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Manure Transfers in the Midwest and Factors Affecting Adoption of Manure Testing

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Using manure as a substitute for commercial fertilizer could potentially reduce fertilizer costs and also reduce non-point source pollution. Livestock farmers in Missouri and Iowa were surveyed regarding their manure management practices. Eighty-one percent of turkey farmers versus 5% of beef farmers transferred manure to other farmers. Fifty-one percent of farmers who transferred manure indicated it had been tested. Factors decreasing adoption included higher off-farm incomes, solid versus liquid manure, and more animal units per acre. Factors increasing adoption included distance transferred, a contract for the manure, payment, and thinking that manure testing was profitable.

Key Words: manure markets, manure testing, nutrient management

JEL Classifications: Q12, Q15, Q16

Agricultural runoff contributes a high percentage of non-point source water pollution in the United States, and livestock manure is a major contributor (Abdalla and Lawton, 2006; Ribaudo et al., 2011; Smith, Schwarz, and Alexander, 1997). Agriculture has become more specialized than in the past, resulting in some farmers with no livestock and others with livestock but essentially no land for manure application. This results in more complex manure management issues than on diversified farms (Ribaudo et al., 2003). Farms specializing in livestock may not have enough land to apply their manure in line with crop needs and the excess nutrients may cause water quality problems.

There are potential on-farm issues as well since the emission of nutrients is also a loss for the individual farmer in terms of wasted resources (Asche, Roll, and Tveteras, 2009; Griffin and Bromley, 1982). The use of manure as a substitute for increasingly expensive commercial fertilizer by crop farmers may be a viable option to provide income for livestock farmers and reduce nutrient pollution. If crop farmers replace some fertilizer with manure from livestock farmers who might otherwise over-apply it due to limited land area, it may result in fewer excess nutrients being applied overall (Bosch and Napit, 1992; Van Dyke et al., 1999). However, this will only occur if both transferred manure and commercial fertilizers are properly applied as far as quantities and timing.

The nature of these manure transfers and markets for manure are topics that have not been extensively studied. Interest is increasing

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though, due to fertilizer costs, renewable energy, and water quality issues (e.g., Carreira et al., 2007; Jensen et al., 2010). In the Chesapeake Bay area, active efforts are underway to facilitate manure transfers, especially of poultry manure, to improve water quality (e.g., Collins and Budumura, 2005). These efforts are likely to increase given the total maximum daily load (TMDL) that was implemented in late 2010.

There are however, disadvantages of using manure, such as the transportation costs of manure, weed seeds, and odor (Collins and Budumura, 2005; Norwood, Luter, and Massey, 2005). In addition, the heterogeneous nature of manure, which is due to differing dry matter content and volatilization of nitrogen compounds such as ammonia, is problematic. The composition of manure at excretion varies due to diet and species (dairy having the highest water content and poultry the lowest), and after excretion due to manure collection, storage, and handling conditions (Van Horn, 1998). While almost all phosphorous in manure can be collected and used as fertilizer, and while over 60% of nitrogen could be collected under ideal farm conditions, only 40% of the nitrogen is typically available (Van Horn, 1998). This represents a wasted resource as well as a source of air pollution (Ribaudo et al., 2011).

Given the variable composition of animal manure, the level of uncertainty when using manure is higher than for commercial fertilizer. Farmers thus need to test it for its nutrient content frequently to reduce this uncertainty (Halstead, Kramer, and Batie, 1990). In addition, best management practices (BMPs), such as manure testing, can help to improve water quality. Nonpoint source pollution will be reduced if manure is not applied in excess of crop nutrient requirements and if fertilizer applications take account of manure nutrients.

The use of soil testing is well-established and it has been widely studied. Manure and soil testing are complementary BMPs that when practiced together can decrease water pollution. Comprehensive nutrient management plans (CNMPs) created for livestock farms therefore incorporate both of these practices. CNMPs are required for concentrated animal feeding operations (CAFOs) and for farms participating in some government programs (U.S. Department of Agriculture Natural Resources Conservation Service, 2003).

The current literature on the testing of manure for nutrient content is much less developed than that for soil testing, and adoption rates are lower. For example, survey results from 994 dairy farms in Pennsylvania indicated that 77% checked the box "none" for manure testing of nutrients, while only 20% tested for nitrogen, phosphorous, and potassium (Dou et al., 2001). Furthermore, more respondents tested their soil than tested manure, and more also kept track of soil testing records than manure testing records (Dou et al., 2001).

This paper analyzes data collected from a survey of 3,000 Iowa and Missouri livestock farmers who were asked questions about their manure management practices. Previous research using this dataset found that only 20%[1] of livestock farmers tested their manure at least annually (Gedikoglu and McCann, 2012). Factors increasing adoption were size of farm, perceived profitability of the practice, and whether they agreed the practice was time-consuming. Factors decreasing the likelihood of adoption were off-farm income over $100,000, having solid or both solid and liquid manure versus liquid manure, agreeing the practice improved water quality, and agreeing that the practice was complicated.

