is now $0.07, a small but meaningful number. This small positive number indicates that, based on the increased nitrogen fertilizer price, manure is a valuable resource to crop production and not a by-product to be handled in the cheapest manner possible. An additional tonne of manure contributes to, rather than detracts from, profit just as do crop land and livestock production.

Table 2. Two kilometer hauling manure hauling distance simulation and maximum economic manure hauling distance simulation for year 2001 fertilizer prices.

	Units	2001 Fertilizer Prices	
		Haul Manure 2 km	Haul Manure 13 km
Feedlot-Farm Profit	$	$17,986	-$71,562
Cattle Fed on Barley Grain-Corn Silage Diet	Head	16,009	16,009
Tonnes of Barley Grain Purchased	Tonnes	18,931	18,931
Tonnes of Supplement Purchased	Tonnes	821	821
Corn Silage Cropland	Hectares	1,036	1,036
Corn Silage Sold	Tonnes	39,364	39,364
Manure Produced	Tonnes	34,856	34,856
Manure Applied to Corn Silage	Tonnes	34,856	0
Compost Produced and sold	Tonnes	0	12,381
Nitrogen Fertilizer Purchased	kg	70,586	174,109
Phosphate Fertilizer Purchased	kg	14,867	69,644

The shadow value (profit contribution of having one more hectare) of cropland has decreased from $811 (for year 2000 fertilizer prices) to $750 (for year 2001 fertilizer prices) due to increased nitrogen costs. However, the shadow value of livestock has increased to $78 (an increase of $3) in response to the increased nitrogen price. This increase in the shadow value of livestock can be attributed to the increased value of the manure produced by the livestock.

In the second simulation of the pair based on the year 2001 increased nitrogen fertilizer price it is demonstrated that manure can now be hauled up to 13 kilometers before being replaced with purchased inorganic fertilizer. Depending on the location of crop land from a particular feedlot, this increased hauling distance could mean that crop land previously not receiving applications of manure for purely economic reasons could now have manure applied to it. Activity levels for this 13 kilometer hauling distance scenario are the same as those in the 9 kilometer hauling distance scenario based on the year 2000 fertilizer prices. Profit is lower due to increased fertilizer costs.

Conclusions

The WBFM LP model provides integrated crop-livestock producers with a tool that enables them to examine optimal choices for their operation given the biophysical and economic conditions unique to their operation. The simulations conducted for this analysis were simple, involving a comparison of optimal decisions under two different fertilizer price scenarios and the maximum distance that manure could be hauled based on the price of fertilizer. In reality, prices and costs are constantly changing. This simple demonstration shows how a program using a whole-farm approach can assist crop-livestock producers in assessing the effects economic variables on their operation. Furthermore, it demonstrates that this same program can be used to examine options such as manure hauling distances within a whole-farm planning framework.

Results of this simulation indicate that, from an economic standpoint, manure cannot be transported relatively large distances. The value of manure to an operation increases with the cost of substitute commercial inorganic fertilizers. Fertilizer prices do not change the optimal activities at the feedlot-farm but will significantly the impact distances which manure can be transported in an economically optimal manner. Changes to the fertilizer prices also change the inherent value of manure to the crop-livestock production system. Finally, if nutrients can be supplied to crops by inorganic fertilizers at a lower cost than they can be supplied by manure, manure will have a negative value to the operation. If nutrients can be supplied in a more cost effective manner using manure rather than inorganic fertilizer, however, manure provides a positive contribution to overall feedlot-farm profitability.

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