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Diffusion of Innovations and Public Communication Campaigns: An Examination of The 4R Nutrient Stewardship Program

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Abstract
This project is an examination of how strategies for innovation in fertilizer application are communicated to agricultural communities. Specifically, this project examines the 4R Nutrient Stewardship Program-a public - communication campaign seeking to encourage the use of specific strategies, tools, and best practices in fertilizer application. The campaign is advanced by the Fertilizer Institute, an industry trade association, and targets local agricultural communities within the United States. To understand how this campaign functions to encourage adoption of innovative fertilizer application behaviors, this project draws on the principles of diffusion of innovations theory as well as established concepts within public relations, including issues management.

Keywords
Public Communication Campaigns, Diffusion of Innovations, Fertilizer Runoff, Water Contamination

The 4R Nutrient Stewardship Program is a public communication campaign that seeks to encourage changes in fertilizer application behaviors with the goal of reducing runoff. The 4R campaign promotes the diffusion of innovations in fertilizer use by agriculturalists as a method for reducing the runoff leading to water contamination. This campaign seeks to proactively reduce fertilizer runoff and improve water quality through education and outreach as a means of the need for new policies regulating fertilizer use.

The focus of this investigation is the 4R Program's efforts to address water quality issues in the Maumee River Watershed, a large watershed within the western Lake Erie basin. The Maumee Watershed flows through all or part of 18 Ohio counties (Ohio Environmental Protection Agency, 2018a). The Maumee River is a principal tributary of Lake Erie and is surrounded by farm land. The watershed has experienced several major contamination events as a result of fertilizer runoff, prompting efforts to regulate runoff. Communities in the Midwestern United States have been the target for many of these efforts given the presence of large numbers of agricultural operations in close proximity to the Great Lakes.

This examination is informed by diffusion of innovations theory, a framework describing the process whereby a community adopts a new innovation (Rogers, 2003). By illustrating the process of diffusion, diffusion of innovations theory can answer questions about how strategic messaging decisions influence behavioral change across targeted populations. The goal of this project is to explore a public communication campaign seeking to encourage behavioral change within an agricultural community using diffusion of innovations theory. Fertilizer runoff is a significant environmental contaminate resulting in risks to public health.

The 4R Nutrient Stewardship Program

The 4R Nutrient Stewardship Program codifies nutrient runoff reduction strategies in ways that are memorable and easily communicated. The Fertilizer Institute suggests that following the 4R strategies allows the producer to achieve desirable goals of "increased production, increased farmer profitability," as well as "enhanced environmental protection and improved sustainability." The 4Rs refer to four key considerations farmers should include in their fertilizer application decisions- specifically, farmers should choose the right fertilizer source, applied at the right rate, the right time and in the right place, all according to their specific context (TFI, 2016). These four considerations are designed to invite farmers to think more critically about fertilizer application.

The 4R program was created by the Fertilizer Institute in association with the International Plant Nutrition Institute in response to issues of fertilizer runoff (TFI, 2016). The Fertilizer Institute is an industry trade association that it has existed in some form since the 1800s and serves as the voice of the industry. The Institute describes its mission on its website:

> TFI is the voice of the fertilizer industry, representing the public policy, communication, stewardship and sustainability and market intelligence needs of fertilizer producers, wholesalers and retailers as well as the businesses that support them with goods and services (TFI, 2016, NP).

As more areas around the world experience issues with water quality, the Institute has identified a need for new runoff reduction efforts, ideally efforts that encourage voluntary adoption of strategies by agriculturalists, such as the 4R Nutrient Stewardship Program. These efforts are encouraged as ways to protect and improve water quality and prevent potential government regulation.

Dramatic cases of water contamination from fertilizer runoff have brought attention to the problem. One particularly important case was the Toledo, Ohio water crisis in 2014. During this event the city of Toledo water supply became contaminated by the toxin microcystin, which had been produced by cyanobacteria that had multiplied at a high level in Lake Erie due to fertilizer runoff. The Toledo water crisis raised public awareness about fertilizer runoff and increased political pressure for change. In addition, this case called attention to the Maumee River Watershed as a major source of runoff (Seeger & Seeger, 2017).

The campaign's primary purpose was to address the problem of runoff through voluntary measures and prevent the introduction of new policies regulating fertilizer application. To achieve this, the campaign is structured around two objectives. The first is to encourage adoption of innovations in fertilizer application strategies among farmers. The secondary objective of this campaign is to publicly demonstrate that both the fertilizer industry and the agricultural community are invested in reducing fertilizer runoff and are taking proactive measures. The 4R Nutrient Stewardship program was used to engage with individual partners, stakeholders, and state-level associations and promote changes in fertilizer practices. The Fertilizer Institute also places and promotes stories about reduction of nutrient runoff in various media outlets, sponsors conferences and workshops, and engages in direct lobbying.

Diffusion of Innovations

Diffusion of innovations theory prescribes a number of important elements that should be incorporated into campaigns seeking to facilitate diffusion. Most notably, diffusion of innovations theory emphasizes the importance of local community members and opinion leaders as nodes of influence in communication networks. diffusion of innovations theory also describes a number of characteristics of an innovation that campaigns may emphasize to maximize an innovation's likelihood of being adopted. These include relative advantage, compatibility, complexity, trialability, and observability. The primary purpose of diffusion of innovations theory is to describe how an innovation diffuses throughout target populations.