This research uses a subset of the data to examine the issue of manure transfers off the farm and the factors affecting whether that manure was tested for nutrient values. As indicated above, interest in manure transfers is increasing since it has the potential to improve water quality if the manure is applied appropriately. However, if the manure is not tested, environmental improvements are less likely. The increasing cost of commercial fertilizer is motivating interest in manure as a substitute so information on nutrient content can also improve profitability. To our knowledge, the rate of manure testing for transferred manure and factors affecting adoption of

[1] That research excluded CAFOs to focus on voluntary adoption. When CAFOs are included, the adoption rate for the whole dataset is 22%.

this practice have not been examined previously. Additional factors may be relevant, which could affect extension program design. Our survey asked respondents whether manure was transferred to other farms, whether that manure was tested for nutrient content, and various characteristics associated with the manure transaction.

In the next section, the literature on adoption in general, and the adoption of nutrient-related practices in particular, is presented. This leads to the presentation of our empirical model. The results on the nature of manure transfers in the Midwest as well as the regression examining the factors affecting manure testing are then presented.

Literature Review

This analysis will focus on manure testing that has been done on manure transported off the farm. Since no research has been conducted on this specific issue, the literature review will address a variety of factors that affect whether or not farmers adopt manure testing and other environmental practices. The general literature on adoption in both the economics and sociology disciplines is extensive (see publications by Feder, Just, and Zilberman, 1985; and Rogers, 2003). Recent comprehensive reviews relating to agri-environmental practices include Prokopy et al. (2008) and Pannell et al. (2006). In what follows, we present the more general literature relating to a variable of interest first and then the literature relating to nutrient management and manure testing, as available.

Characteristics of Adopters

The use of agricultural technologies and practices varies by socioeconomic characteristics such as age, education, off-farm income, and environmental attitudes. Age negatively affects technology as well as practice adoption (Rogers, 2003). The adoption of agricultural BMPs (Knowler and Bradshaw, 2007; Prokopy et al., 2008) and the adoption of nutrient management BMPs (Walton et al., 2008; Weaver, 1996) decreases for older farmers. Halstead, Kramer, and Batie (1990) found that younger dairy farmers in Virginia were more likely to express interest in a manure testing service. In this analysis, the variable age is expected to have a negative influence on testing manure transferred off the farm.

Higher levels of education increase technology and practice adoption (Rogers, 2003). Higher levels of education lead to the adoption of management-intensive BMPs such as soil testing, conservation tillage, integrated pest management, and insect management technology (Fuglie and Kascak, 2001; Prokopy et al., 2008). In a study of the beef cattle production industry in Louisiana, the adoption of nutrient management BMPs increased as the level of the farmer's education increased (Kim, Gillespie, and Paudel, 2005). However, Halstead, Kramer, and Batie (1990) did not find education to be a significant factor affecting potential adoption of manure testing in Virginia, and Weaver (1996) found a negative effect on manure nutrient management among Pennsylvania farmers. Manure testing, and effectively using that information, is a management-intensive practice and thus requires higher management ability. Individuals with higher education are better able to understand the benefits of using manure nutrients more precisely (Ribaudo and Johansson, 2006; Walton et al., 2008). Higher education levels are thus expected to result in higher rates of adoption in our study.

Off-farm income affects whether agricultural producers will adopt a technology or practice although the direction of the impact varies by study (Gedikoglu, McCann, and Artz, 2011). In general, those with low off-farm incomes spend more time on the farm, and are more familiar with agricultural issues than those farmers who are employed off the farm, thus making them more likely to adopt agricultural technologies (e.g., Dorfman, 1996). Jensen et al. (2010) found poultry producers with a higher percentage of off-farm income were less likely to express interest in an energy cooperative. Lambert et al. (2006) found that management intensive BMPs such as pest management and nutrient management were more likely to be adopted by larger farms whose primary occupation was farming. We expect that since manure testing is management intensive and since those with no off-farm income may have an incentive to use manure nutrients more carefully to reduce fertilizer costs, those with no off-farm income will be more likely to test manure.

Farm Characteristics

The characteristics of the farm such as soil and climatic factors, size, and compatibility with the existing farming system, can also affect adoption of new agricultural practices and technologies. Areas that produce crops with high nutrient requirements would be more likely to adopt nutrient management practices since the benefits of gathering and using that information would be higher. Farms located in Illinois, Indiana, or Iowa are more likely to use precision technologies (Daberkow and McBride, 1998) due to the intensity of crop production, especially corn production, in these states. Hoag and Roka (1995) found that manure nutrients were more carefully managed in Iowa than in North Carolina. Benson, Farrand, and Young (2000) found that net phosphorous demand (crop requirements minus manure P available) was higher in Iowa than Missouri. Based on the literature, we expect Iowa farmers to be more likely to test manure transported off the farm than those in Missouri.

