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Economics of hauling dairy slurry and its value in Wisconsin corn grain systems

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Abstract:

To evaluate the potential of using dairy slurry for corn (*Zea mays L.*) production in Wisconsin grain systems, custom manure hauler bids were combined with corn production expenses to develop enterprise budgets in which slurry provided corn nutrient needs. A scenario was developed in which a recipient grain farmer shares manure hauling costs with the dairy farmer supplying the slurry. Results showed that by sharing manure hauling expenses, profitable hauling distances more than doubled (from 3.2 to 7.6 km). These results suggest that grain and dairy farmers could enter into beneficial manure contracts having both economic and nutrient conservation advantages.

Introduction

Farmers specializing in grain crop production have typically relied solely on commercial fertilizer for their crop nutrient needs. Yet like so many other inputs, fertilizer prices have risen to record high levels in recent years reducing already-tight profit margins. Wisconsin Statistics Service (USDA-NASS, 2000, 2008) shows prices per pound for nitrogen (N), phosphate (P_2O_5), and potash (K_2O) increased by 123%, 89%, and 41% between 1999 and 2007. This largely explains why the cost of fertilizer purchases for corn production in Wisconsin nearly doubled from \$86 to \$164 ha^{-1} (\$35 to \$66 ac^{-1}) during approximately the same period (USDA–NASS, 2000, 2008). As fertilizer prices increase there is a growing incentive for grain farmers to utilize alternative nutrient sources such as manure. Manure provides nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and other nutrients, as well as serving as a soil conditioner by increasing organic matter and improving porosity and water-holding capacity (Safley et al., 1986; Eghball and Power, 1994; Eghball et al., 2002).

At the same time that fertilizer prices are climbing, expansion within the dairy industry has left some dairy farmers confronted with larger and larger quantities of manure to manage. The proportion of dairy farms with more than 200 cows in Wisconsin grew rapidly between 1999 and 2005. By 2005 these larger farms included 32% of the state's cows and accounted for 34% of the state's milk production (USDA-NASS, 2006). These larger farms also tend to have higher stocking rates according to a study by Saam et al. (2005). Approximately 80% of larger farms use a lined slurry pit for long-term manure storage (Turnquist et al., 2006), and custom operators haul a large percent of this slurry in Wisconsin (K. Erb, personal communication, September 2006). The use of custom manure haulers with their specialized labor and equipment makes it easier to envision manure brokering between larger dairies and grain farmers; a transfer that could improve profitability and environmental stewardship for both parties. Cabot et al. (2004) reported that manure brokering is promoted in nine states. In addition, a number of web-based interactive spreadsheets have been developed to calculate the fertilizer value of manure, and to aid dairy farmers in estimating the costs of hauling manure on their own farms.

Factors that influence the potential economic value of manure as a crop input include its nutrient concentration, soil test levels, the crop's nutrient requirements (Araji et al., 2001), and, most importantly, the distance it must be hauled (Flemming et al., 1998; Araji and Stodick, 1990). Manure nutrient content itself is a function of animal species, housing, management, feed ration, manure storage, and climate (Eghball et al., 2002). As a result, manure nutrient content is variable. Peters and Combs (2003) found that while mean total nutrient contents for 746 liquid dairy manure samples in Wisconsin were similar to "book values" reported in the Livestock Waste Facilities Handbook (MWPS, 2000) the standard deviations for those nutrients were between 41% (N) and 78% (P_2O_5) of mean values.

Breakeven hauling distances are also affected by initial soil fertility. If soil test levels are high it means that the P and K present in manure are not actually necessary for maintaining crop yield levels in the short term. Application of these nutrients would therefore not be economical. When Best Management

Practices indicate that a grain farmer should not purchase additional P and K for corn production, the "value" placed on manure as a fertilizer is lowered, decreasing the distance slurry can be hauled.

Work has been done on the management of poultry (Govindasamy and Cochran, 1995; Araji et al., 2001; Paudel et al., 2004), swine (Fleming et al., 1998) and cattle manures (Freeze and Sommerfeldt, 1985; Araji and Stodick, 1990, Adhikari et al., 2005), generally assuming application of those manures to soils with optimum soil test values. Araji and Stodick (1990) working in Idaho found that the breakeven hauling distance for transferring solid beef manure from feedlot to field to replace fertilizer purchases in a grain-grain-fallow rotation averaged 12.9 km. Working in central Texas, with solid dairy manure (50% moisture), Adhikari et al. (2005) found that breakeven hauling distance for corn was 16.6 km (10.3 mi) in the first year of application.

