

Operation size effect on hauling distance requirements for feedlot and dairy excretory-P utilization on surrounding cropland

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SUMMARY

An input-output model of beef and dairy operations in northern Colorado was used to show how manure hauling costs increase as size of operation increases when manure was used to meet surrounding cropland (corn silage) phosphorus (P) fertilizer requirements. The CO₂eq greenhouse gas emissions increase from fuel use for transporting manure for this example case increased from 0.5 to 4.9 lbs per feedlot steer fed annually as operation size increased from 1000 to 100,000 head fed annually. Similarly in dairy operations, CO₂eq emissions from fuel use for manure transportation increased from 3.9 to 24.7 lbs per head annually for 100 to 4000 cow dairy operations. As fractions of total operation emissions, however, manure hauling represents a minor component of total (<0.4%). Given the northern Colorado assumptions, hauling distance for manure does increase to more than 5 miles for feedlots of 20,000 head per year or dairies with 4000 cows.

Keywords: Manure phosphorus, Greenhouse gas, dairy, feedlot

INTRODUCTION

Proper management of manure from livestock is critical to environmental quality. Phosphorus (P) is an essential nutrient for all plant life. Manure can be an excellent source of phosphorus for field crops. Concerns arise however, if the manure applied to field crops is not readily incorporated into the soil or if run-off

contaminates surface water (Colorado State University, Cooperative Extension Bulletin XCM-175 (1994)). Typically, soil and manure are analyzed prior to application to tailor application rates.

METHODS

A spreadsheet model was developed to estimate the distance required for manure distribution according to crop uptake of P for Weld county Colorado feedlot and dairy operations. The P output was calculated from dietary-P input minus product-P retention analyses characterizing Weld county production systems (Johnson, et al., 2003a,b). Typical dietary ingredient mixtures and herd dynamics were those suggested by CSU feedlot and dairy extension specialists. Milk production estimates were from Colorado Agricultural Statistics (2003) and Weld county Dairy Herd Improvement statistics from 2001. Diet dry matter intake requirements for animal maintenance, growth and milk as well as the P content of ingredients was estimated from the NRC Nutrient Requirement publications (1996, 2001).

Manure production and P content from dairy and feedlot operations were from Cooperative Extension publications (Colorado State University, Cooperative Extension Bulletin XCM-175, 1994 and 1.220, 2002). These estimates served as a means of comparison with the results from the spreadsheet model.

Phosphorus fertilization of corn was based on the P-content of corn silage harvested (Colorado Cooperative Extension Bulletin XCM-175 (1994)) and corn silage yields were based on Colorado Agricultural Statistics (2003). This hauling distance exercise also assumes that one-half of the land area surrounding any given feedlot or dairy would accept manure usage as the P-fertilizer source. Hauling distance was then calculated as:

- Miles to edge of area required = (square root of (Ac/640 x f use))/2.

- Maximum hauling distance (to corner field) = 2 x miles to edge.
- Average hauling distance = (max miles)/2, thus = miles to edge.
- Where Ac = acres of crop to use the manure P from a given operation size; f use = fraction of surrounding cropland accepting manure to meet P needs.

For example, a 500-cow dairy producing 39.75 t US of manure-P per year (from dry and lactating cows plus their replacements), spreading the manure on land producing 27 t of corn silage needing 72 lbs of P₂O₅/ac will require 1102 ac of corn silage crop to utilize the amount of P within the manure. Given these assumptions of a corn silage crop and one-half of farmers use manure, the maximum manure hauling distance is approximately 1.86 mi. and the average hauling distance 0.93 mi. from the dairy.

In the Colorado model, the amount of manure dry matter (DM) produced was estimated from the volatile solids (VS)/0.82. The weight of manure hauled was calculated assuming dairy manure was 54% DM when hauled and 68% DM for feedlot cattle manure. Fuel costs were estimated as 0.88 kcal/lb/mi (Pimental, 1980), 20.2 tonne C/TJ, and \$1.11/gal.