Farm size (often measured by acres or sales) positively affects the adoption of technology (Feder, Just, and Zilberman, 1985) and BMPs (Daberkow and McBride, 1998; Lambert et al., 2006; Prokopy et al., 2008). Larger size increased adoption of precision soil sampling (Walton et al., 2008), soil testing, integrated pest management, and conservation tillage (Fuglie and Kascak, 2001). Larger Iowa farms were early adopters of Nitrogen-Trak kits (Contant and Korsching, 1997). With livestock farms, the effect of size may be accentuated since CAFOs are required to have CNMPs. Contractual relationships may also affect adoption of some practices. A study of dairy farmers in Louisiana showed that larger farms were more likely to adopt BMPs than smaller farms (Hall et al., 2007). Larger sized farms will adopt other manure management techniques such as CNMPs and the use of phytase (Key, McBride, and Ribaudo, 2008). Larger farms were more inclined to adopt manure testing than smaller farms (Cooper and Keim, 1996; Halstead, Kramer, and Batie, 1990). The Halstead article included two measures of size, corn acres and number of cows but only the latter significantly affected interest in manure testing. The Cooper and Keim article found that both total acres and net farm income were significant. Rather than traditional measures of size, the ratio of animals to land may be of interest. Farmers who have more animals and also have more acres can substitute manure for fertilizer but if they have excess manure relative to crop needs, the fertilizer savings due to more precise application are low. These farmers would be more likely to view manure as a disposal issue rather than as a nutrient resource. In this study, the variable animal units (AU, as defined by EPA[2]) divided by total acres is expected to have a negative influence on manure testing.

Manure testing can depend on whether the agricultural producer is utilizing solid or liquid manure, and whether there are adequate storage facilities for the manure. Gedikoglu and McCann (2012) found that farmers who had liquid manure were more likely to calibrate manure spreaders and test manure, in part due to the greater variability in nutrient content of liquid manure. Farmers who had adequate manure storage capacity were more likely to conduct manure testing (Halstead, Kramer, and Batie, 1990; Nowak, Shepard, and Madison, 1998). Those with little or no storage capacity may view manure as more of a disposal issue. We expect farms with liquid manure and those with more storage capacity to be more likely to test manure.

The adoption of a variety of BMPs such as soil and manure testing should occur if

[2] Animal units were calculated from livestock numbers using conversion factors from the Environmental Protection Agency to make different types of livestock comparable. The conversion factors used were the following: dairy cow = 1.4 animal units, fed beef cattle = 0.7, beef cow = 1, swine < 55 lbs = 0.05, swine > 55 lbs = 0.3, broilers = 0.003, and turkeys = 0.011.

a livestock producer is using a CNMP to address issues such as water quality and soil health since they are required components. Having a CNMP has been shown to be a positive influence on manure testing (Halstead, Kramer, and Batie, 1990). Also, a CNMP is legally required for some types of operations. The variable CNMP is thus expected to have a positive influence on manure testing.

Manure Transfer Characteristics

As indicated in the introduction, while manure can be a source of valuable nutrients, and have other positive impacts on soil quality, crop farmers are reluctant to use it for a variety of reasons including odor, weed seeds, transportation costs, and uncertainty (Collins and Budumura, 2005; Nunez and McCann, 2008; Ribaudo et al., 2003), which affects their willingness to pay for manure (Norwood, Luter, and Massey, 2005). Nevertheless, manure transfers occur and manure often has a positive price. Manure can be a substitute for fertilizer if unit costs of manure nutrients, including costs such as hauling distance, hauling cost, amortized equipment cost, and application costs (Hoag, Lacy, and Davis, 2004), are lower than using commercial fertilizer.

The physical distance between sellers and buyers affects the sale of manure, since search costs are increased if people are not neighbors and since hauling costs rise as distance increases. The transportation of manure is thus fairly limited according to the literature (Hoag, Lacy, and Davis, 2004). Dilution of nutrients in liquid manure means that the transportation cost is higher per unit of nutrient compared with solid manure, but our study controls for that with the manure type variable. Buyers will have an incentive to purchase manure that has already been tested with known nutrient value if they are incurring higher transportation costs. In this analysis, the distance manure was transferred is expected to positively affect manure testing.

Contracts between buyers and sellers facilitate the exchange of quality goods and services (Hart and Moore, 1988), and are formed under the presence of transaction costs. These in turn are influenced by the level of uncertainty, frequency of trade, and the amount of transaction investment related to the trade (Williamson, 1979). If there is a contract between a buyer and seller of manure, both benefit from manure testing. The seller has an incentive to test the manure for nutrient value to ensure that the product has the nutrient value stipulated in the contract. Similarly, the buyer has an incentive to purchase a product that has been tested for nutrient value to make better decisions about the use of other inputs such as fertilizer. On the other hand, enforcement of informal contracts among agricultural producers is quite effective given that interaction between individuals is high. In addition, a reputation effect can discourage shirking since individuals are expected to interact in the future as well (Shelanski and Klein, 1995). In this study, having a written contract for the manure transfer is expected to be a positive influence on manure testing.

Whether farmers are paid for manure is expected to affect manure testing since buyers are presumably paying for the nutrients in the manure as a substitute for fertilizer. Schnitkey and Miranda (1993) concluded that separate increases in livestock profits, crop prices, and fertilizer prices would lead to an increased use of manure by farmers. This is similar to Hoag and Roka (1995) who found that the value of manure is determined by factors such as crop prices, and the total quantity of manure produced. However, farmers recognize the other benefits of manure use, including improved soil structure, higher organic matter, increased water retention, and micronutrients (Hoag, Lacy, and Davis, 2004). If farmers pay for manure, they are demonstrating that they value it as a source of nutrients and a soil amendment, but these farmers also would want to ensure that they are getting what they paid for. In this analysis, the variable payment for manure is expected to positively affect manure testing.