Diffusion of innovations theory's utility at identifying factors influencing adoption, as well as its wide applicability to a variety of contexts, make this theory useful for understanding how communities and individuals respond to innovations and make adoption decisions (Rogers, 2003). Diffusion of innovations theory has been used widely in marketing, organizational theory, international development, and social change to understand how communities come to adopt innovative new strategies, technologies, and ideas (Baumgart-Getz, Prokopy, & Floress, 2012). The theory in its current form is a product of decades of research across a variety of fields.

The four main elements of the diffusion process include the innovation itself, the channels the innovation is communicated through, the time period when the process takes place, and the social system the innovation is diffused through. Rogers (2003) defined innovation as "an idea, practice, or project that is perceived as new by an individual or other unit of adoption" (p. 12). The term innovation often carries connotations of newness, uniqueness, value, benefits, and change (Smudde & Courtright, 2015). An innovation's likelihood to be adopted is determined by five core characteristics of innovations: relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003).

Relative advantage refers to a potential adopters' perception of an innovation as better than the idea, process or technology it replaces. Some perceived benefit to the innovation over existing ideas or technologies is necessary for it to be adopted. Compatibility refers to the degree that a potential adopter perceives the innovation as compatible with his or her values, norms, and needs.

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Complexity is a term referring to the perceived difficulty of the innovation to be understood, used, or implemented. Innovations that are simple and easy to apply are more likely to be adopted. Trialability is a factor describing how much the innovation can be experimented with without commitment. A trial application can help the adopter explore the innovation, identifying what value it may add before fully adopting it. Finally, observability refers to the degree the value added by adopting an innovation is visible to other potential adopters (Rogers, 2003).

Diffusion occurs through both mass media and interpersonal channels. Innovations often move from mass media to interpersonal channels through opinion leaders. Opinion leaders are interpersonal sources who are trusted by others to evaluate innovations and provide guidance about whether or not to adopt (Lazarsfeld et at., 1948; Valente & Davis, 1999). Information flows from opinion leaders to potential adopters in one-to-one or group communication contexts (Sivayoganathan & Tedrick, 1986). Because what opinion leaders think about an innovation shapes the attitudes of others towards that innovation, opinion leaders provide an interpersonal channel for innovations to diffuse throughout a social system (Telg et al., 1996). Mass media channels are particularly important during the early stage of the diffusion process and are helpful as individuals are learning about innovations, however, these efforts are generally most effective when combined with interpersonal channels (Scherer, 1979). Interpersonal channels are more important during the middle and late stages of the diffusion process, when individuals are weighing the advantages and disadvantages of adoption.

Mass media and interpersonal communication channels can be further described as either *cosmopolite* or *localite*. Cosmopolite channels link potential adopters with sources outside of their social system. Localite channels link potential adopters with sources within their social system. Information about innovations almost always enter a system through cosmopolite channels, however, as the innovation diffuses through the system, localite channels become more widely used. It is important to note that all mass media channels are cosmopolite, however, not all interpersonal channels are localite (Rogers 2003). A potential adopter may communicate interpersonally with an individual outside of their social system.

The successful diffusion of an innovation is often facilitated by change agents, individuals or groups seeking to encourage the adoption of an innovation by another group (Rogers & Shoemaker, 1971). Change agents are often opinion leaders, internal interpersonal sources trusted by community members to evaluate innovations because of their expertise. According to Rogers (2003), the behavior of change agents is strategic, as it is a "process of customizing the design and delivery of a communication program based on the characteristics of an intended audience" (p. 367). Haider and Kreps (2010) recommended campaigns "leverage the influential capacities of change agents" to more successfully influence attitudes of community members (p. 4).

Another main element of diffusion – time - refers both to the novelty of an innovation (as dependent upon the relative earliness/lateness of an adoption in the diffusion process) as well as to the rate of an innovation's diffusion through a social system. The rate of diffusion follows a *S*-shaped adoption curve, corresponding to a process where a few individuals (early adopters) adopt an innovation and then over time more members adopt the innovation. This process continues until a point of saturation is reached or when about half of the population has adopted the innovation (Rogers, 1995). After this point adoption rates slow, as there are fewer potential adopters left in the population and those that remain are resilient towards adopting. The curve may be shorter for innovations that are valued highly and are therefore adopted quickly, or longer for innovations that take longer to catch on or fail to completely diffuse.

The final element of diffusion is the social system through which the innovation diffuses. An individual's likelihood to adopt an innovation is dependent in part upon the innovation decisions of others within their social system. Wide social contact with other potential adopters within a social system is positively related to innovativeness (Unay Gailhard et al., 2015). As more individuals in a system adopt, the observability and compatibility of the innovation increases, as do positive interpersonal messages about the value added by the innovation. Within social systems individuals seek to influence others to adopt similar behaviors and worldviews as themselves (Smudde & Courtright, 2015). Early adopters can serve as opinion leaders driving adoption through trial and error, and subsequent communication about an innovation (Valente & Davis, 1999).