Carbon dioxide (CO₂) emissions from fossil fuel use during manure hauling were estimated on a per herd basis using equations from Intergovernmental Panel on Climate Change (2001). A more extensive description given in previous publications (Johnson, et al., 2003a,b).

RESULTS AND DISCUSSION

Our input-output model of Weld county feedlots predicts a 21% larger P excretion than that given in Colorado State University, Cooperative Extension Service estimates of feedlot manure P (34.6 vs. 28.5 lbs P₂O₅ per head per year for CSU spreadsheet and CES estimates, respectively). Runoff losses may account for some of this difference. Dairy cow P excretion is some 40%

higher than the extension estimates of manure-P per cow (122 vs. 86 lbs P₂O₅ per cow per year for CSU spreadsheet and CES estimates values, respectively). However, part of this difference is from the inclusion of total herd excretion including replacement heifers expressed as total P per milking cow. Another important cause of higher estimates from the current exercise is likely due to increased intakes associated with increased milk production per cow considered in the current Weld county model (24,299 lbs per year). As with the American Society of Agricultural Engineers (ASAE) estimates of VS and nitrogen excretion (Nex) for dairy cows in the US, such published estimates frequently lag behind due to continuously increasing dairy cow production levels.

Land area around a given site expands proportionally with the square of distance out from the site (Table 1). With assumptions aforementioned, a maximum hauling distance of 5 mi will allow feedlots which finish a little under 20,000 head/yr, ~ 8000 head capacity turning at 2.5 times per year, to dispose of all livestock manure on nearby corn fields as limited by manure-P content. Similarly, a 5 mi manure hauling distance will accommodate a dairy under 4000 milking cows, and developing replacement heifers (Table 1). Greenhouse gas (GHG) or carbon dioxide equivalent (CO₂eq) emissions from the combustion of diesel fuel for manure hauling over various distances indicates a non-linear relationship (Table 1). The \$ cost of hauling the manure on a per head basis also increased in a non-linear pattern, increasing approximately 10 times from the 100 head scenario to 100,000 head feedlot operations (Table 1). The cost of hauling manure increased even more dramatically in the dairy system, from \$0.18 per head for 100-head dairy to \$1.14 per head in the 4000 head dairy. The fractional \$ cost of hauling manure appears to be inconsequential, amounting to < 1% of non-feed operational totals (Table 1). Cost estimates are based on 2002 prices. It should be noted that manure hauling costs are to the field only, and

does not include loading or spreading, injection costs or the embodied costs of equipment involved. Also, manure in these simulations is assumed to be handled at 54 and 68% DM, for dairy and feedlot systems, respectively. If liquid from manure flush systems is hauled, costs will increase.

IMPLICATION

The phosphorus content of manure can be a limiting factor in application to crops. As feedlot or dairy production systems enlarge, so must the area to which manure is applied to surrounding fields. Likewise, carbon dioxide emissions from fossil fuel combustion and the \$ cost to haul manure to the cropping field increases as the operation size increases. These simulations estimate that the manure hauling distance doesn't increase to more than 5 miles for feedlots of less than 20,000 head per year or with dairies with less than 4000 cows.

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Table 1. Size vs manure hauling distance for feedlots and dairies using manure to meet the P requirement of corn silage grown on half of surrounding farmland.

Size, head/yr	Max haul, mi	Ave haul, mi	CO ₂ eq, t	CO ₂ eq, lbs/hd	Manure hauling, \$/hd	% "other" costs
Feedlot:						
1000	1.2	0.6	0.25	0.5	0.02	0.435
10,000	3.9	1.9	7.78	1.6	0.07	
20,000	5.5	2.8	22.0	2.2	0.10	
50,000	8.7	4.3	86.9	3.5	0.16	
100,000	12	6.1	246	4.9	0.23	
Dairy:						
100	0.8	0.4	0.20	3.9	0.18	0.008
1000	2.6	1.3	6.18	12.4	0.57	
2000	3.7	1.9	17.5	17.5	0.81	
4000	5.2	2.6	49.5	24.7	1.14	