Perceptions about Manure Testing

Adoption also depends on the perceptions about the specific practice (Rogers, 2003). The adoption of BMPs increases with the perception that the adoption of BMPs is profitable (Prokopy et al., 2008). Lambert et al. (2006) conclude that the adoption of three management intensive BMPs was higher among commercial farmers because they viewed the practices as profitable. Profitability and low costs were major determinants of whether or not Iowa swine farmers use manure management techniques that improve nutrient capture (Fleming, Babcock, and Wang, 1998). Manure testing will help to decrease input costs such as commercial fertilizer because it enables farmers to complement manure nutrients with specific amounts of fertilizer nutrients to meet crop nutrient requirements (Lory and Kallenbach, 2008; O'Donoghue, MacDonald, and Nehring, 2005). The actual cost of manure testing is relatively low in the Midwest, about $40 per sample. One sample per year is required to comply with a CNMP (Lory, 2012). The variable "This practice is profitable, it improves my bottom line" is expected to positively affect manure testing. The variables "This practice is time consuming" and "This practice is complicated" will decrease adoption of manure testing.

Awareness of the effects of conservation behavior on the environment as well as environmental attitudes affect the likely adoption of BMPs (see reviews by Knowler and Bradshaw, 2007; Pannell et al., 2006; and Prokopy et al., 2008). Individuals must have knowledge about the environmental impacts of their actions but also be motivated to act on that knowledge. Knowledge of the environment positively correlates with adoption of BMPs. For example, in a study of Oregon watersheds, informing other agricultural landowners about conservation practices positively affected the use of agricultural BMPs (Habron, 2004). Other studies such as Lynne, Shonkwiler, and Rola (1988) have shown that those who have strong views on the use of non-renewables will spend more effort on conservation. Studies examining both profit-related and environment-related variables affecting adoption of nutrient management technologies found that profitability was a stronger predictor than environmental attitudes (Contant and Korsching, 1997; Gedikoglu and McCann, 2012; Weaver, 1996). In this analysis, the Likert scale variable "This practice improves water quality" is expected to either increase or have no effect on adoption of manure testing.

Risk or uncertainty associated with a practice has been found to affect the adoption of agricultural practices (Feder, Just, and Zilberman, 1985). The adoption of technology by farmers also depends on the individual's attitude regarding risk. Those farmers who are less risk averse are more likely to adopt BMPs (Prokopy et al., 2008). The observed overapplication of commercial fertilizers may occur to minimize the risk of lower yields (Ribaudo et al., 2011; Sheriff, 2005). The heterogeneity of manure raises the issue of uncertainty with respect to manure as a substitute for commercial fertilizer. More specifically, the level of nitrogen in manure is not known without testing (Wang and Sparling, 1995). It has been found that farmers who use both manure and fertilizer are more likely to over-apply nitrogen than those who only use commercial fertilizer, which may reflect their need to dispose of manure (Ribaudo et al., 2011). The levels of uncertainty regarding the use of manure as an input will decrease once testing is implemented, since actual levels of nutrients will be known (Liu, Zhang, and Jiang, 2009). Manure testing, especially for liquid manure, can thus be a risk decreasing technology.

Empirical Model

The empirical model for whether agricultural producers tested the manure transported off the farm for nutrient content is based on findings from the literature. The dependent variable *TEST* took on binary values, whether the manure was tested or not. According to the literature review, there are a number of variables that are predicted to affect adoption of manure testing in general, and also manure transported off the farm. Farmers who are younger (Halstead, Kramer, and Batie, 1990; Walton et al., 2008) and more educated (Walton et al., 2008) are more likely to adopt manure testing. Those with more off-farm income are less likely to adopt manure testing (Gedikoglu and McCann, 2012; Lambert et al., 2006). Farmers from Iowa are expected to be more likely to adopt nutrient management practices (Daberkow and McBride, 1998). Although the literature indicates that size of farm will have a positive impact on adoption (Cooper and Keim, 1996; Gedikoglu and McCann, 2012; Halstead, Kramer, and Batie, 1990), we expect the ratio of animal units to total acres to have a negative effect on adoption. Those with a high AU/acres ratio will be more likely to have excess nutrients and thus less likely to benefit from manure testing, all else equal. Having liquid manure (Gedikoglu and McCann, 2012), more storage capacity, and a CNMP (Halstead, Kramer, and Batie, 1990) will increase adoption.

In addition, the transaction characteristics are expected to increase adoption. Manure that was transported a greater distance, was subject to a contract, and was paid for will be more likely to be tested. Although these characteristics have not been previously related to manure testing, they follow from research on the value of manure by Hoag, Lacy, and Davis (2004) and others. Perceptions regarding profitability of manure testing (Gedikoglu and McCann, 2012) and a positive effect on the environment (Prokopy et al., 2008) are expected to increase adoption. Perceptions that it is time-consuming or complicated are expected to decrease adoption. The following variables are thus hypothesized to affect the adoption of manure testing:

Age (−), *Education* (+), *Off-farm income* (−), *Iowa* (+), *Aggregate Animal Units/Crop Acres* (−), *Liquid Manure* (+), *Manure Storage Capacity* (+), *CNMP* (+), *Distance* (+), *Contract* (+), *Payment for Manure* (+), *Perceived Profitability* (+), *Time Consuming* (−), *Complicated Practice* (−), *and Improves Water Quality* (+).

