Journal of Extension

Volume 55 | Number 6 Article 48

12-1-2017

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December 2017
Volume 55
Number 6
Article # 6FEA5
Feature

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Abstract

Agriculture's negative effect on water quality has become increasingly well documented. Farmers have a range of conservation practices available, yet rate of adoption is not optimal. Extension and other agricultural stakeholders play a key role in promotion of conservation practice adoption. We used survey data to examine relationships between farmers' integration in agricultural social networks and diversity of conservation practices used. Farmers who were more engaged in agricultural organizations and social networks tended to report greater diversity in nutrient best management practices. Conversely, less "connected" farmers reported less management practice diversity. Opportunities for Extension to engage with both groups exist.

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Introduction

Over the last several decades, the negative effects of nitrogen and phosphorus pollution on aquatic and marine ecosystems have been increasingly well documented. Iowa is one of many major farming states in the Mississippi River Basin (MRB) that contribute to Gulf of Mexico hypoxia (McLellan et al., 2015). In 2013, the State of Iowa released a nutrient reduction strategy (NRS) establishing goals for reducing the amounts of nutrients entering major waterways. Iowa established statewide nonpoint source pollution goals of a 41% reduction in nitrogen loadings and a 29% reduction in phosphorus loadings to meet the larger goal of a 45% reduction in nitrogen and phosphorus loadings for the MRB (Iowa State University [ISU], 2012).

A growing body of research has indicated that significant reductions in nutrient loss will require the widespread adoption of multiple agroecologically appropriate nutrient management and other conservation practices (Castellano & Helmers, 2015; Drinkwater & Snapp, 2007; ISU, 2012; McLellan et al., 2015). In other words, for MRB-wide nutrient loading reduction goals to be met, many farmers will need to adopt or improve implementation of a diverse array of practices that can reduce nutrient loss (Helmers et al., 2007). However, to date most nutrient management practice adoption research has focused on single practices, such as growing cover crops or implementing conservation tillage (Arbuckle & Roesch-McNally, 2015; Baumgart-Getz, Stalker Prokopy, & Floress, 2012; Prokopy, Floress, Klottor-Weinkauf, & Baumgart-Getz, 2008; Sundermeier Fleming Fallon, Schmalzried, & Sundermeier, 2009). A gap exists in the literature regarding factors that might be associated with simultaneous use of a diversity of practices.

Our objective for the research reported here was to understand the factors associated with farmers' implementation of multiple nutrient management practices. Following the call by Reimer et al. (2014) to reinvigorate the historical focus on social ties as critical arbiters of adoption and diffusion (Rogers, 2003), we examined key nodes in agricultural social networks. Specifically, we investigated relationships between Iowa farmers' use of diverse nutrient management practices, with a particular focus on practices related to nitrogen management, and their (a) use of Extension and other public sources as well as private sources for nutrient management information, (b) involvement in agricultural and conservation organizations, and (c) self-rated opinion leadership status in agricultural social networks.

Methods

The Survey

Iowa State University Extension and Outreach (ISUEO) collected study data through the 2012 Iowa Farm and Rural Life Poll, a statewide annual survey of Iowa farmers conducted by the National Agricultural Statistics Service (NASS), the sample for which is drawn from the Census of Agriculture master list frame. Surveys were mailed to 2,219 farmers in February 2012, and we received surveys from 1,296 farmers, for a 58% response rate. Survey questions were developed on the basis of literature review and in consultation with content experts. The survey questions were pilot tested with farmers and other agricultural stakeholders and reviewed by survey specialists at NASS. The survey process was a modified version of that proposed by Dillman, Smyth, and Christian (2008) and involved an initial mailing of the survey followed by mailing of a postcard reminder and then a second mailing of the survey. Because the variable of interest was use of nutrient management practices, the analysis reported here was limited to the 996 respondents who planted corn and/or soybean in 2011 and for whom nitrogen management practices and strategies were most relevant.

