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Abstract

This article discusses a study that explored choice of fields for manure application by livestock feed growers in three northern Colorado counties. Using results from a mail survey, matched pairs of manured and nonmanured fields were analyzed. Among the field characteristics considered, distance from a manure source, expected yield, cost savings through nutrient substitution, and field size were the most significant factors affecting farmers' manure-application choices. Understanding such factors may provide Extension agents with discussion points for influencing farmers to protect water quality and air quality while making their work lives easier and improving their crop yields.

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Introduction

This article discusses a study that explored livestock feed growers' choices of fields for manure application. The study involved a mail survey of farmers supporting livestock production along the South Platte River in three northern Colorado counties (Sustainable Agriculture Research and Education [SARE], 1999). Understanding the farmers' decision process was deemed important because of manure's contribution to excess levels of nutrients in the rivers and water tables of industrial-scale livestock production areas. In parts of these rural study areas, approximately 70% of the household wells were found to contain water with nitrate levels above 10 mg/L, the level designated as acceptable by the Environmental Protection Agency (EPA) (Hall, 1996; SARE, 1999). Heavy manure application densities could be reduced by applying manure to more fields, thereby covering larger areas at lower densities. Although about half of the respondents housed livestock, only 3% of this group's operations were large enough to be required to file nutrient management plans. Most operations were unregulated and free not to use best management practices if they chose not to.

Farmers are de facto stewards of the land and water. Therefore, it behooves us, as a society, to be aware of factors that affect farmers' resource management choices and the long-term ecological implications of those choices. In addition to having an impact on water quality, manure application decisions are relevant to air quality and mountain ecosystem protection. Natural resource managers and researchers have become aware of pollution and biodiversity loss resulting from airborne nutrients released through manure redistribution (Baron et al., 2000; Beem, 2008; Gebhart et al., 2011; Rueth & Baron, 2002). Farmers make decisions under conditions of ambiguity and uncertainty (McCown, 2005). McCown (2005) suggests that interested parties are more likely to successfully influence farmers' decision making not by telling farmers what they *should* do but by understanding what factors affect their decision making regarding specific resources and considering the variables particular to those decision situations. As a small step toward that end, I explored some factors related to farmers' choices of field(s) on which to apply manure.

Research Questions

This article discusses factors that make one field more appropriate, in the farmer's mind, for manure application than another field. This discussion is based on a section of the mail-survey questionnaire that addressed differences in field characteristics between a "typical manured field" and a "typical nonmanured field," for farmers who used manure on some fields. The research questions were based on the expectation that the choice of whether to apply manure on a specific field would relate to certain factors for the reasons described below.

- Distance, in miles, from a (potential) source of manure. Transportation cost is a key factor. Previous research shows that the distance is typically no more than 3–5 mi (Hall, 1996; Hoag, Lacy, & Davis, 2004; SARE, 1999).

- Field size, in acres. The farmer might attempt to match the amount of manure available with a field that would accommodate that amount, avoiding overapplication and/or the need to supplement with other fertilizer. Among operations that reported both a manured and a nonmanured field, the sizes of the manured fields ranged from 5 to 290 acres, as follows: 5–19 acres, 19%; 20–29 acres, 23%; 30–49 acres, 24%; 50–99 acres, 15%; and 100–290 acres, 19%.

- Potential or expected yield of the field, as estimated on the basis of the previous year's yield. Adding manure might be a factor for increasing yield, especially if manure is perceived as a supplement.

- Reduced commercial nitrogen fertilizer applied (measured in pounds per acre). Because manure is cheaper than commercial fertilizer, applying it reduces fertilizer input cost.

- Soil type (sandy, loam, or clay). Added manure might improve soil's nutrient composition, texture, and water-retention characteristics. Farmers rated approximately 24% of their field soils as sandy, 68% as loam or sandy loam, and 8% as clay or loamy clay. These figures were approximately the same for both manured and nonmanured fields.

- Crop grown on the field (typically corn, beets, or soybeans in the study area). Some crops benefit from manure's nutrients more than others. Approximately 73% of the manured fields were corn fields. Other crops grown on the manured fields included soybeans, beets, potatoes, wheat, hay, and assorted vegetables, and the proportion of fields planted with each of these crops was about

4%.