Data and Methods

The data for this analysis was collected from a mail survey of 3,000 Iowa and Missouri livestock farmers (half in each state). The survey was conducted in spring 2006. Farmers were asked questions about their manure management and the factors that impacted their decisions. More specifically these farmers were asked questions about manure management BMPs, including manure testing, as well as about manure transfers. The design of the survey used the methodology developed by Dillman (2000). Our pretest resulted in minor modifications of the survey instrument. The final survey was sent out with a signed cover letter and a return postage-paid envelope. Two weeks later a reminder postcard was sent and the full packet was resent to those who had not responded. The survey resulted in an effective response rate of 37.4%.

Respondents who answered yes to the question of whether they provided manure to other farm operations or individuals in the past two years comprised the subset for this study. After deleting observations with missing responses to some questions, the resulting sample size was 138. The respondents were asked whether they or the farmer receiving the manure tested it for nutrient content before applying it, and this was used as the dependent variable. Given the wording of the question, we cannot distinguish whether the sellers or the buyers tested the transferred manure. Given that we surveyed livestock producers (the sellers) we may be underestimating the level of manure testing since the sellers would only be aware of testing by buyers if they were told. However, John Lory (2012) indicates that buyers in the Midwest seldom test the manure themselves. Angela Rieck-Hinz (2012) indicates that in Iowa, if manure is tested, it is tested by the originators of the manure. This is due to the nature of Iowa's manure regulations. A separate question on the survey asked whether the farmers tested manure annually. Eighty-three percent of the farmers who said the transferred manure was not tested did not test manure annually. Of those who indicated the manure transferred in the last two years was tested, 76% tested their manure annually. These results, plus the data in Table 1 showing that suppliers and custom applicators applied most of the manure, support our emphasis on the sellers.

Some questions used a Likert scale to gauge respondents' beliefs or level of agreement with various statements. Respondents ranked their answer choices using a scale where one was strongly disagree, three was neutral, and five was strongly agree. For this analysis these responses were made into categorical variables; answer choices four and five became agree, three was neutral, and answer choices one and two became disagree which served as the base category.

Maximum likelihood was used for this binary response model. The density of y_i given x is (Wooldridge, 2002):

$$F(y|x_i;\beta) = [G(x_i;\beta)]y\,[1 - G(x_i;\beta)]1 - y,\ y = 0,1.$$

The log-likelihood function takes the following form:

$$\ell i(\beta) = y_i \log[G(x_i\beta)] + (1 - y_i)\log[1 - G(x_i\beta)]$$

and the log likelihood for sample size N is denoted by

$$L(\beta) = \sum\nolimits_{i=1}^{N} \ell_i(\beta),$$

where $G(\circ)$ is the logistic cumulative distribution function and $\hat{\beta}$ is the logit estimator. Analysis was conducted using SPSS software (SPSS, Inc., Chicago, IL).

Results and Discussion

Table 1 presents some general findings on manure transfers by species for the full dataset. Most studies of manure management focus on a specific livestock species so this dataset is unusual in that it allows us to compare species using the same survey instrument. In our dataset, beef cattle farms have the most acres (owned plus rented), followed by beef cow and swine finishing operations, while turkey farms have the least. Dairy farmers spend the highest number of hours per year applying manure so in addition to the labor-intensive nature of milking, they also spend about four hours per week applying manure. Broiler and turkey operations were much more likely to transfer manure off the farm, which may be related to the nature of this farming system and the high dry matter content of the final product mentioned earlier. The beef operations were the least likely to transfer manure, perhaps due to their larger acreages for application or to manure being more difficult to collect from

Table 1. Manure Application and Transfers Off the Farm, by Species

					For Those Who Transferred Manure:				
							Who Applied Manure? (%)		
Livestock Species	No. of Farms	Total Acres	Average Hours/ Year Applying Manure[a]	Percent who Transferred Manure	Average Maximum Distance, in Miles[b]	Percent Who were Paid for Manure	Custom Applied	Recipient Applied Manure	Supplier Applied Manure
Dairy cows	176	460	225	13.07	2.35	26.09	26.09	21.74	43.48
Fed beef cattle	170	811	159	5.29	2.05	11.11	22.22	0.00	55.56
Beef cows	147	718	66	5.44	2.78	25.00	14.29	28.57	42.86
Swine < 55 lbs	30	453	59	26.67	2.95	12.50	37.50	12.50	50.00
Swine > 55 lbs	205	686	119	29.27	4.25	23.33	37.29	11.86	49.15
Broilers	59	501	115	57.63	14.78	82.35	72.73	12.12	15.15
Turkeys	103	304	85	81.55	13.66	83.33	32.53	30.12	31.33

[a] Average of responses to the question "Approximately how many hours per year do you spend applying manure?".
[b] Relating to manure transfers, farmers were asked "What was the maximum distance the manure was transported?".

feedlots versus barns. Swine operations were intermediate.