Innovations are adopted in a pattern that follows a normal distribution. Rogers (2004) identified five adopter groups according to their readiness to adopt new innovations. These are: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, and (5) laggards. He recognized innovators as the first 2.5% to adopt an innovation. Early adopters are the next 13.5%. The early majority are the next 34%. Following are the late majority, for another 34%. Last are laggards, the remaining 16%. Some literature identifies a final category, skeptics, that adopt an innovation only at the very end of the diffusion process because few alternatives remain (Smudde & Courtright, 2015). The distribution of adoption of an innovation over time is consistent with seeing diffusion of innovation as a process. It also allows for the breadth of an innovation's diffusion to be tracked based on how many people in a social system report adopting the innovation. Rogers (2004) notes that diffusion takes time.

Eventually diffusion reaches *critical mass*, the point in the diffusion process where the increase in new adopters is perpetuated by communication within the social system (Valente, 1993). This may be achieved when there is a perception that most everyone else in the system is adopting the innovation, because the value added by the innovation is significant (Mahler & Rogers, 1999). Rogers (2004) suggested critical mass is the point where enough individuals have adopted an innovation that "further diffusion becomes self-sustaining" (p. 13). Prior to achieving critical mass, external organizations and policymakers must invest resources and energy toward driving adoption. This may include developing and disseminating messages through campaigns. Once a point of critical mass is reached, internal interpersonal pressures drive further adoption, and external attempts to encourage adoption become less effective.

Diffusion Research in Agricultural Communities

An extensive body of research has examined diffusion of innovations theory in the context of agricultural communities (See Hamilton, 1973, Riesenberg & Gor 1989, Veil, 2010, Baumgart-Getz, Prokopy & Floress, 2012). In one of the earliest studies, Ryan and Gross (1943) sought to understand the diffusion and adoption of hybrid seed corn in Iowa farming communities. Because hybrid seed corn increased production yields by close to 20%, Ryan hypothesized the innovation would be adopted quickly. Surprisingly, the researchers discovered farmers took an average of seven years to transition from first planting hybrid seed to 100% adoption. Because farmers were less familiar with the innovative hybrid corn seed, they were reticent to adopt. Adoption was driven by media visibility of an innovation, as well as by local farm operators communicating information about the innovation to their communities. Social knowledge, as well as sources of information about an adoption, were found to be drivers of adoption.

Baumgart-Getz, Prokopy and Floress (2012) conducted an extensive meta analysis of studies examining the adoption of innovations related to conservation and management by U.S.

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farmers. The authors examined 31 social factors assessed over 25 years of adoption research exploring farm management practices. The variables that were consistently found to have the most significant impact on adoption included access to high quality of information; the financial capacity of the farmer; and connection to agencies, local communities, or groups of farmers. The impact of quality of information is consistent with Rogers' overall theory, as those farmers who have information about innovations are likely to have a better understanding of the proposed innovation and consequently have higher rates of adoption. Quality of information is a function of the source farmers are using to gain information about an innovation. Financial capacity gives a farmer greater ability to experiment with new techniques and innovations, while being part of a network may enhance social influence and create opportunities for trialability and observability.

Diffusion of innovations theory not only has utility as a frame for understanding what motivates changes in practices, but also as a frame for the design, analysis, and evaluation of campaigns. Such campaigns are an important activity in agricultural communications (Boone, Meisenbach, & Tucker, 2000; Tucker, 1996). Specifically, campaigns have been widely used to promote innovation in agricultural practices, including innovations in sustainable practices (Röling & Jiggins, 1994), pest control practices (Heong, Escalada, Huan, & Mai, 1998), and livestock vaccination (Heffernan, Thomson, & Nielsen, 2008), among many others.

Research Questions

We sought to examine the effectiveness of the 4R Nutrient Stewardship campaign at promoting the diffusion of 4R practices among communities in the region of the Maumee River Watershed. This involved identifying the reach of campaign messaging, the breadth of diffusion of the innovation, and the sources that are most effective in promoting the 4R principles. Therefore, we propose the following specific research questions for this study:

> RQ1: Do agriculturalists within the Maumee River Watershed perceive that they have knowledge of the 4R principles?
> RQ2: How do specific information sources relate to individual's adoption of 4R practices within the Maumee River Watershed?
> RQ3: What is the extent of the diffusion of the 4R frameworks' prescribed runoff reduction strategies through agricultural communities within the Maumee River Watershed?

The answer to the first question will provide an indication of the success of the campaign in introducing the principles to the key target audience. Knowledge of an innovation and its potential benefits is a key first step in the diffusion process. The answer to the second question will identify the sources of information that are associated with that knowledge, and whether these sources make use of cosmopolite or localite channels of communication. Finally, the answer to the third question will provide some indication of the success of the 4R Nutrient Stewardship Program as a strategy to facilitate the diffusion of runoff reduction strategies. Contextualized within the bigger picture of campaigns generally, the answer to these three questions will also provide insight into the larger process of innovation as promoted by public communication campaigns.

Methods

The data used in this study were collected from farmers in the Maumee River Watershed from the end of December of 2015 until early March 2016 by The Ohio State University's College of Agriculture, Food and Environmental Sciences using a survey questionnaire. Funding for this project was made available through the 4R Research Fund, a research initiative established by the

fertilizer industry to support the documentation and measurement of the 4R nutrient stewardship program. Several procedures were used to facilitate an adequate return rate of surveys. A postcard indicating that a survey would be sent to the respondents was mailed to increase awareness of the study. This postcard included a web address for the online version of the survey. One week later a paper copy was mailed out to those who had not participated online. A second reminder postcard was sent out two weeks later, followed by second copy of the survey (Prokup et al. 2017).