The Model

We used ordinary least squares regression to examine the relationships between the dependent variable nitrogen management practice diversity (number of practices used to manage nitrogen) and selected predictor variables. The primary research expectations (hypotheses) were that greater diversity in nitrogen management practice use would be positively associated with

1. preference for receiving nutrient management information in face-to-face settings;
2. tendency to use Extension and other public sources for nutrient management information;
3. tendency to use private sector sources for nutrient management information;
4. greater involvement in agriculture and natural resources conservation organizations; and
5. higher self-rated opinion leadership levels.

Data Analysis and Results

Dependent Variable: Nitrogen Management Practice Diversity

As noted, the dependent variable was nitrogen management practice diversity, or the number of different practices used to manage nitrogen. We used practice diversity as the dependent variable for two reasons. First, the use of a scale to measure a diverse set of best management practices (BMPs) that address water quality impairments aligns with Rogers's (2003) argument. This argument posits that certain kinds of technologies and innovations are not isolated elements but instead are potentially part of "technology clusters" consisting of distinct but related elements of a technology that address a common outcome (e.g., nutrient loss abatement) (Rogers, 2003). Second, as noted in the introduction, to meet Iowa's NRS goals, nearly all farmers will have to incorporate a wide range of practices into their agricultural systems. An understanding of the factors that predict use of higher or lower levels of practice diversity may help guide outreach efforts related to increasing practice diversity.

We addressed the dependent variable through the use of a simple summative scale measuring the degrees to which the farmers employed 18 practices for managing nitrogen. Percentage distributions are provided in Table 1. The list of practices, which contained both commonly used practices and newer, innovative BMPs, was developed on the basis of the practices published in Iowa's NRS and in consultation with ISUEO field agronomists and soil scientists who work with farmers and conduct research on the effectiveness of various practices. Farmers indicated level of use for each nutrient management practice by choosing from five options: *not familiar with*; *familiar with, but do not use*; *limited use*; *moderate use*; and *heavy use*. For the analysis reported here, we combined the options *not familiar with* and *familiar with, but do not use* into the category *do not use*, resulting in a 4-point scale. We created the scale by summing responses for the 18 practices and dividing by 18. The potential numerical values for the practices thus ranged from 1 to 4. Because of a slight kurtosis, one outlier value of 4 was removed, resulting in a scale mean of 1.82, with a standard deviation of 0.39. A Cronbach's alpha coefficient of .786 indicated sufficient internal reliability. The resulting scale represents a measure of conservation practice diversity and degree of implementation at the time the poll was conducted, not long-term use of the specified practices.

Table 1.

Percentage Distributions for Iowa Corn/Soybean Farmers' Levels of Use of Nitrogen Management Practices

Nitrogen management practice	Do not use	Limited use	Moderate use	Heavy use
Crop rotations	4.6	9.7	35.4	50.4
Yield goals	10.4	16.7	43.8	29.2
Soil testing	13.5	20.3	39.5	26.7
Animal manure	39.1	21.6	23.2	16.1
Variable fertilizer rate	40.8	23.2	22.5	13.4
Soil temperatures	37.5	26.8	25.2	10.6
Plant legumes	44.3	25	21	9.7
Nitrification inhibitor (e.g., N-Serve)	60.5	15.2	13.8	10.6
Integrated crop management	59.8	22.8	13.4	3.9

Test strips	61.2	24.2	9.7	4.9
Cover crops	71.1	18.4	8.1	2.4
Stalk nitrogen tests	72.1	17.5	6.2	4.1
Late spring nitrogen test	70.2	19.9	6.8	3.1
Corn Nitrogen Rate Calculator (maximum return to nitrogen)	78.1	12	7.6	2.3
Aerial photos or remote sensing	75.3	14.8	7.6	2.2
Urease inhibitor (e.g., Agrotrain)	81.1	9.9	5.5	3.5
Coated urea (e.g., ESN)	83.1	10.4	4.6	1.9
Canopy sensors for nitrogen deficiency	92.8	4.8	2.1	0.3