Respondents who transferred manure were examined in more detail. Similar to the finding regarding the percentage of broiler and turkey operations on manure transfers, their manure was also transferred a longer distance, about 14 miles on average versus less than three miles for most of the other types of livestock. They were also more likely to be paid for their manure. None of the farmers indicated that they paid someone to accept their manure. We also asked who applied the transferred manure. Broiler manure was much more likely to be applied by custom applicators than the other types of manure. Turkey manure was applied about equally by custom applicators, the recipient, and the supplier. In all cases, more suppliers than recipients applied the manure and this difference was greatest for the manure from beef cattle operations. Together, sellers and custom applicators account for 64 to 88% of the manure applications. It is clear from the information in Table 1 that species differences exist for manure, which affect the perceived value of that manure and thus payment. It is also clear, in line with the literature, that most manure is transported very short distances so even county-level data on nutrient balance will overlook some localized areas with high potential for excess nutrient applications.

Farmers who answered yes to whether their manure was transferred to other farms represent the dataset for our analysis of factors affecting manure testing. Since species may be correlated with other aspects of the farming system such as AU/acre and type of manure, species are not included in the subsequent analysis. The descriptive statistics for this analysis are listed in Table 2. Nine farmers who indicated "Don't know" for the dependent variable were removed from the dataset. Fifty-one percent of the manure that was transferred was tested for nutrient content (versus 22% for the full dataset). This supports the hypothesis that manure transfers have value. The average age of respondents from the subset was 49 years old. As far as highest level of education achieved, 40% had a high school diploma, with the second most common category being 30% with some college or vocational school. The portion of respondents who reported no off-farm income was about 31%.

For these operations, the average number of animal units (as defined by the U.S. Environmental Protection Agency) was 1,170, while the average farm size was 358 acres. Compared with the farm sizes in Table 1, these have fewer acres. Fifty-eight percent of operations have only solid manure and 16% have only liquid manure, while the rest have both types on the farm. Fifty-one percent of these farmers reported that they had prepared a CNMP approved by the U.S. Department of Agriculture Natural Resources Conservation Service.

The mean maximum distance between buyers and sellers was eight miles. This is higher than the mean for all species except broilers and turkeys and is affected by the long distances some of the turkey manure was transported (100 miles, versus a maximum of 12 miles for both types of swine manure). The mean is also affected by the fact that turkey/poultry operations accounted for slightly over half of the observations of farmers who transported manure off the farm. Only 11% of respondents used a written contract for their manure transfer, but despite the low number of contracts written, 57% of respondents were paid for manure. The lack of contracts in this type of exchange could imply that the transaction costs associated with contracting are too high, thus causing buyers and sellers to exchange manure based on informal rules such as social norms. Given the short distances that most manure is transferred, they are likely to know each other well.

Using the descriptive statistics for farmers who transferred manure, the perception of whether or not manure testing is regarded as profitable, time consuming, or complicated was also examined. The proportion of respondents that agreed manure testing was profitable was 56%, while 34% thought it was time consuming and only 16% thought it was complicated. Furthermore, 59% of respondents agreed that manure testing improved water quality.

The survey question of "Did you or the person you sold manure test it?" formed the dependent variable. A number of tests for

Table 2. Descriptive Statistics: Factors that Affect Adoption of Manure Testing ($n = 138$)

Variable	Description	Mean	SD	Range
Dependent variable				
"Did you or person you sold manure test it?"	1 = Yes, 0 = No	0.51	0.50	0–1
Farmer characteristics				
Age	Age in years	49.00	11.21	25–93
Education	Categorical variable			
Less than high school		0.13	0.34	0–1
High school diploma	Base category	0.40	0.49	0–1
Some college or vocational school		0.30	0.46	0–1
Bachelor's degree and graduate degree		0.17	0.38	0–1
Off-farm income	Categorical variable			
None	Base category	0.31	0.46	0–1
$0 to $9,999		0.14	0.35	0–1
$10,000 to $24,999		0.16	0.37	0–1
$25,000 to $49,999		0.25	0.43	0–1
$50,000 to $99,999		0.11	0.31	0–1
$100,000 or more		0.03	0.17	0–1
Farm characteristics				
Location	Iowa = 1; Missouri = 0	0.47	0.50	0–1
Aggregate animal units	Animal units	1170.00	1990.73	8–20820
Farm size	Number of acres owned + rented − rented out to others	358.40	526.34	0–3780
AU/acre	Aggregate animal units/farm size	11.20	32.92	0.05–347
Solid manure	Solid = 1, Liquid = 0	0.58	0.49	0–1
Solid and liquid manure	Both solid and liquid = 1, Liquid = 0	0.26	0.44	0–1
Manure storage capacity	1 = greater than 6 months, less than 6 months = 0	0.55	0.50	0–1
CNMP	Prepared a CNMP plan = 1; otherwise = 0	0.51	0.50	0–1
Manure transfer characteristics				
Distance	Maximum distance manure was transported (miles)	8.00	16.27	0–100
Contract	Contract between you and other farmer = 1; otherwise = 0	0.11	0.31	0–1
Value of manure	Were you paid for the manure = 1; otherwise = 0	0.57	0.68	0–1
Perceptions about manure testing	Disagree is the base category for each variable			
Profitability (neutral)		0.32	0.47	0–1
Profitability (agree)		0.56	0.50	0–1
Time consuming (neutral)		0.39	0.49	0–1
Time consuming (agree)		0.34	0.48	0–1
Complicated practice (neutral)		0.38	0.49	0–1
Complicated practice (agree)		0.16	0.37	0–1
Improves water quality (neutral)		0.29	0.45	0–1
Improves water quality (agree)		0.59	0.49	0–1