Respondents

The population of interest was corn and soybean farmers with over 50 acres in the Maumee River Watershed. Once the initial sampling frame was identified, the sample was further stratified according to farm size: farms 50 to 249 acres (15%), 250 to 499 acres (13%), 500 to 999 acres (22%), 1000 to 1999 acres (31%), and 2000 plus acres (19%). This sample closely matches the census data for Ohio farms operating with over 50 acres of land (Prokup et al. 2017).

The final sample included 3,273 farmers. Names and mailing addresses were obtained from the company Farm Market ID. Of the 3,273 initial contacts, some surveys were unopened, some farmers asked to be removed, and others indicted they were no longer farming. This left a total sample of 2,574 respondents, of which 748 were returned usable, for a response rate of 29.1% and a total sample for analysis of 748 (Prokup et al. 2017).

Variables and Measurements

Respondents completed questions ranging from perceived issues of nutrient runoff, to current nutrient application practices, to attitudes toward hiring Nutrient Service Providers. Demographic information was also collected about the farmer and the farm operation. While results of the survey were used in a variety of research projects (see Prokup et al. 2017 for a full descriptive summary of findings), the present study examined selected survey items that directly assessed the variables of knowledge, sources of information, and extent of diffusion.

Knowledge

Two items were used to evaluate perceived knowledge of innovations. The first was a single Likert-type item designed to assess respondents' perceived understanding the 4R principles. Respondents were asked to rank their agreement with the statement, "I feel that I have a pretty good understanding of the four nutrient management principles." This item made use of a five-point Likert-type measurement with anchors of -2 (strongly disagree) and 2 (strongly agree).

The second perceived knowledge item evaluated relative understanding and asked respondents to rank their agreement with the statement, "I feel that I am better informed about nutrient stewardship than most farmers." This scale also made use of a 5-point Likert-type measurement with anchors of -2 (strongly disagree) and 2 (strongly agree). This was an important measurement for perceived knowledge as it relates to diffusion because it contextualized understanding relative to the larger agricultural community.

The mean of these two items was used to operationalize each respondent's knowledge of the 4R principles. Cronbach's alpha was calculated and the items demonstrated adequate reliability, $\alpha = .74$. The mean value of these two items was thus used as a single metric for knowledge, $M = .71$, $SD = .72$.

Sources of Information

Respondents were also asked to report how often they receive information about nutrient

stewardship from a variety of sources. Eleven potential information sources were rated with a five point Likert-type scale with anchors of 0 (never) and 4 (frequently). Potential sources were categorized into two groups, *Localite* (sources that make use of localite channels of communication) and *Cosmopolite* (sources that make use of cosmopolite channels of communication). Sources were also grouped into mass media channels as well as interpersonal channels. The sources of "crop advisor/consultant, your fertilizer applicator or retailer, a family member or farm partner," and "other farmers in your community" were sources that made use of localite channels. The sources of "the county extension agent, University Extension, the farm bureau, the county soil and water conservation district, the 4R Brochure, commodity groups" and "USDA NRCS" can be understood as sources that make use of cosmopolite channels. Descriptive statistics for these eleven potential information sources are provided in Table 1.

Table 1. *Sources of Information*

Source	**Channel Direction**	**Channel Type**	**Mean**	**SD**
Professional/industry magazines	Cosmopolite	Mass media	2.42	.97
Your fertilizer applicator or retailer	Cosmopolite	Mass media	2.21	1.14
Your county Soil and Water Conservation District	Cosmopolite	Mass media	2.17	1.03
University extension generally	Cosmopolite	Mass media	1.82	.91
Your county Extension agent	Cosmopolite	Mass media	1.80	1.31
USDA NRCS	Cosmopolite	Mass media	1.80	1.02
Farm Bureau	Cosmopolite	Mass media	1.68	1.05
Commodity Groups	Cosmopolite	Mass media	1.36	1.02
A family member or farm partner	Localite	Interpersonal	1.63	1.14
Your crop advisor/consultant	Localite	Interpersonal	2.21	1.23
Other farmers in Your community	Localite	Interpersonal	1.77	.98
A family member or farm partner	Localite	Interpersonal	1.63	1.14

Extent of Diffusion

The extent of diffusion is used here to refer to the proportion of the agricultural population that has adopted the prescribed runoff reduction strategies. A binary measure asked respondents to report whether they had changed 4R-related practices on their farm in the past three years (since the inception of the 4R Nutrient Stewardship Program). The proportion of individuals within a social system reporting adoption is the degree the innovation can be considered to have diffused through the social system.

Results

The survey data were analyzed using the IBM Statistical Package for the Social Sciences (SPSS v.24).

Knowledge

A one-sample *t*-test was used to answer research question one, which asked if agriculturalists within the Maumee River Watershed perceive that they have knowledge of the 4R principles. The perceived knowledge score was compared to a hypothesized population mean of 0, which was chosen as a neutral midpoint denoting neither high nor low levels of knowledge. The perceived knowledge score (M=.71, SD=.72) was statistically significantly higher by 0.71 (95% CI, 0.66 to 0.76) than the knowledge comparison score of 0, $t(739) = 26.63$, $p = .0005$, $d = .98$. Respondents had a level of perceived knowledge regarding the 4R principles statistically significantly above 0 according to this test.