- Type of irrigation (furrow, sprinkler, or drip). Some irrigation systems are more likely to transport nutrients deeper into the soil, even beyond the root zones of the plants.
    - Manured fields—furrow, 65%; sprinkler, 26%; no irrigation, 9%
    - Nonmanured fields—furrow, 67%; sprinkler, 26%; no irrigation, 8%
- Ownership status of the field. Presumably, long-term improvement of a rented field would be a waste of resources because the farmer renting the field might not end up using the field for a long period. Although there were no major differences in manure application between owned and rented fields, the eastern (more rural) sample had about half the field-rental rate (17%) of the western sample (35%). (See the "Methods" section for more information about the two samples.)

Methods

The mail survey was conducted in two areas along the South Platte River in Colorado where there is a prevalence of large feedlots, supported by numerous farming operations. The first survey round was conducted in Weld County, and the second was conducted in Logan and Morgan Counties. We asked farmers to consider a typical manured field and a typical nonmanured field from their previous growing season and to answer a set of questions relating to the above-mentioned factors for each of the two fields. This methodology provided appropriate data for matched-pair comparisons of the field characteristics that might distinguish manured fields and nonmanured fields in our sample areas. Having pairs of fields matched by the operator-respondent means that each pair comparison controls for all other operation-related characteristics; only the field-specific data for the manured field and the nonmanured field are different in each case. A dozen follow-up phone interviews were conducted with a few farmers, manure hauler-spreaders, and crop consultants to gain insights into some of the mail-survey results.

In the first survey round, we addressed the questionnaires to approximately 1,100 farmers in the feedlot area of Weld County, using a list obtained from the Farm Service Agency. We sent a follow-up postcard 3 weeks later and a second copy of the questionnaire 3 weeks after that. On the basis of questionnaires returned with notes from some farmers or their families, we determined that approximately 200 of these farmers were no longer active. Given the return of 273 valid questionnaires, the return rate was approximately 30%. Two years later, we sent approximately 600 questionnaires to the farmers of a similar livestock area farther east along the South Platte River. This area included two counties (Morgan and Logan), and those lists were provided by the Colorado State Cooperative Extension Service and the U.S. Department of Agriculture's Natural Resource Conservation Service. These mailings yielded a similar return rate of around 32%. Because of the differences in time and locale of the two survey rounds, a location variable identifying each case as part of the eastern or western sample was designated. Farms in the eastern, more rural, sample were roughly twice as large in field size and total acreage. Later, the phone interviews were conducted with informants in various roles within the livestock industry to gather personal opinions to explain some of the survey results.

Results and Discussion

This section presents the statistical results found by modeling the data using conditional logistic regression. The likelihood of a farmer's applying manure to a particular field appears to be correlated (inversely) to the distance of the field from a manure source and to the expected corn-yield potential of the field. The relationship between likelihood of manure application and field size is more complicated.

Distance from a Manure Source

Distance from a manure source is inversely related to likelihood of manure application largely because transportation is a major cost factor: Longer distances result in higher transport costs (see Table 1). More than one interviewee stated that a standard practice is to haul manure from a feedlot to a field about the same distance as that from which the farmer had previously hauled corn or silage *to* the feedlot (or even to the same field). This practice apparently represents a "nutrient replenishment," or "nutrient recycling," approach. The fact that farmers actually follow this practice is corroborated by the relationship of the variable "Expected Yield" and the odds of a field being manured (see Table 1).

Expected Corn Yield

Expected corn yield is positively associated with using manure. This may be because applying manure to a high-yield field does not likely harm the yield, and might even boost it. A lower yield expectation might lead a farmer to stick with the more conventional (and possibly more reliable) approach of using strictly commercial fertilizers. This finding is consistent with a study indicating that farmers are less interested in monitoring the amount of nitrogen applied to a crop where they rely on manure to supply much of the nitrogen (Wortmann, Koelsch, Shapiro, Deloughery, & Tarkalson, 2005). Several interviewees mentioned that a field is often used to produce corn for several seasons in a row. So the reported yield may have been boosted additionally by fertilizer and manure applied over a period of several years.