goodness of fit for the logistic regression were examined. After conducting the Omnibus Tests of Model Coefficients, it was found that the model is statistically significant therefore the null hypothesis that $H_0 = \beta_1 \ldots \beta_k = 0$ can be rejected. The logit model in its fullest form predicted 84.1% of the cases correctly, and the pseudo r-square value using the Cox and Snell was 0.509 and the Nagelkerke was 0.679. Furthermore, the Hosmer and Lemeshow Test showed that there is no difference between the observed and predicted values of *y*, indicating that this model is appropriate for this data set. Finally, diagnostic tests such as the tolerance values and variance inflation factors found that the model did not display multicollinearity.

Regression results are shown in Table 3. Factors that were found to be significant at the 10% level in the adoption of manure testing for manure transferred off the farm were: three off-farm income levels, AU/acre, type of manure, distance manure transferred, having a contract for the manure transfer, payment for manure, and perceived profitability.

Table 3. Logit Regression Results: Factors that Affect Adoption of Manure Testing ($n = 138$)

Variable	Coefficient	SE	*p*-Value	Marginal Effects (dy/dx)
Farmer characteristics				
Age	0.022	0.038	0.565	0.004
Education				
Less than high school	1.171	1.196	0.327	0.200
High school diploma	—	—	—	—
Some college or vocational school	−0.588	0.690	0.395	−0.128
Bachelor's degree and graduate degree	0.410	0.898	0.648	0.082
Off-farm income				
None	—	—	—	—
$0 to $9,999	−2.563	1.100	0.020	−0.564
$10,000 to $24,999	−1.520	1.035	0.142	−0.356
$25,000 to $49,999	−2.001	0.879	0.023	−0.451
$50,000 to $99,999	−2.608	1.352	0.054	−0.566
$100,000 or more	−1.113	1.406	0.428	−0.266
Farm characteristics				
Location – Iowa	1.258	0.829	0.129	0.261
AU/acre	−0.029	0.014	0.035	−0.006
Solid manure versus liquid	−3.059	1.142	0.007	−0.552
Solid and liquid manure	−1.964	0.989	0.047	−0.446
Manure storage capacity	−0.023	0.757	0.976	−0.004
CNMP	1.021	0.772	0.186	0.219
Manure transfer characteristics				
Distance	0.187	0.100	0.060	0.040
Contract	2.393	1.300	0.066	0.317
Value of manure	1.937	0.793	0.015	0.414
Perceptions about manure				
Profitability (neutral)	0.651	1.145	0.570	0.131
Profitability (agree)	2.283	1.234	0.064	0.482
Time consuming (neutral)	−0.384	0.908	0.673	−0.082
Time consuming (agree)	0.476	0.929	0.609	0.098
Complicated practice (neutral)	−0.890	0.785	0.257	−0.195
Complicated practice (agree)	−1.043	0.931	0.263	−0.242
Improves water quality (neutral)	−0.341	1.101	0.757	−0.074
Improves water quality (agree)	−0.300	1.048	0.775	−0.063
Constant	−1.037	2.505	0.679	

All coefficients for off-farm income were negative compared with the base of no off-farm income. Those with off-farm income levels between $0 and $9,999, $25,000 and $49,999, and $50,000 and $99,999 were significantly less likely to test manure than the base category, in line with expectations. The results of the marginal effects also indicate that the magnitude of the impact of these variables is substantial. Livestock producers with off-farm income may have less incentive to thoroughly test manure due to less focus on agriculture, time constraints, or the higher opportunity cost of their time, as indicated in the literature review. Only the off-farm income category more than $100,000 was significant for the full dataset (Gedikoglu and McCann, 2012).

As far as farm characteristics, as animal units per acre increase, farmers are significantly less likely to test manure, although the magnitude of the effect is small. This result is in line with our hypothesis. These may be farmers that are not purchasing fertilizer so would not save money by more precisely applying manure on their own farms, so what is transferred is thus less likely to have been tested, all else equal. Put more simply, these farmers may be treating manure as a disposal problem rather than as a source of nutrients.

The type of manure is both significant and important. Manure that was solid, or both solid and liquid, was significantly less likely to be tested compared with the base category of only liquid manure. This result is the same as Gedikoglu and McCann (2012) and is in line with expectations. It should be noted from Table 1 that solid manure, such as that from broiler or turkey operations, was more likely to be transferred off the farm. The negative sign on these variables could result from the difficulty of sampling solid manure or the fact that the liquid manure is more variable due to dilution and nitrogen volatilization so testing reduces the uncertainty regarding the composition of the manure.

Soil testing and manure testing are complementary practices that are included in a CNMP. As mentioned earlier, a CNMP is required for CAFOs and also for farms receiving Environmental Quality Incentives Program (EQIP) funding. While the sign was positive as expected, this variable was not significant at the 10% level.