Relatively little work has been done, however, on the economics of hauling dairy slurry and its value as a replacement for commercial fertilizer in grain systems. Slurry is a somewhat unique material due to the high volumes available, specialized equipment for hauling it, and its relatively low nutrient concentration. The objective of this study was to evaluate the economic potential of expanding the sound use of dairy slurry in corn-based production systems in Wisconsin. The following issues are addressed:

1. How much does it cost to load, haul, and spread dairy slurry within 8 km (5 mi) of its source?
2. What is the value of dairy slurry in corn production systems?
3. How far can dairy slurry be hauled, if hauling costs are partitioned between dairy and grain farmers?

Materials and Methods

Costs Associated with Manure Application.

Custom hauler interviews were used to estimate manure hauling rates for Wisconsin. A sample was developed using the Wisconsin Custom Manure Applicators list provided by the Professional Nutrient Applicators Association of Wisconsin (PNAAW, 2008). Operations were chosen that used straight-truck mounted slurry tanks to haul and spread manure. Custom hauler rates include the fixed and variable costs associated with the agitation, loading, hauling and spreading of dairy slurry. In addition to operation specifics, each custom hauler interviewed was asked to develop a bid for emptying a slurry pit onto fields at five different distances (1.6, 3.2, 4.8, 6.4, and 8 km) from the slurry source. An aerial photo showing the slurry pit, the location of five different fields, and the clearly delineated route to those fields was given to each custom hauler. Initial bids were all given in English units and subsequently converted to metric. Total cost for emptying the manure pit was calculated by combining the custom hauler's bid with his estimate of fuel usage (normally paid for directly by the contracting dairy farmer).

Initial assumptions used to determine total costs included (1) a slurry pit capacity of 7571 m^3 (2 x 10^6 gal), and (2) broadcast application of slurry at a rate of 93.5 m^3 ha^{-1} (10,000 gal ac^{-1}) using 11.4 to 15.1 m^3 (3000 to 4000 gal) capacity truck mounted slurry tanks. For all the scenarios, a single slurry pump and pit agitator were used. Average haul times and custom hauler charges were calculated for fields at 1.6 km increments from the slurry pit out to 8 km. Total costs to empty the slurry pit were estimated by Equation 1.

$$C_t = Bid + Fuel\ Cost \qquad (1)$$

Where C_t is the total cost to empty the slurry pit and land-apply its contents. This is determined by summing the custom hauler bid (*Bid*) for each distance increment with the total fuel costs. Fuel costs (Equation 2) were calculated as the product of fuel usage rate ($_f$), equipment number ($_n$), fuel price (F_p) and machinery hours (H_m) for slurry trucks (T), pit pumps (P) and pit agitators (A) respectively.

$$Fuel\ Cost = [(T_f \times T_n \times F_p \times H_m) + (P_f \times P_n \times F_p \times H_m) + (A_f \times A_n \times F_p \times H_m)] \qquad (2)$$

Slurry Nutrient Composition.

Data from the University of Wisconsin (UW) Soil and Forage Analysis Laboratory (SFAL) in Marshfield Wisconsin was used to determine typical slurry characteristics and nutrient composition. The data set consisted of 713 dairy slurry analyses conducted at the lab between March of 2002 and September of 2005. Although the percent dry matter of these slurry samples were variable (mean = 5.1; s.d. = 2.8), a standard specific gravity (994.6 g l^{-1} or 8.3 lbs gal^{-1}) was used to convert lab results to total nutrients per volume.

Value of Slurry as a Fertilizer Replacement in Cash-Grain Systems.

In this study, slurry value is calculated as the estimated fertilizer replacement savings (1st thru 3rd year manure credits) per hectare, minus the costs a grain farmer is willing to assume in order to transport manure to the field (see Equations 3a and 3b below).