Sources of Information

A binomial logistic regression was performed to answer research question two, which asked if specific information sources relate to individual's adoption of 4R practices within the Maumee River Watershed. Specifically, this regression was used to ascertain the effects of eleven information sources about nutrient stewardship on the likelihood that farmers have changed their 4R-related practices on their farm in the past three years. The logistic regression model was statistically significant, $\chi^2(11) = 108.89$, $p < .0005$. The model explained 19.7% (Nagelkerke R^2) of the variance in 4R related farming practices and correctly classified 67.8% of cases. Sensitivity was 80.8%, specificity was 49.7%, positive predictive value was 69.1%, and negative predictive value was 65.0%. Of the eleven predictor variables, only crop adviser/consultant ($p < .001$), professional/industry magazines ($p = .037$), and the Farm Bureau ($p = .05$) were statistically significant and had a positive relationship to changing farm practices. For every one unit increase in reported frequency of information from their crop adviser/consultant, professional/industry magazines, or the Farm Bureau, the odds of a farmer changing their practices on the farm increased by 1.43 (crop adviser/consultant), 1.24 (professional/industry magazines), and 1.21 (Farm Bureau). A comparison of the eleven predictor values is provided in Table 2.

Table 2. *Comparison of Sources of Information*

	B	**SE**	**Wald**	***Df***	***P***	**Odds Ratio**	**95% CI for Odds Ratio**	
							Lower	Upper
Your County Extension Agent	0.12	0.11	1.07	1	0.30	1.12	0.90	1.39
University Extension	0.17	0.13	1.61	1	0.20	1.18	0.91	1.54
Farm Bureau	0.19	0.10	3.79	1	0.05	1.21	1.0	1.46
Your County Soil and Water Conservation District	0.07	0.11	0.41	1	0.52	1.07	0.87	1.33
Your Crop Advisor/ Consultant	0.36	0.10	13.4	1	0.00	1.43	1.18	1.73
Your Fertilizer Applicator or retailer	0.10	0.10	1.0	1	0.33	1.11	0.90	1.36
USDA NRCS	-0.03	0.18	0.10	1	0.75	0.97	0.78	1.19

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Professional/Industry Magazines	0.21	0.10	4.36	1	0.04	1.24	1.01	1.51
Commodity Groups	-0.11	0.10	1.18	1	0.28	0.89	0.73	1.10
A family member or farm partner	0.15	0.10	2.42	1	0.12	1.16	0.96	1.40
Other farmers in your community	0.07	0.11	0.37	1	0.55	1.07	0.86	1.34

Extent of Diffusion

This study looked at the overall percent of respondents that have changed 4R-related practices in order to answer research question 3, which asked to what extent the 4R frameworks' prescribed runoff reduction strategies have diffused through agricultural communities within the Maumee River Watershed. A change in behaviors is thought to be an indication of adoption. The majority of respondents, 56.4% (N = 748), indicated they changed their 4R-related practices on their farm in the past three years. Changes since the inception of the campaign are understood as adoption. Diffusion of innovations prescribes the following distribution of innovators: 2.5% early adopters, 13.5% early majority, 34% late majority, and 16% laggards (Valente, 1993). Taken together, innovators, early adopters, and early majority constitute 50% of the population distribution. This positions the diffusion of the 4R framework's prescribed runoff reduction strategies firmly in the late majority stage of the diffusion process.

Discussion

The goal of this project was to explore a public communication campaign seeking to encourage behavioral change within an agricultural community using diffusion of innovations. Specifically, this project assessed the effectiveness of the campaign in facilitating the diffusion of 4R related practices through the target agricultural communities.

Research question 1 asked: Do agriculturalists within the Maumee River Watershed perceive that they have knowledge of the 4R principles? Knowledge of an innovation is identified by Rogers (2003) as the first stage of the innovation-decision process, and is an important prerequisite to adoption (Baumgart-Getz, Prokopy, & Floress, 2012). The results of the survey indicate respondents feel they do understand the 4R principles of nutrient stewardship. Perceived understanding, when compared with the instrument midpoint of relative understanding, was statistically significantly higher than the selected knowledge comparison score. Responses to the question, "I feel that I have a pretty good understanding of the four nutrient management principles," as a self-reported, perceived knowledge score were measured to be .71 on a scale ranging from -2 (strongly disagree) to 2 (strongly agree), indicating solid agreement. Because the four nutrient management principles are the basis of the 4R campaign, it is likely that the campaign has improved perceived understanding of the innovation, at least to some degree. While perceived understanding is not a measure of actual understanding, the results for RQ1 show that individuals are familiar with the 4R program and believe that they have some knowledge of the 4R principles.

Research question 2 asked: How do specific information sources relate to individual's adoption of 4R practices within the Maumee River Watershed? The results for RQ2 indicated three specific sources of information were significantly associated with adoption of the 4R principles. The logistic regression analysis of information sources about nutrient stewardship accounted for roughly 20% of the likelihood of farmers reporting they had adopted 4R-related practices on their farms. The three sources of information associated with change, listed in order of significance,

were the crop advisor/consultant, the professional/industry magazines, and finally, the Farm Bureau. Crop advisor/consultant and the professional/industry magazines were sources explicitly used by the 4R campaign, while the Farm Bureau is an organization that communicates information about agricultural innovations to agricultural communities, including information about the 4R principles (Snyder, 2018). These conclusions are broadly consistent with research by Licht, and Martin (2006) who found that Iowa corn farmers used a variety of channels including mass media or general information and interpersonal communication for specific information (p. 19). Consultants were identified as primary sources of information while extension agents were used in evaluating information provided by other sources.

