4R Nutrient Stewardship in the Western Lake Erie Basin

A DESCRIPTIVE REPORT OF BELIEFS, ATTITUDES AND BEST MANAGEMENT PRACTICES IN THE MAUMEE WATERSHED OF THE WESTERN LAKE ERIE BASIN

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Executive Summary

Harmful algal blooms and eutrophication are threatening Lake Erie, a vital ecological and economic resource in the Great Lakes region. Phosphorus lost through agricultural run-off from the Maumee River Watershed appears to be the greatest contributor to the current problem. To better understand farmers' perspectives in this region, particularly current nutrient management practices and barriers to implementation of recommended practices, researchers from The Ohio State University's College of Agriculture, Food and Environmental Sciences conducted a survey in the winter of 2016.

Concerning the characteristics of our sample[1], most farms rotate between corn and soybeans while only one-third of farmers plant a cover crop or winter wheat on a given field. About one-third of farmers utilize manure as a source of fertilizer for some or all of their fields, with 13% reporting use the past year on a given field. Conservation tillage (30 to 90% crop residue) was the most common type of tillage (44.4%), however, no-till (32.8%) and conventional tillage (22.8%) were also used by a large percentage of farmers. The average age was about 57 years old. Over half of respondents received at least some college education while the remainder did not continue formal education past high school. The median farm size was 300 for owned acreage and 500 for rented acreage. 28% of the farms sampled were under 500 acres, 23% were between 500 and 1000 acres, 31% were between 1000 and 2000 acres, and the remaining 18% were over 2000 acres.

The majority of farmers (~80%) had great concern for the ecological health of Lake Erie and how they can minimize their farm's impact on the lake. Most appear to understand the connection between the phosphorus applied to their field and the eutrophication of Lake Erie, however, there was around 10% to 20% of the population that did not share the same concern or understanding. Similarly, a majority of farmers show a willingness to adopt recommended practices, but there is a small percentage that is currently unwilling to adopt many recommended practices. Although this could reduce the likelihood of positive change in Lake Erie, there is no evidence that these operations are proportionally more responsible for the nutrient loss issues, or that changes in their behavior are key to improving water quality. In fact, around 60 to 90% are willing to consider adopting new practices, and in many cases this potential level of adoption may be enough to achieve the recommended phosphorus reductions for Lake Erie (Scavia et al., 2016).

Although the current farming population is largely motivated to adopt new practices, there are several significant barriers associated with recently recommended practices. In regards to cover crops, approximately 25 to 40% of respondents were concerned about fall planting windows, interference with spring planting, and/or the short-term costs. Over half of respondents viewed the cost of specialized equipment for subsurface fertilizer placement as too great and that injecting nutrients ran counter to a no-till approach. One-third of respondents also viewed alternatives to broadcasting as taking too much time.

Those willing to adopt recommended practices tend to be more informed about nutrient stewardship from a variety of both private and public sector sources and more concerned about future regulation. Perhaps due to less exposure to nutrient stewardship information, farmers less willing to adopt tended to have lower awareness of 4R principles, concern for environmental issues and nutrient loss, and awareness of state regulatory requirements. For those practices that involve significant financial investments and new technologies there does seem to be a positive effect of farm size and/or income. Applicator training and working with a consultant is often positively associated with adoption. Generally speaking, increased

[1] The survey was conducted using best practice in sampling and administration to ensure representativeness of the target population. However, there is always the chance of a response bias where the characteristics, beliefs or practices of the particular sample vary in some way from the population.

efficacy or a belief in the effectiveness of a recommended practice is one of the strongest correlates of adoption. As a result, the best target audience moving forward is the future adopters, who account for 20-50% of our sample for any given practice. These individuals indicate a willingness to change their practices, and tend to be less constrained by potential barriers while sharing some of the same motivations of the innovators. Engaging these individuals in outreach focused on how to implement practices effectively is likely to result in the necessary increases in adoption over time. However, it will be critical that this outreach comes from those sources that are trusted (e.g., crop consultants, Extension personnel), involves some degree of peer to peer learning, and that the opportunities to learn be as personalized and hands-on as possible.