Fertilizer replacement values are based on the assumption that the field is in a corn-soybean rotation and that the slurry is incorporated as part of fall tillage. These values are further modified based on soil test levels (optimum vs. high). The optimum soil test category, as defined by UW Extension, indicate soils on which crop yields are optimized with nutrient additions approximately equal to the amount of nutrients removed by the harvested crop (Kelling et al., 1998). On fields with high soil test levels of P and K these nutrients are less limiting to corn or soybean growth, and therefore have little to no fertilizer replacement value. In some cases, the Wisconsin Nutrient Management 590 Standard criteria for surface water protection, requires that field applications of manure be based on a Soil Test Phosphorus (STP) strategy. While manure may be applied to meet the N needs of a crop on soils that test below 50 mg kg^{-1} in STP, between 50 and 100 mg kg^{-1} manure may be applied not to exceed P removal by the crops over a rotation (8 year max), and if STP exceeds 100 mg kg^{-1} no P additions in manure or fertilizer are permitted (USDA-NRCS, 2005). All additional nutrients required beyond those supplied in the dairy slurry are applied according to UW recommendations. A three-year availability series for manure nutrients (Kelling et al., 1998) is used to determine fertilizer saving in the 2nd year soybean and 3rd year corn phases of the rotation (Table 1). Total slurry value is calculated by estimating the cost savings obtained by using dairy slurry instead of fertilizer over a three year period, including the cost of manure hauling, and for years 2 and 3, assuming a specific required rate of return to equity capital (Equations 3a and 3b).

$$VM = [FC1_{CONV} - FC1_{MAN}] - C_{manure} + PV_{y2\&3} \quad (3a)$$

$$PV_{y2\&3} = [(FC2_{CONV} - FC2_{MAN}) / (1+K)^1] + [(FC3_{CONV} - FC3_{MAN}) / (1+K)^2] \quad (3b)$$

Where VM is the one-time fertilizer replacement value of manure used for corn production, FC represents the fertilizer costs to produce corn with ($_{MAN}$) and without ($_{CONV}$) dairy slurry, C_{manure} is the amount a farmer pays in transportation costs for the slurry, and $PV_{y2\&3}$ is the present value of fertilizer saved for years two and three defined by Equation 3b. The numbers associated with the fertilizer cost (FC) indicate to which year in the rotation the fertilizer costs correspond, with years one and three representing the corn phases of the rotation. The present value of fertilizer saved for years two and three is used to account for future savings in fertilizer obtained from a one-time slurry application assuming soybeans is grown in year two and corn is grown again in year three. In this model (Equation 3b) the required rate of return on equity capital K is set at 11%.

Table 1. Average slurry nutrient content and estimated three-year availability of 713 slurry samples submitted to the University of Wisconsin - Soil and Forage Analysis Laboratory (SFAL) in Marshfield, WI†

	total nutrients (kg m^{-3})	**1st year available**		**2nd year available**		**3rd year available**	
		available nutrients (kg m^{-3})	***as % of total†***	***available nutrients (kg m^{-3})***	***as % of total‡***	***available nutrients (kg m^{-3})***	***as % of total***
N	2.48	0.99¶	40.0%	0.28	11.2%	0.14	5.6%
P_2O_5	0.90	0.54	60.0%	0.09	10.5%	0.05	5.3%
K_2O	2.31	1.85	80.0%	0.25	10.7%	0.12	5.3%

† Of 713 slurry samples average %DM =5.1
† First year nutrient availability as a percent of total nutrients applied is taken from standards used by the University of Wisconsin - Soil and Forage Analysis Lab (SFAL) in Marshfield, WI.
‡ Second and third year nutrient availabilities as percent of total nutrients applied are taken from the University of Wisconsin Extension Publication A2809 (Kelling, 1998).
¶ N availability is for incorporated slurry; un-incorporated slurry N availability is estimated as 30% of total nutrients applied (0.74 kg m^{-3})

Grain Enterprise Budgets.

Enterprise budgets are used to evaluate the profitability of a corn grain system where slurry is the primary nutrient input in the corn phase of a corn-soybean rotation. Here we define profitability as the difference in returns per hectare between this system and the same systems utilizing solely commercial fertilizer. It was assumed that all growers would apply 93.5 l ha^{-1} of starter fertilizer (7-21-7 weighing 1.34 kg l^{-1}) regardless of subsequent fertilizing practices for corn, would take 44 kg N ha^{-1} credit for following soybeans, and that corn yields would be at least equal in the manured and fertilizer-only systems (Jokela, 1992; Eghball and Power, 1999, Sanford et al., 2009). Budgets are further supplemented with ten-year statewide average input values (1997 to 2006) for Wisconsin taken from the UW Extension "PEPS" program (Profits through Efficient Productions Systems http://corn.agronomy.wisc.edu/PEPS/2005.pdf) for corn grain. These are budgets (n = 323) from top-level corn producers in grain systems. Average yields from PEPS were 12.1 Mg ha^{-1} during the 10 years of data sampled.