The crop advisors/consultants are change agents that fit the conventional profile of an opinion leader, a critical source of information identified by diffusion of innovations as using localite channels of communication. Crop advisors are individuals who are "knowledgeable about plants and soil. They maintain a close relationship with their client and scout their fields for problems that may arise during the growing season" (AgCareers.com, 2018, NP). Crop advisors advise farmers about a range of issues, such as seed selection, pest and disease management, and fertilizer use. They typically have advanced education and may be certified in their state. Opinion leaders can be key sources of information in a program seeking to encourage the diffusion of an innovation (Valente & Davis, 1999; Gregory, 2010). Crop advisors interact regularly with farmers and serve as key opinion leaders about issues of fertilizer use, and can therefore be considered localite interpersonal channels of communication (Schwartz, 1994).

Professional/industry magazines could refer to a number of materials, including standard farm magazines like *Ohio Farmer.* Many professional documents were made available to farmers in the form of brochures about the 4R principles distributed by fertilizer retailers, as well as a short guidebook entitled *A Pocket Guide to 4R Nutrient Stewardship*. The brochure and *Pocket Guide* were key materials in the 4R Nutrient Stewardship Program and focus explicitly on the 4R principles. These materials were designed by the Fertilizer Institute and given to representatives within the community for local distribution. Although the *Pocket Guide* and brochure were cosmopolite, mass media channels of communication, they were designed to be distributed by retailers and may have functioned as collateral materials to support peer-to-peer communication within the farmers' social system. These materials primarily communicated the innovation characteristics of compatibility and relative advantage. Using local change agents, such as fertilizer retailers, for distribution and emphasizing compatibility may increase farmers' feelings of connectedness with their local community, which has been shown to influence the adoption of agricultural innovations (Baumgart-Getz, Prokopy & Floress 2012).

These results are consistent with previous research that has identified the Farm Bureau as an important part of agricultural diffusion networks (Meyer, 1985, Lubell & Fulton, 2007). The Farm Bureau is an independent, voluntary organization that serves to organize and educate farmers about new agricultural methods. The Farm Bureau describes itself as, "The unified voice of agriculture" (Farm Bureau, 2018, NP). While the Bureau primarily makes use of mass media channels of communication, it is organized down to the local county level with representatives working directly with farmers. In many cases, the Bureau may function as a localite source with both mass media and interpersonal channels, as it often organizes locally and interacts with local opinion leaders. However, most of its communications would be categorized as cosmopolite.

Fertilizer retailers and nutrient service providers were not associated with adoption, despite the 4R Nutrient Stewardship Program prioritizing these groups as key change agents. Although fertilizer retailers and nutrient service providers utilize interpersonal communication to facilitate

adoption, their connections to external organizations make retailers and providers cosmopolite channels of communication. As a result of the close professional relationships that exists between retailers and providers and the Fertilizer Institute's member organizations, potential adopters may believe that retailers and providers have more loyalty to the Fertilizer Institute than to farmers within the social system. The Ohio 4R certification program provided incentives to retailers and providers to encourage their customers to adopt the 4R principles, and this may have created pressures that limited the influence of retailers and providers within the social system.

Some sources are more likely to reach the target audiences, and some sources will be more persuasive than others at different stages of the diffusion process (Baumgart-Getz, Prokopy, & Floress, 2012). The results for RQ2 indicate that some of the channels emphasized by the 4R Nutrient Stewardship Program are associated with adoption. Localite channels, specifically the crop advisers, were associated with adoption. However, cosmopolite and mass media channels still appear to be the primary sources of information concerning the 4R principles. This conclusion is broadly consistent with the diffusion of innovations theory.

Research question 3 asked: What is the extent of the diffusion of the 4R frameworks' prescribed runoff reduction strategies through agricultural communities within the Maumee River Watershed? The results indicate a 56% adoption rate for the 4R principles. At the late-majority stage of adoption, localite interpersonal channels should be more influential, but the influence of cosmopolite channels should still be felt. Opinion leaders seem to be particularly important in facilitating the adoption of innovative 4R practices. Other sources that used interpersonal channels, such as "other farmers in your community" and "a family member or farm partner," were not significant sources of information regarding 4R practices, indicating that diffusion of the 4R principles may not yet have reached the point where further diffusion is driven by peer-to-peer communication. Because cosmopolite channels were found to be associated with adoption more so than localite interpersonal channels, the 4R Nutrient Stewardship Program appears to have not yet achieved the critical mass stage of diffusion.

Rogers (2004) noted that innovators are the first 2.5% to adopt an innovation, followed by early adopters at 13.5%, the early majority at 34%, the late majority for another 34%, and laggards as the remaining 16%. These results indicate the 4R innovations have entered the late majority stage of adoption. This suggests the diffusion may be moving towards a state where the majority of information about an innovation comes from inside the social system and "further diffusion becomes self-sustaining" (Rogers, 2004, p. 13). Results for RQ2 indicated the diffusion of the 4R innovations may not yet be self-sustaining, as cosmopolite channels were associated with adoption more so than localite interpersonal channels. Peer-to-peer communication between community members is broadly consistent with diffusion entering a self-sustaining stage in the diffusion framework. The primacy of sources of information that make use of localite interpersonal channels would be seen as one indication that the diffusion may have been successful and may be moving towards becoming self-sustaining (Rogers, 2003; Valente & Davis, 1999).