All the manure transfer characteristics were significant and had the expected signs, indicating that the nutrient content of manure transferred off the farm is central to these transactions. In this analysis, the distance manure was transferred and having a contract for the manure were both found to have a positive and significant effect on adoption of manure testing. It is more valuable for the seller or buyer who transports the manure a greater distance to test the manure, ensuring a known quality of product to justify the transportation costs. Manure is a heterogeneous product, thus buyers and sellers may want to mitigate any uncertainty by including manure testing as part of a contract. Further research could examine whether having a contract is more likely for liquid manure, and whether it depends on frequency and size of the transaction (i.e., manure transfer amount) or the pre-existing relationship between buyers and sellers.

As mentioned previously, the majority of the farmers who transferred manure off the farm were paid for it, thus indicating that buyers placed a positive value on manure nutrients and other potential benefits for soil quality. The logit results show the variable "*payment for manure*" was positive and significant. Similar to the effect of paying higher transport costs for longer distances, if someone is paying for a product, they will want some assurance of its quality. The marginal effects indicate that being paid for the manure is also one of the more important factors affecting adoption. Agreeing that manure testing is a profitable practice also increased the likelihood of adopting manure testing and the magnitude of this effect was fairly large, similar to the findings of Gedikoglu and McCann (2012). Since the economic significance of manure testing is partly reflected in the distance, contract, and payment variables, the fact that all four are significant is somewhat surprising.

Perceptions about the water quality effects of manure testing were not significant and in fact, the coefficient was negative rather than positive. This effect was significant and negative when analyzing the full dataset. This is another indication that the value of manure nutrients, rather than the water quality impacts, is driving manure testing. This is similar to the results of Contant and Korsching (1997) who suggested that education programs focus on the profitability aspects of the Nitrogen-Trak kit, rather than its environmental benefits, as well as other studies that found minimal effects of environmental attitudes on farmers' BMP adoption (e.g., Gedikoglu, McCann, and Artz, 2011). Contrary to the results of Gedikoglu and McCann (2012) for the full dataset, perceptions regarding whether the practice was time consuming or complicated were not significant.

Conclusions

Since agriculture has been identified as one of the major causes of non-point source water pollution, it is imperative that inputs such as manure and commercial fertilizers be used in ways that limit off-site impacts. The results regarding manure testing of this subset of farmers who transfer manure to other farmers are more optimistic than the results found when looking at the dataset as a whole, which found only a 22% adoption rate for manure testing. Nevertheless, there is room for improvement since almost half of the manure was not tested. Non-point source regulation is currently under the discretion of state and local governments, since the Clean Water Act does not require livestock producers who are not CAFOs to adopt BMPs such as manure testing and soil testing (Ribaudo and Johansson, 2006). Policies to improve nutrient management will thus rely on voluntary adoption.

Our results regarding manure transfer characteristics suggest that agricultural producers may be led to more efficient use of manure nutrients (e.g., using manure test results to limit applications in excess of plant nutrient requirements), and thus improved environmental outcomes as the value of the nutrients increases. While the increasing value of manure may result in more efficient use of this resource, normal markets are unlikely to fully internalize the externalities associated with nutrients. A fertilizer tax would make manure nutrients even more valuable, further encouraging the efficient use of these nutrients. Other market induced mechanisms, which involve coordination between government agencies and agricultural producers that internalize the externalities, which arise from non-point source pollution, have also been suggested (Abdalla and Lawton, 2006).

The comparison of manure transfers by species shows that some types of operations are more able to take advantage of demand for nutrients by crop farmers. Technological changes in manure management, or even in livestock production systems, that improve the value of manure nutrients may also result in a wider variety of operations being able to profitably sell their manure at longer distances. New manure transport technologies may also be beneficial (Carreira et al., 2007).

Our results also suggest that educational programs focused on the positive effects of manure testing regarding reduced uncertainty (especially for liquid manure) and increased profitability are likely to be more effective than those focused on the water quality impacts. Educational efforts for farmers with off-farm income need to be expanded and provided in formats that are useful and accessible to these farmers. Furthermore, farmers receiving manure may need assistance from Extension or consulting firms to understand the manure and soil test results to reduce their fertilizer costs and increase the likelihood that water quality will improve. Manure testing results are less well understood by farmers than soil testing results (Motavalli, 2011).

Further research on manure markets in different geographical contexts would be useful. In the Midwest, manure is transferred to other farms, and in the case of poultry and turkey manure, over fairly long distances and at positive prices. The manure testing results also indicate that farmers receiving the manure value the nutrients it provides. Our results may be somewhat optimistic compared with areas with higher livestock concentrations, lower crop nutrient requirements, or where the population density is higher leading to more conflict over issues such as manure odor.

Other potential areas for future research include asking questions regarding the percentage of manure transferred off the farm and about characteristics of the buyer(s) that may affect testing. Complementary research focused on buyers/recipients rather than suppliers would provide important insights on their reasons for using manure and their understanding and use of manure test results. Given that custom applicators seem to play a major role in application of manure transferred off the farm, especially for broiler litter, their role in manure transfers and management should be explored.

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