Sensitivity Analysis.

For the manured system, two scenarios are presented. The two scenarios are: (1) "Standard Scenario" - dairy farmer covers all fuel and hauling costs to transport dairy slurry to the field (e.g. dairy farmer applying slurry to his own or rented land), and, (2) "Shared Scenario" - dairy farmer covers loading and hauling costs within the first 1.6 km (1 mile) from the pit (a common limit to which slurry is transported; Jackson-Smith et al., 1997, Powell et al., 2007), and the neighboring grain farmer pays all additional costs to transport dairy slurry to fields beyond that distance. These scenarios are evaluated using three-yr N fertilizer replacement values in both high fertility and optimum fertility soil conditions. In the high fertility case, applications of P and K would not elicit a positive crop response and are therefore not valued (N-only value), whereas in the optimum fertility case all three nutrients are valued (full value) since corn would respond positively in these conditions not only to N but to P and K applications as well. Additional sensitivity analyses are conducted on the "shared scenario" to determine the factors that would most likely affect the profitability of transporting slurry to somewhat distant grain fields.

1. Variable manure nutrients: mean, +1 standard deviation, and –1 standard deviation
2. Variable N price: 1999, 2007, and 2007+20%
3. Variable diesel price: 1999, 2007, and 2007+20%
4. Variable corn yields: 2006 Wisconsin statewide average corn yield of 9.0 Mg ha^{-1} vs. PEPS average of 12.1 Mg ha^{-1}.

Results and Discussion

Cost of Hauling and Spreading Dairy Slurry.

Of eight custom haulers invited to participate in this project, six returned completed questionnaires after initial phone contact was made. The six custom operators interviewed all used an hourly rate for hauling and spreading dairy slurry and generally daily rates for agitators, pumps and other equipment. All the haulers developed their bids to empty a 7571 m^3 slurry pit using truck mounted slurry tanks with 11.4 to 15.1 m^3 capacity. Approximately 30% of all custom haulers registered by the Professional Nutrient Applicator Association of Wisconsin in 2007 (PNAAW, 2008) use these truck mounted slurry tanks. Other common systems include large semi-trucks (29%) and tractor pulled dragline systems (30%), particularly in the northeastern part of the state. The custom haulers interviewed owned 57 trucks in total, representing 38% of the registered state fleet (PNAAW, 2008).

Custom hauler bids were variable. For example, when emptying the manure pit and spreading the slurry on approximately 80 ha at 4.8 km distance, bids ranged from $10,200 to $19,970 with a median value of $13,256. The primary reasons for the range in final bids were equipment age, the number of trucks in a hauler's fleet, and their estimated hauling time (road speed) which was largely a function of the tire width and tread used. In our sample, truck fleets ranged from 6 to 16 tankers. A linear model, fit to the log transformed bid data, was chosen over a linear, quadratic and cubic model, fit to the non-transformed bid data, based on its superior fit and a clear exponential trend in the raw data (Table 2). For this analysis, the exponential solution to the selected model was then used to interpolate custom hauling costs within the 8 km distance from the slurry source for which data was collected. Model fitting was performed using R statistical computing software version 2.6.2 (2008).

Table 2. Summary of regression models fit to custom hauler bid data in order to interpolate between data points collected at 1.6 km (1 mi) increments out to 8 km (5 mi). The exponential model was chosen to best represent the non-linear trend in custom hauler *Bid* with distance.

fit	model[†]				R^2	Adj.-R^2
Linear	*Bid* = 5457.6 + 1922.9*km				0.56	0.54
Quadratic	*Bid* = 8544.9 + 279.3*km + 170.2*km^2				0.57	0.54
Cubic	*Bid* = 7176.3 + 1473.5*km – 112.7*km^2 +19.5*km^3				0.57	0.52
Natural Log	*ln(Bid)* = 8.85592 + 0.13737*km				**0.60**	**0.58**
		Coefficient	***Standard Error***	***t-value***	***Pr >|t|***	
		Intercept	0.11	77.9	<0.0001	
		km	0.02	6.5	<0.0001	
		F-Statistic	***Num. d.f***	***Den. d.f.***	**p-value**	
		41.65	1	28	<0.0001	
		Exponential Model Form[‡]				
		Bid = $7015.8e^{(0.13737*km)}$				