Introduction

Background

Lake Erie is the most biologically and economically productive of the Great Lakes; however, this productivity is increasingly threatened by Harmful Algal Blooms (HABs) caused by phosphorus run-off from agricultural fields (ODA, ODNR, OEPA, & LEC, 2013; GLC, 2014). The toxicity of HABs not only poses health risks to those recreating in the lake, but also to large urban centers, such as Toledo, Ohio, as demonstrated by the Toledo Water Crisis in early August 2014 when the HABs impacted the drinking water of half a million people. Additionally, eutrophication and algae also pose a threat to the region's multi-billion dollar sport fishing and tourism economy (GLC, 2014).

Lake Erie's HABs are fueled primarily by phosphorus that washes into Lake Erie. While phosphorus can enter the lake through a variety of sources and take multiple forms, the primary source is dissolved reactive or soluble phosphorus from non-point sources entering the lake through the Maumee River (ODA et al., 2013). Nonpoint sources, including agriculture, are estimated to be responsible for about 61% of the total phosphorus load entering Lake Erie each year; in the WLEB, nonpoint sources are estimated to contribute over 80% of the annual total phosphorus load (Ohio EPA, 2010). A variety of Best Nutrient Management Practices (BNMPs) are available to prevent fertilizer from washing off farm fields and entering the watershed (see Table 1). Many of these practices relate to the "4Rs" of nutrient management: applying the *right* source/type of fertilizer at the *right* rate, at the *right* time of the year and in the *right* place. More information on the 4R Nutrient Stewardship program can be found at: http://www.nutrientstewardship.com/4rs.

Table 1. Description of BMPs assessed in the survey

BMP (As Presented to the Respondent)	Description (Not Presented to Respondent)
Planting cover crops after fall harvest, assuming the weather is favorable	Cover crops help hold the soil in place and prevent erosion and run-off. They can also take up residual nutrients (as tissue matter) left over after the fall harvest.
Avoiding broadcasting when the forecast predicts a 50% or more chance of at least 1 inch of total rainfall in the next 12 hours	Avoiding broadcast fertilizer application prior to a rain event limits the storm-pulsed runoff contributing to HABs.
Avoiding surface application of phosphorus on frozen ground	Fields are often exposed during the fall/winter after harvest. Precipitation, or snowmelt, can wash exposed soil and nutrients into the watershed.
Determining rates based on regular soil testing once within the rotation (or every 3 years)	Regular soil testing can inform how much fertilizer is needed. This prevents excess from being added that cannot be used by the crop.

Subsurface placement of fertilizer (via banding or in-furrow with seed)	Injection of fertilizer below the surface of the soil prevents it from being washed away during a rain event and makes it more readily available to the crop.
Incorporating broadcast fertilizer (via tillage)	Incorporating fertilizer reduces the amount of broadcast fertilizer that may be washed away during a rain event.
Installing or updating subsurface tile	Improved subsurface tile allows for better soil drainage and subsequently more ideal conditions for growing crops and retaining soil nutrients
Adding subsurface tile drainage management (via blind inlets or controlled drainage)	A farmer can control the amount of water (and the associated run-off) leaving a field by using a drainage management system.
Changing the crop rotation from soybean/corn to include wheat, regardless of price	Incorporating wheat into the crop rotation reduces soil erosion and run-off.

In order for BNMPs to be effective at addressing Lake Erie's HABs, a large portion of the farmers living in Lake Erie's watersheds must collectively adopt the practices. For example, a recent study indicates a 40% phosphorus load reduction (from 2008 values) is possible with the adoption of multiple practices across the watershed (Scavia et al., 2016). The best possible scenario involves widespread adoption of cover crops, subsurface placement and filter strips on 50 to 80% of the managed land. To better understand how farmers viewed nutrient stewardship and 4R related practices, we conducted a survey of farmers living in the Maumee Watershed, the largest of Lake Erie's watersheds, and Sandusky River watershed. We were interested in learning how farmers viewed nutrient stewardship, specifically to identify the motivations and constraints that differentiate farmers who adopt and implement the recommendations from those who do not.

Study Area

The focus of this study was the western Lake Erie Basin, including the Maumee and Sandusky river watersheds. This includes a total of 10 HUC-8 watershed boundaries spanning much of northwestern Ohio and extending into southern Michigan and eastern Indiana. The Ohio Lake Erie Task Force has identified nutrient run-off from within the Maumee Watershed as the primary source contributing to Lake Erie's HABs (ODA et al., 2013). The Maumee River begins near Fort Wayne, Indiana, and empties into Lake Erie in Toledo, Ohio. The Sandusky River while not the dominant source of phosphorus in the western basin, extends through four largely agricultural counties before entering the Lake in Sandusky, Ohio.