Table 1.
Conditional Logistic Regression of Manured/Nonmanured Fields

	Model 1		**Model 2**		**Model 3**	
VARIABLES	b (*SE*)	*OR*	b (*SE*)	*OR*	b (*SE*)	*OR*
Distance (mi) to a manure source	-0.272** (0.113)	.761**	-0.254** (0.128)	0.775**	-0.283* (0.160)	0.753*
Field expected-yield (standardized	1.099** (0.460)	3.001**	1.789*** (0.570)	5.983***	1.763*** (0.562)	5.830***

)			
Commercial nitrogen applied (lbs/ac)		-0.0235*** (0.0056) .977***	-.0258*** (0.0064) 0.974***
Field size			-.0376* (0.0204) 0.963*
Interaction - field size*Eastern (more rural sample)			0.0303 (0.0219) 1.031
N - matched field pairs	111 pairs	105 pairs	101 pairs
Pseudo R2	.106	.362	.408

Dependent variable: Field was Manured (1) or Not Manured (0). OR = odds ratio. Standard errors are shown in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

Reduction of Commercial Nitrogen Fertilizer Applied

Reduction of commercial nitrogen fertilizer applied provides a distinct cost savings. Substituting manure as fertilizer for its cost reduction creates reliable savings. Whether a farmer chose to lower operation cost for a field by applying manure or chose to apply manure to the field and was thereby able to reduce commercial nitrogen applied is not clear, as this analysis only indicates correlation. The relationship is consistent with either decision type.

Field Size

Field size has a complicated relationship to likelihood of manure application. Because manure is available in finite amounts and farmers often prefer to handle an entire field uniformly, we might expect smaller fields to get manured. However, one farmer explained, larger fields are more suited for efficient manure spreading because less vehicle turning is required. Commercial fertilizer is lighter and easier to apply and can be applied in virtually any amount; matching supply to fields is not an issue. Size of a field, thus, has countervailing implications, which may imply interactions with other factors. In Model 3 (Table 1), the interaction of field-size with sample location is included. The eastern sample had notably larger fields, and its typical manured fields were larger than the nonmanured ones. For future research, field size could be considered in conjunction with amount of manure available.

Location

Location was a significant factor. The effect of yield was somewhat different between the two areas studied. This may involve physical and cultural differences between these areas. One area receives about 40% more annual precipitation, and in one area, there is a higher diversity of crops. While this relationship was not as statistically significant, it was nevertheless substantive and would be worth exploring through further research comparing the manure management criteria of farmers in different counties or regions. In Model 3, I have included location in interaction with field size.

Field Ownership

Field ownership data showed that rented fields were more likely to be manured than owned fields, possibly as a less costly way to maximize yield than using commercial fertilizer. A typical farmer may see the extra cost of renting the field as a reason to keep other costs down for that field. Because this relationship was not statistically significant, it was not included in the models.

Other Factors

Other factors were not statistically significant but did show a tendency toward influencing manure-application decisions, and some of these were mentioned by interviewees. Soil testing, where it is used, can indicate the need for organic matter and other nutrients. One hauler-spreader said he recommends basing manure-application choice not on a need for nitrogen but rather on the idea of supplementing soil organic matter. For nitrogen, he recommends spreading commercial nitrogen. A dairy operator expressed his disagreement with water-quality regulations that limit manure application on sandy soils; he said that these soils are exactly the ones needing augmentation through the addition of manure's organic matter and nutrients. Soil fertility, he said, is the key to healthy plants that can effectively use excess nutrients.

Conclusion

In this study of northern Colorado farmers, the most significant criteria in a farmer's choice of fields for manure application are characteristics that reduce the overall cost of fertilizing through substitution of manure while still obtaining a high expected yield. Although manure-management best management practices typically emphasize strategies such as containment of manure away from open water flows, use of grass filter strips, and agronomic application rates, farmers' decisions are also influenced by field-specific factors. Like many farming decisions, the choice of fields on which to apply manure appears, not surprisingly, to be driven largely by the bottom line. Any attempt to influence manure management practices, whether to protect water quality or air quality, are more likely to be effective if they reduce costs and/or provide increased likelihood of financial success for the operation.

Understanding and discussing pragmatic issues such as those described above may help Extension agents encourage practices that protect water quality and air quality while making farmers' work lives easier and improving yields. For example, an agent might discuss the value of substituting manure for commercial fertilizer in relation to the expected yield for the field. Or an agent could help a farmer identify the benefits of applying manure on a field that might otherwise have been perceived as too small or too large to be appropriate. Avoiding manure application on windy days might be seen as beneficial in that more nitrogen might actually be incorporated into the soil and become available to crops. In some cases, special incentives, or at least some additional benefit to the farmer, might be required to achieve cooperation.

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