Independent Variables

We addressed five variables related to aspects of the farmers' agricultural social networks. Three variables centered on information sources: One was preferred format for receiving information on nutrient management, and two related to sources the farmers used for information on nutrient management. The fourth variable was degree of involvement in agricultural and conservation organizations, and the fifth was self-rated standing as an opinion leader within the agricultural community. An additional variable we examined was number of corn or soybean acres planted.

Information Sources

For the preferred information format variable (which we termed Face2Face), we measured whether farmers preferred receiving nutrient management or fertilizer application rate information from Extension via face-to-face formats, such as field days or workshops, or non-face-to-face formats, such as online videos or downloaded publications. Each option was scored as *yes* = 1, *no* = 0. Fifty-six percent of farmers indicated that they preferred face-to-face formats, versus 44% who preferred non-face-to-face formats.

For the two variables related to information sources used by the farmers, we measured their tendencies toward using public sector sources (PubFirstNM) and private sector sources (PrivFirstNM) for nutrient management information. We provided respondents with a list comprised of two public sector entities ("Iowa State University Extension" and "USDA/NRCS/SWCD Service Center") and three private sector entities ("fertilizer or ag chemical dealer," "seed dealer," and "private crop consultant") and asked them to indicate which they would turn to first for information on nutrient management and which they would turn to first for information on fertilizer application rates. Each option was scored as checked = 1, not checked = 0. Responses on the two items were summed, resulting in a range from 0 (respondent would not consult the source first for either type of information) to 2 (respondent would consult the source first for both types of information). The mean for the public sector entity variable (PubFirstNM) was .29, and the mean for the private sector entity variable (PrivFirstNM) was 1.62, indicating that farmers were more likely to turn to private sector sources for nutrient management information.

Involvement in Organizations

We also examined the variable of level of involvement in Iowa-based farm organizations (AllOrgInvolv). Farmers were asked to rate their involvement in 10 organizations using a 5-point scale ranging from *never been a member* to *very active* (Table 2). We summed the responses to form a scale that ranged from 10 to 36, with a mean of 15 and a standard deviation of 3.61. A Cronbach's alpha coefficient of .646 indicated marginal internal reliability.

Table 2.

Percentage Distributions for Iowa Corn/Soybean Farmers' Involvement in Agriculture and Natural Resources Conservation Organizations

Agriculture/natural resources conservation organization	Have never been a member	Was a member, but not now	Member, not active participant	Active	Very active
Iowa Farm Bureau Federation	18.8	17.5	49.6	11.0	3.1
Iowa Farmers Union	94.4	2.7	2.4	0.3	0.2
Iowa Corn Growers Association	50.9	13.3	30.1	5.0	0.6
Iowa Soybean Association	46.2	13.0	35.3	4.9	0.6
Iowa Pork Producers Association	63.4	26.4	7.1	2.4	0.7
Iowa Cattlemen's Association	66.6	18.4	9.5	4.2	1.2
Practical Farmers of Iowa	94.5	3.1	1.5	0.5	0.3
Iowa Organic Association	97.5	1.4	0.5	0.3	0.2
Iowa Natural Heritage Foundation	94.6	2.8	2.3	0.3	0.1
Iowa Environmental Council	97.7	1.1	0.8	0.2	0.1

Opinion Leadership

The final social network variable was the degree to which farmers saw themselves as opinion leaders within their agricultural social networks (OpinLeader). The scale we used to address this variable consisted of seven items that measured key dimensions of opinion leadership (Table 3). The summed responses ranged from 7 to 34, with a mean of 19.3 and a standard deviation of 4.56. A Cronbach's alpha coefficient of .864 indicated solid internal reliability.

Table 3.