Table 3 shows the hauling, fuel, and total costs per hectare to haul dairy slurry, as well as the cost to go an extra 1 km. For example the cost to load and haul dairy slurry from the pit to a distance of 2 km is approximately \$153 ha^{-1}. This includes \$114 ha^{-1} custom hauler charges for loading, agitation, hauling, and spreading and \$39 ha^{-1} for fuel. Of the total cost per hectare to empty the pit, approximately \$118 ha^{-1} is for agitation and loading and \$35 ha^{-1} is for transportation and spreading. The cost to go an additional 1 km increased with distance from the slurry pit in this study and ranged from \$19 to \$42 ha^{-1}.

Table 3. Change in dairy slurry application cost with distance from source – Southern Wisconsin.[§]

km	Custom hauler charge per hectare[††]	Fuel per hectare[§]	Total cost per hectare (haul + fuel)	Cost difference from previous km (haul + fuel)
1	\$99.33	\$35.02	\$134.35	--
2	\$113.92	\$39.47	\$153.38	\$19.03
3	\$130.64	\$44.48	\$175.12	\$21.74
4	\$149.83	\$50.12	\$199.95	\$24.83
5	\$171.82	\$56.48	\$228.31	\$28.36
6	\$197.05	\$63.65	\$260.71	\$32.40
7	\$225.99	\$71.73	\$297.72	\$37.01
8	\$259.17	\$80.84	\$340.01	\$42.29

Value of Dairy Slurry in Cash Grain Systems.

Based on the spring 2007 market value of N, P_2O_5, and K_2O[¶], the total first year value of manure nutrients in 1 m^3 of average dairy slurry is \$2.58. When applied at a standard rate of 93.54 m^3 ha^{-1} the total

[†] bid = estimated hauling cost (less fuel) in U.S. dollars given at 1.6km (1mile) increments out to 8 km (5 mi)
[‡] Used to return custom hauler bids to non-transformed dollar amounts. Obtained by exponentiating both sides of the log linear model.
[§] Equations used for conversion from \$ ac^{-1} at 1 mile increments to \$ ha^{-1} at 1km increments are: bid (\$ ac^{-1}) = $86.614e^{0.137km}$, and fuel (\$ ac^{-1}) = $31.078e^{0.1195km}$
[††] Wisconsin custom hauler rates: truck mounted slurry tank - \$47 to \$65 hr^{-1}, slurry pit pump - \$300 to \$500 day^{-1}, slurry pit agitator - \$150-300 day^{-1}.
[§§] \$0.76 l^{-1}: WI Co-op price, summer 2006. Range in equipment fuel usage of interviewed haulers: slurry truck – 19 to 30 l hr^{-1}, tractor for slurry pit pump or agitator 19 to 45 l hr^{-1}.
[¶] \$1.09 kg^{-1} N (\$0.49 lb^{-1} N), \$1.16 kg^{-1} P_2O_5 (\$0.53 lb^{-1} P_2O_5) , \$0.47 kg^{-1} K_2O (\$0.21 lb^{-1} K_2O)

fertilizer value of these nutrients would be \$241 ha^{-1} (Table 4). Over a three-year period in a corn-soybean-corn rotation on a field with optimum soil test values, the fertilizer replacement value of this slurry would increase to \$287 ha^{-1} before correcting for the 11% required rate of return on equity capital. In economic terms, slurry value can be defined in two ways: (1) the "in use" value of the dairy slurry as a replacement for purchased fertilizer, or (2) the value "in exchange" (the price a "consumer" agrees to pay for the slurry). Frequently a grain farmer's "willingness to pay" is less than the "in use" value due to quantifiable factors such as inherent nutrient variability, difficulty in calculating actual application rates, potential soil compaction, as well as many non-quantifiable factors like the social costs resulting from odor, risk of potential run-off, and the transaction costs of setting up contracts. In this study we have used the "in use" value, and defined two methods in which the costs associated with agitation/pumping, transportation and spreading of dairy slurry are met: (1) all by the dairy farmer himself, or (2) a shared scenario in which the grain farmer contributes to the overall cost of transporting the slurry.