Finally, the overall goal of this study was to assess the effectiveness of the 4R campaign at promoting changes in nutrient management in the region of the Maumee River Watershed. The results suggest that about half of farmers report perceived knowledge about the principles, they have adopted some or all of the principles, and there has been an increase in adoption throughout their network. The conclusion that 56% of respondents indicate some change in 4R practices suggests the campaign has been at least partially successful in achieving the strategic goal of promoting innovation in fertilizer practices. These results indicate the 4R campaign may be achieving some success in promoting changes in nutrient management. However, it does not

appear that campaign communication has yet achieved sufficient saturation of adoption for further diffusion to become self-sustaining.

The impact of the 4R Nutrient Stewardship Program on water quality is not clear. However, some sources do indicate modest improvement (Felton, 2017). While harmful algal blooms have continued to occur in Lake Erie, none have been at a level to impact domestic water supplies since the Toledo water crisis. Chris Winslow, director of the Ohio Sea Grant program, noted that the 2017 harmful algal bloom was not as serious as it had been in years past (Johnston, 2017). However, these variations are also driven by weather and climate conditions and may not be connected to changes initiated through the 4R Program. The Maumee River remained on the Ohio Environmental Protection Agency 2018 list of rivers with impaired water quality. The Agency noted, "most of the 31 waters placed on the nitrate watch list are in northwestern Ohio" (Ohio Environmental Protection Agency, 2018b, NP).

Another important point is that the 4R Nutrient Stewardship Program, and any related changes in 4R practices, did not prevent new fertilizer regulation from being put into place. In July 2015, the Ohio General Assembly passed Senate Bill 1, limiting the application of fertilizer and manure on frozen, snow-covered, or saturated fields (Ohio Legislature, 2018). This legislation was in direct response to the Toledo water crisis and was part of a larger plan for agricultural practices and water quality in Ohio, Michigan, and Ontario. In 2018, Michigan finalized details of a plan to cut phosphorus inputs to Lake Erie, identifying three main goals: 1) "minimize the extent of oxygen depleted zones in the waters of the central basin of Lake Erie; 2) maintain healthy animal and plant life in the western and central basins; and 3) maintain cyanobacteria (blue-green algae) levels that do not produce concentrations of toxins" (MDARD, 2018, para 2). Michigan's plan does not include regulation of fertilizer use, but instead calls for the implementation of agricultural best practices.

Some environmental and advocacy groups seem to regard the 4R Nutrient Stewardship Program favorably, indicating that some of the Fertilizer Institute's public image goals may have been achieved. The 4R Nutrient Stewardship Program was cited by the National Wildlife Federation as a positive step taken by the agricultural community because "nutrient management on participating farm fields minimize the potential for runoff and maximizes crop use of nutrients" (Hesse, 2018, para 3). In addition, the Fertilizer Institute has begun working with The Nature Conservancy to promote the 4R principles (Martin, 2016). Endorsements by environmental groups and the inclusion of 4R principles in the Ohio EPA plans for water quality improvement suggest that the campaign is visibly demonstrating efforts were being made to reduce runoff. This was one of the goals of the campaign. The 4R campaign appears to have reduced friction and increased harmony between fertilizer organizations and at least some of their key publics, even if the long-term effect on water quality is unknown.

Conclusions

Several conclusions can be drawn from this study. First, public communication campaign efforts may have some utility in facilitating the diffusion of innovations to address environmental problems. The primary goals of the 4R Nutrient Stewardship Program were to facilitate the diffusion of the 4R principles to the local agricultural community and to improve water quality. These goals supported the larger vision of The Fertilizer Institute to represent the policy and public communication needs of the fertilizer industry (TFI, 2016). The adoption of the 4R principles by farmers will limit fertilizer runoff and may reduce the severity of harmful algal blooms. It is not possible to conclude at this point that the 4R Nutrient Stewardship Program has reduced fertilizer

runoff or improved water quality. However, this study suggests that the 4R Nutrient Stewardship Program is a factor in the adoption of nutrient stewardship principles within the target public.

This study adds to a very large and diverse body of research concerning communication and the diffusion of innovations. This study demonstrated diffusion is supported by information sources, including opinion leaders and change agents such as crop advisors. It is well known that opinion leaders such as crop advisors and consultants play an important role in influencing adoption and diffusion (Baumgart-Getz, Prokopy & Floress 2012; Riesenberg & Gor 1989; Rogers 2003; Ryan & Gross, 1943). The fact that the group promoting the innovation was an industry trade organization is a unique factor in this campaign. Much diffusion research has focused on diffusion efforts led by not-for-profit organizations or governmental agencies (Hanan, 2009; Mulgan et. al., 2007; Okaka, 2010; Valente & Saba, 1998). Industry trade associations, such as the Fertilizer Institute, can leverage significant resources and can create opportunities for member organizations to speak with one voice. Trade associations' may be more effective in promoting innovations within an industry than other organizations, due to their unique access to critical information and resources. In addition, the Fertilizer Institute, through its member organizations, had representatives near the communities targeted for innovation. The use of local change agents is an established tactic for facilitating diffusion, however, change agents may be most effective when they are opinion leaders. Opinion leaders such as crop advisors can access localite, peer-to-peer networks and make effective use of word-of-mouth communication. Rogers (2003) suggested activating peer networks can be effective as a method for accelerating diffusion. Baumgart-Getz, Prokopy, and Floress (2012) also emphasize that innovation in agricultural communities can be enhanced through the use of local networks to disseminate information, including information for extension services.