Percentage Distributions for Opinion Leadership Among Iowa Corn/Soybean Farmers

Opinion leadership statement	Strongly disagree	Disagree	Uncertain	Agree	Strongly agree
It is important to me to keep	1.3	6.5	12.4	62.4	17.4

up with the latest farm management practices and strategies.					
Other farmers tend to look to me for advice.	7.3	33.2	42.1	15.9	1.5
I consider myself to be a role model for other farmers.	7.4	32.9	41.9	16.6	1.1
Extension staff, crop advisers, and others involved in agriculture tend to look to me for advice.	18.0	51.6	25.4	4.8	0.2
I take a leadership role in local agricultural matters.	15.8	49.9	22.4	11.0	0.8
Compared to other farmers, I tend to use more innovative management practices and strategies.	8.7	33.3	33.4	21.5	3.2
My opinions matter in the local agricultural community.	13.6	30.2	37.9	17.1	1.2

Corn and Soybean Production

We also included the single variable of corn or soybean acres planted in 2011 to control for magnitude of acreage on which nitrogen management practices would be relevant (CornSoyTotalAc). The mean acreage was 459.

Regression Results

Ordinary least squares regression models indicated the relationships between nitrogen management practice diversity and the selected agricultural social network factors (Table 4). We employed a hierarchical regression approach in which we entered explanatory variables into the model in groups to understand their relative strengths as predictors. Model fit and collinearity statistics indicated a good-fitting model and no major multicollinearity issues.

Table 4.

Ordinary Least Squares Regression of Agricultural Social Network Variables Predicting Diversity in Nutrient Management Practice Use

	Model 1				**Model 2**				**Model 3**			
Variable	**B**	***SE***	**Std. B**	**Sig.**	**B**	***SE***	**Std. B**	**Sig.**	**B**	***SE***	**Std. B**	**Sig.**
Constant	1.21	.091		.000	.822	.092		.000	.876	.092		.000
Face2Face	.072	.026	.091	.005	.041	.024	.051	.093	.050	.024	.062	.040

PubFirstNM	.066	.045	.097	.142	.041	.042	.060	.320	.034	.042	.050	.415
PrivFirstNM	.002	.041	.003	.967	.007	.038	.011	.857	.001	.038	.002	.978
AllOrgInvolv	.036	.004	.327	.000	.022	.004	.198	.000	.019	.004	.175	.000
OpinLeader					.032	.003	.369	.000	.029	.003	.337	.000
CornSoyTotalAc									.000	.000	.124	.000
Adj. R^2 (cum.)	.133				.247				.265			
F	33.90***				57.05***				50.91***			
N	855				855				855			

Note. B = beta. *SE* = standard error. Std. B = standardized beta. Sig. = significance. Adj. R^2 (cum.) = adjusted R^2 (cumulative). *F* = F statistic. *N* = number of respondents.
$*p < .05$. $**p < .01$. $***p < .001$.

Information Sources

About 13% of the variance in respondents' nitrogen management practice diversity was explained by the variables that centered on information sources. The coefficient for Face2Face was positive, indicating that farmers who preferred to learn about nutrient management through in-person formats, such as field days, meetings, and workshops, reported more diverse nitrogen management practices than those who preferred other formats. This result supported our first hypothesis. Neither of the variables related to farmers' preferred information sources for nutrient management information (PubFirstNM and PrivFirstNM) were significant. Therefore, regarding our second and third hypotheses, we cannot use our findings to draw conclusions about associations between farmer tendencies to turn to either public or private sources and their use of diverse nutrient management practices.

Involvement in Organizations

Level of involvement in agricultural organizations (AllOrgInvolv) was significantly and positively associated with nitrogen management diversity, indicating that farmers who were more involved in agriculture and natural resources conservation organizations used more diverse nutrient management practices than those who were less involved. This result supported our fourth hypothesis.