Table 4. First year available nutrient content (kg m^{-3}) and market value (\$ ha^{-1}) of dairy slurry applied at 93.54 m^3 ha^{-1}

Nutrient	**Nutrient Price \$ kg^{-1}**	**Average Manure Nutrient Concentration**†		**High Nutrient Concentration (Mean + 1sd)**‡		**Low Nutrient Concentration (Mean + 1sd)**	
		Nutrient Composition kg m^{-3}	Market Value	Nutrient Composition kg m^{-3}	Market Value	Nutrient Composition kg m^{-3}	Market Value
N (*incorporated)*	1.09	0.99	\$100.94	1.38	\$140.70	0.60	\$61.18
P_2O_5	1.16	0.54	\$58.59	0.81	\$87.89	0.26	\$28.21
K_2O	0.47	1.85	\$81.33	2.61	\$114.75	1.08	\$47.48
Total	--	--	**\$240.87**	--	**\$343.34**	--	**\$136.87**

Corn Production with Commercial Fertilizer.

Baseline returns per hectare for a cash grain system not utilizing manure as a nutrient source, nor including any government payments, were calculated to be \$568 ha^{-1} based on the PEPS production data and 2007 fertilizer and corn prices (\$0.12 kg^{-1} [\$3.10 bu^{-1}]). Under these optimum soil test conditions farmers would apply 78 kg P_2O_5 ha^{-1} and 56 kg K_2O ha^{-1}. However, when P_2O_5 and K_2O are not limiting to corn growth as a result of high soil test levels and therefore are not included in the fertilizer purchases (except as starter) returns per hectare increase significantly to \$650.

Corn Production with Dairy Slurry.

When dairy slurry is the main source of corn nutrients, the greatest factors influencing distance traveled and profitability are: 1) payment scenario, 2) valuation of slurry nutrients (N-only vs. N:P:K), and 3) manure nutrient content. Figure 1 shows the distance that average dairy slurry can be hauled under two payment scenarios at optimum soil test levels (corn responsive to N:P:K additions). In this scenario slurry can be moved approximately 3.2 km to a dairy farmer's owned or rented land. If a grain farmer pays the additional costs after the first 1.6 km, it can then be hauled 7.6 km. Therefore, on fields that are closer, it could be quite profitable for a grain farmer to enter into this type of agreement with a dairy farmer. When the field is high in available P and exchangeable K however, no additional P and K beyond starter fertilizer is necessary, and returns per hectare for corn production increase to \$650 with fertilizer-only and slurry hauling distances decrease. For the scenario in which the dairy farmer pays all hauling costs, there is no profitable

† Average slurry nutrient content of 713 samples collected and analyzed at the UW Soil and Forage Analysis Lab in Marshfield, Wisconsin. 2002 to 2005.
‡ sd = standard deviation

distance to haul the slurry when it is only valued for its N content. In the shared scenario the breakeven hauling distance drops from 7.6 (with optimum soil nutrient levels) to 5.5 km.