The results also provide interesting insights into the distinction between localite and cosmopolite channels as conceptualized in diffusion. This study suggests external organizations, in this case a trade association, are able to activate and use localite channels in ways that blur the line between cosmopolite and localite communication. Such strategies may involve providing resources to opinion leaders, such as brochures or talking points, that can be used to support word-of-mouth communication Carl (2006) noted that the power of word of mouth communication has been understood in campaign scholarship for some time. Efforts by organizations to create "buzz," which he defined as "contagious talk about a brand, service, product, or idea" is a more recent development (p. 601). Buzz involves the use of local change agents to drive peer-to-peer communication around a product, innovation, or idea. The ways that cosmopolite and localite channels interact and affect each other is an area where more research is needed, especially as new technologies of digital communication develop and as the channels blur and become harder to identify. Some diffusion scholarship challenged traditionally dichotomous perspectives of mass media and interpersonal channels (Valente & Saba, 1998; Rogers, 1999). Contemporary scholarship has shown that emergent digital tools can function at the intersection of interpersonal communication and mass communication, creating a new conceptual space termed *masspersonal communication* (O'Sullivan & Carr, 2017). There may be need for a revised diffusion frame that understands cosmopolite and localite channels as interactive and interwoven with each other in the contemporary media landscape that intertwines with interpersonal communication.

Limitations and Future Research

The conclusions of this study should be interpreted cautiously within the context of several important limitations. These limitations also suggest future areas of research. First, the data from

the study were limited. Data were collected by researchers at The Ohio State University, focusing within a limited geographic area and on one specific innovation campaign. Scholars should be careful not to generalize from this study nor to expect these results to be consistent in all other campaign contexts. The survey used to collect data on the 4R program in the Maumee River Watershed focused on a broad set of factors and did not collect detailed information about the communication practices of specific sources of information or the larger social structure of the community. Subsequent work could explore these questions in greater detail with a more targeted survey instrument and more comprehensive measures. The survey only examined perceptions of farmers about their knowledge of fertilizer innovations, and employed only two items, which is a limitation in the measure of knowledge used in this study. Logistical challenges like this are common in the development of scales, and this sometimes results in less than optimum measures (Eisinga et al., 2013). That notwithstanding, the two items did constitute a direct and appropriate measure within the context of the larger questionnaire. Future survey work could more rigorously investigate respondents' perceptions of the campaign, as well as sources and channels, to explore how these relate to respondents' perceptions of the value added by innovations.

As with other investigations of public communication campaigns, the goals of the 4R Nutrient Stewardship Program must be inferred to a large degree. Organizations are usually unwilling to open their internal decision-making and strategy deliberations to researchers. In an August 2017 blog post, Lara Moody, the Fertilizer Institute's vice president of stewardship and sustainability programs, wrote:

> All sectors of the fertilizer industry are on board with increasing 4R adoption. Fertilizer application practices are at the center of our industry. Say it's a nice slogan if you want, but applying the right source, at the right rate, the right time and in the right place provides a unifying and actionable message. It has brought significant resources and voices to addressing water quality challenges and preventing nutrient loss (Moody, 2017).

This post indicates the Fertilizer Institute has positioned the 4R campaign as a unifying and comprehensive solution to the fertilizer runoff problem in the Maumee River Watershed. The 4R campaign is the Fertilizer Institute's primary way of addressing the fertilizer runoff issue.

An area for future investigation concerns the role of new media as a source of information. New media, with its very immediate reach and ability to disseminate user-produced content, can blur the lines among localite and cosmopolite channels, mass media and interpersonal channels, and organizational and peer-to-peer communication. Digital spaces may create new opportunities for change agents to be leveraged to enhance a campaign (Nisbet & Kotcher, 2009).

The sources of information identified as important for innovation should be further explored. Specifically, the ways existing community members can function as information sources requires more study. Understanding how opinion leaders functioned as change agents for the 4R Nutrient Stewardship Program may clarify the underlying influence of these individuals in peer-to-peer interactions using word-of-mouth communication. Further exploring how these change agents communicate using cosmopolite and localite channels may reveal new aspects about the process of diffusion. The specific appeals and arguments used by change agents is also important in the success of an innovation (Veil, 2010). Finally, it may be helpful to explore how these agents use resources and specific channels to promote innovation.

Water systems are threatened by a number of factors, including population growth, commercialization of water resources, competition, climate change, and contamination from

agricultural practices. Educating people about innovative practices and technologies, encouraging support for these practices, and facilitating adoption and diffusion of these innovations, are necessary to protect water resources. Behavioral change is also necessary to manage many other public issues that impact both society and organizations. One effective way behavior is changed is through persuasive campaigns. Developing new frames for campaign research is important to both enhance the effectiveness of campaigns and to understand how organizations, including powerful trade associations, influence issues, public policy, and behavior. These new frames can also inform communication practice by enhancing campaign design. Scholars should thus continue to test and evaluate theories, especially diffusion of innovations, in specific case contexts, such as the 4R Nutrient Stewardship Program, to continue to expand and refine this area of scholarship.

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