Opinion Leadership

Approximately 12% of model variance was explained by the opinion leadership variable. The OpinLeader variable was a significant and positive predictor of nitrogen management practice diversity, indicating that farmers who ranked themselves high in opinion leadership used more diverse management practices. This result supported our fifth hypothesis.

Corn and Soybean Production

Magnitude of corn and soybean production was a significant, positive predictor of nitrogen management practice diversity. The relationship between these two variables indicated that the more acres farmers had in corn and soybean production, the greater the diversity of nutrient management practices they used. However, the addition of CornSoyTotalAc to the regression model explained only a small amount (about 2%) of the variance in nitrogen management practice diversity.

Discussion and Implications

As societal pressure to reduce nutrient losses from agriculture mounts across major crop- and livestock-producing regions such as the Corn Belt, calls for farmers to employ more diverse and efficient nutrient management practices are increasing (McLellan et al., 2015). In response, Extension services are examining ways to engage farmers in nutrient reduction programming more effectively (ISU, 2012; Tyndall & Roesch, 2014). Results from our study point to potential pathways for supporting nutrient loss reduction efforts.

We examined relationships between diversity in farmers' use of nutrient management BMPs and preferred formats and sources for nutrient management information, degree of integration in agricultural organizational networks, and position in agricultural social networks. Results showed that farmers who preferred to receive nutrient management information in face-to-face formats, were more involved in agricultural and conservation organizations, and viewed themselves as opinion leaders tended to use more diverse nutrient management strategies. Each of these findings has potentially important implications for agricultural outreach and engagement strategies.

The finding that farmers who preferred to learn about nutrient management through in-person formats such as field days and workshops tended to use more diverse practices is particularly salient given the growth of electronic information delivery methods in the 21st century. Although the relationship is not causal, the correlation between preference for active engagement on the topic of nutrient management and use of more diverse BMPs suggests that face-to-face approaches are an effective means for delivering nutrient reduction strategy programming.

Overall, one of the most significant findings is the robust relationship between level of involvement in agricultural and conservation organizations and use of diverse BMPs. This finding indicates that farmer engagement in organizational social networks may have an important influence on nutrient management. A connection such as this has important implications as more agricultural and conservation organizations are becoming active partners in state-level nutrient reduction strategies (ISU, 2012; Indiana State Department of Agriculture, 2015; State of Minnesota, 2014). Our results indicate that members of such organizations (especially active members) are already using a diverse range of BMPs. This finding also indicates that farmers who are not engaged in such organizations use fewer nutrient management practices. This circumstance poses a challenge to Extension professionals as to how to reach those who are not actively engaged in these agricultural social networks.

The strong relationship between self-rated opinion leadership and use of diverse nutrient management practices is another noteworthy finding. First, although opinion leadership has historically been a critical variable in adoption studies (Rogers, 2003), little research on soil and water conservation practice adoption has focused on the potential association between opinion leadership and conservation behaviors (Prokopy et al., 2008). The strong positive correlation we found suggests that greater focus on opinion leadership in future research might help better explain variation in adoption of conservation practices. Second, the finding suggests that such leaders may be potential local access points in efforts to engage other farmers in nutrient reduction strategies. Our results indicate that researchers should investigate this variable further to understand the impact it has in influencing adoption behavior.

Although our findings on the positive relationships between the variables we studied and better BMP outcomes are important, it is essential to consider the corollary, negative relationships as well. In other words, what about the farmers who are less active and central in the agricultural and conservation community? Our results present a puzzle in that farmers who are less "connected" reported lower levels of BMP diversity. That is, the farmers who likely are most in need of engagement on nutrient management also are more difficult to reach, at least through the channels we examined. Nontraditional approaches to education and outreach that involve a variety of social agents may be needed to reach such farmers.

Acknowledgments

This research was supported by the Iowa Nutrient Research Center and the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project No. 3704 was sponsored by Hatch Act and State of Iowa funds.

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