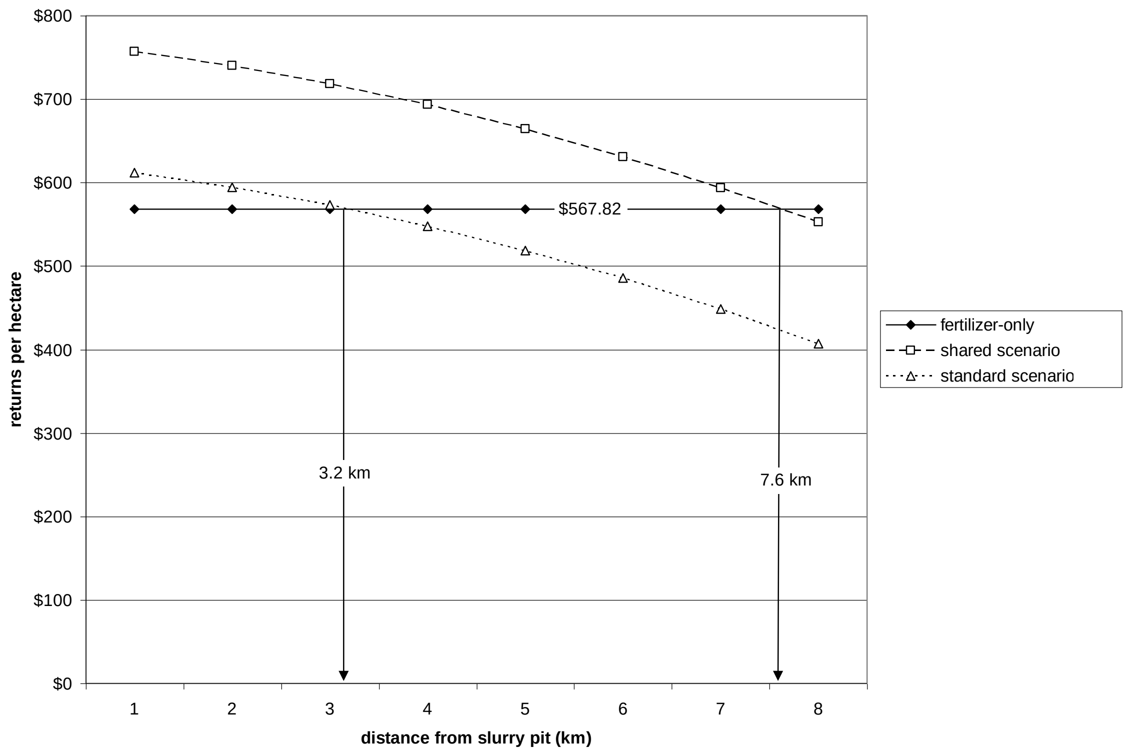

Figure 1. Effect of payment scenario (shared vs. standard) on breakeven hauling distances of dairy slurry in a corn grain system when N, P & K are all required for crop production.

Effect of Slurry Nutrient Composition on Profitability.

In addition to variability in initial soil test levels, not all manure slurry has an average nutrient content. When looking at the shared payment scenario, with soils at optimum fertility (Figure 2), dilute slurry (1 standard deviation below mean nutrient content) can be hauled to approximately 6.9 km, while more concentrated slurry (mean nutrients + 1 standard deviation) could be profitably transported in excess of 8 km from its source.

Effect of Nitrogen and Diesel Price on Hauling Distances.

Fluctuations in N price affect returns in both the fertilized and manured systems. In the shared payment scenario, on high-test soils, when N is the only limiting nutrient to corn growth, slurry can be hauled 3.6 km for lower (1999) N prices ($\$0.48\ kg^{-1}$ [$\$0.22\ lb^{-1}$]), and up to approximately 6.1 km for higher N prices (2007 + 20%; $\$1.31\ kg^{-1}$ [$\$0.59\ lb^{-1}$]). Both of these distances increase by approximately 2 km when slurry is valued for its N, P, and K content.

When diesel prices were varied from $\$0.19\ l^{-1}$ (1999 prices) to $\$0.84\ l^{-1}$ (2007 +20%), there was a 1 km change in hauling distances under both scenarios. This suggests that increasing prices of N-fertilizer will make the shared scenario more attractive to neighboring farmers, even if accompanied by higher diesel prices.

Effect of Corn Yield on Profitability.

Maintaining the assumption that corn produced with manure and commercial fertilizer will yield equivalently, a reduction in corn grain yield from the 10-year PEPS average does not change the economic relationship between the two nutrient sources (i.e. hauling distances are not affected). It does however affect the overall profitability of the two systems, lowering the returns per hectare in both the fertilizer-only and manured scenarios. Because the PEPS program represents some of the higher yielding grain producers in the state (yield = 12.1 Mg ha^{-1}) a scenario was run using the 2006 Wisconsin statewide yield average of 9.0 Mg ha^{-1} for corn grain. In this situation, corn production prior to government payments results in a greatly reduced return per hectare of $192 compared to $568 ha^{-1} when yields are 12.1 Mg ha^{-1}. When hauling costs are shared and slurry is valued for its N, P and K content, it can be profitably hauled up to 7.6 km. This is the same hauling distance reported using PEPS yield data. At 4 km, we see an increase in returns per hectare compared to when purchased fertilizer is used of $126 ha^{-1} ($318 vs. $192 ha^{-1}). Again this is consistent with our findings using the PEPS corn yield data.

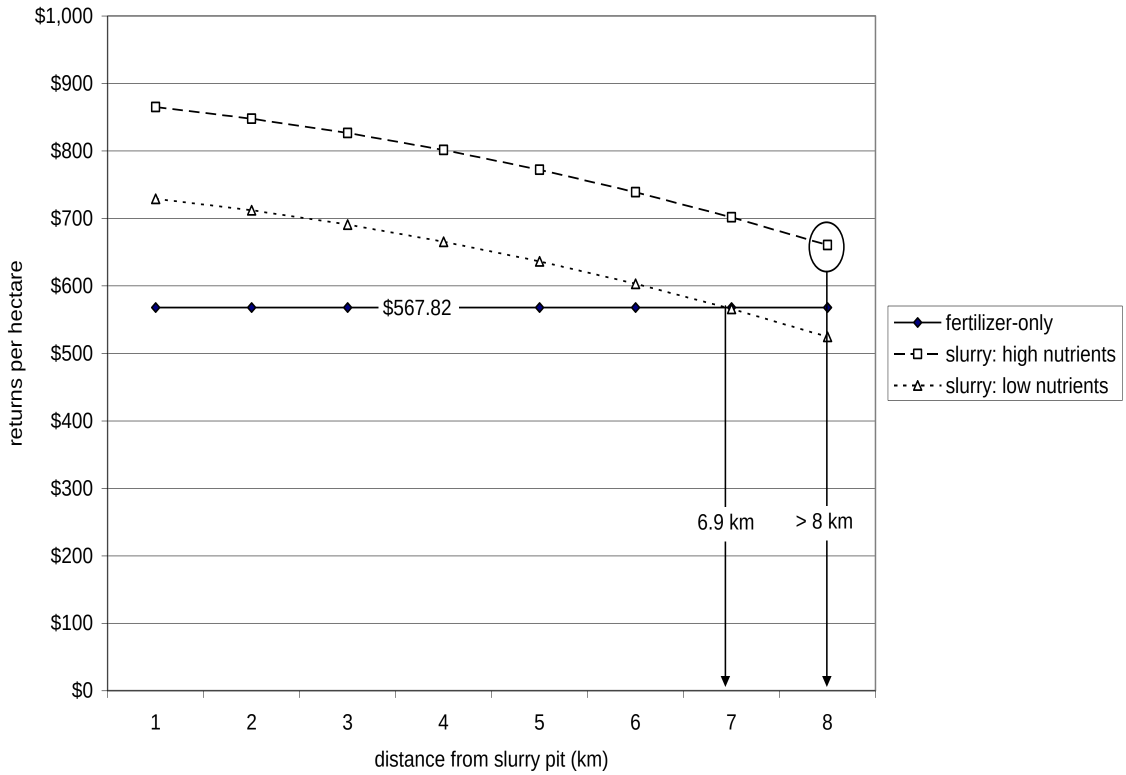

Figure 2. Effect of slurry nutrient content (mean+1 standard deviation, mean-1 standard deviation) on the breakeven hauling distance of dairy slurry in a corn grain system: N:P:K all valued.

Summary and Conclusions

Although the management and hauling of dairy slurry is expensive, this analysis shows that under a number of scenarios returns to a corn production enterprise would increase if slurry is included in the rotation – even if some of the additional transportation and spreading costs were assumed. Moving slurry off the dairy farm could have a major positive impact on the dairy's conservation plan. In the "shared scenario" the neighboring grain farmer pays for additional hauling and spreading costs after the dairy farmer pays for the initial costs of pit agitation, tank loading, and hauling the first 1.6 km. Using 2007 fertilizer prices, and dairy slurry of average composition, the breakeven spreading radius for the dairy farmer increased from 3.2 km when he covered the full costs to 7.6 km when costs were shared.

On production fields that have high soil test values, reducing the fertilizer value of the manure to only its N content, maximum hauling distances in the shared scenario drop from 7.6 to 5.5 km. Looking to the future, this analysis indicates that if N or diesel prices increased by 20% over 2007 prices, the spreading radius would increase by about 0.5 km in the case of the former and decrease by 0.2 km in the case of the latter. Although a reduction in corn grain yield affected the overall profitability of both the fertilizer-only and manured systems, the economic relationship between the two systems did not change.

What the potential consumer (the grain farmer) is willing to pay for slurry may well be lower than its estimated fertilizer replacement value. Nevertheless, this analysis suggests that even with relatively low nutrient concentration in dairy slurry, under modest hauling distances, it would be economically and environmentally advantageous to both dairy and grain farmers to develop manure contracts.

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