Survey Instrument

The purpose of the survey was to investigate how farmers perceived recommended nutrient management practices, to what extent ongoing outreach and education was reaching the farming audience, and to what extent retailer certification was influencing farmer decision making. We were specifically interested in what farmers thought were the limitations and barriers to adopting and implementing recommended practices on their fields. The first section of the survey contained questions about how farmers perceived nutrient run-off in their area and their perceptions of the effectiveness of recommended practices to address run-off. The second section of the survey asked farmers about a typical field on their farm, and current management and nutrient application practices. The third section of the survey contained a choice experiment to examine how farmers make decisions about hiring Nutrient Service Providers (NSPs). The last section of the survey asked farmers a set of demographic questions.

Survey Methodology

Researchers from The Ohio State University's College of Agriculture, Food and Environmental Sciences began developing the survey in summer of 2015. The survey was developed by experts within the college, and then reviewed through two focus groups with farmers to make sure the survey items were clearly worded and clear to potential respondents. The survey draft was finalized and sent to farmers between the end of December of 2015 and early March 2016.

Names and mailing addresses for 3,273 farmers living in the Maumee Watershed were obtained from the company Farm Market ID (http://www.farmmarketid.com). The sample was stratified based on farm size to ensure that we could represent the farmers managing the largest proportion of acreage. The sample was divided by farms 50-249 acres (15%), 250-499 acres (13%), 500-999 acres (22%), 1000-1999 acres (31%), and 2000 plus acres (19%). The final sample closely matched census data for farms over 50 acres (with approximately 28% of the respondents in the under 500 category, 22% in the 500-999 category, and 50% in the 1000 plus category). The census reports 34%, 24% and 40% in each category respectively.

Survey implementation followed the Tailored Design Method (Dillman, Smyth, & Christian, 2009). Farmers were first sent a postcard informing them that a survey was being mailed to them so that they would be aware of the study. This postcard also contained a web address for the survey in case they wished to complete the survey online. One week after the postcards were mailed out, farmers who had not already completed the online survey were mailed a paper copy of the survey with instructions on how to fill it out. A couple of weeks after the first mailing, farmers were mailed a second post card reminding them to fill out the survey. Lastly, a second copy of the survey was mailed out to the farmers who had not responded.

Of the 3,273 farmers who were mailed a survey, 70 addresses were returned unopened as being invalid and 278 farmers contacted us asking to be removed from the study. Another 351 farmers indicated on their survey that they were either no longer farming, or did not plan to farm in the next year. These were also removed from the study. Of the remaining 2,574 farmers that we contacted, 748 returned usable surveys accounting for an adjusted response rate of 29.1%.

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Awareness, Concern and Beliefs about Nutrient Loss

Farmers were asked to identify how aware they were of various nutrient stewardship issues as well as how concerned they were about nutrient loss in agriculture. This section offers insight into farmers' beliefs about how informed they think they are about current nutrient stewardship issues and best-practices, where they receive nutrient stewardship information, and their understanding and concern about their farm's contribution to environmental and nutrient loss issues.

Understanding of Nutrient Stewardship

Farmers were prompted about their awareness and understanding of nutrient stewardship and rated their responses to each prompt from "Strongly Disagree" to "Strongly Agree" (Table 2).

Table 2. Responses and valid percentages for farmers' awareness and understanding of nutrient stewardship

Survey Prompt	N	Strongly disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly agree (%)
I think I am better informed about nutrient stewardship than most farmers.	738	2.2	3.4	41.6	41.3	11.5
I feel that I have a pretty good understanding of the four nutrient management principles.	739	1.5	4.9	16.1	62.1	15.4
I often think about nutrient stewardship as it relates to my farm's profitability.	737	1.5	2.8	14.2	59.8	21.6
I often think about nutrient stewardship as it relates to water quality.	737	1.6	2.3	14.0	59.6	22.5

About half the farmers thought they were better informed than most (41.3% agreed, 11.5% strongly agreed), while a similar percentage neither agreed nor disagreed with the statement (41.6%). Only ~5% disagreed with the statement, indicating they felt less informed than other farmers on the topic.

When asked about their understanding of the four nutrient management principles, a strong majority (77.5%) indicated they had a good understanding of the management principles. Notably, 16.1% of farmers neither agreed nor disagreed that they had a good understanding while ~6% indicated a somewhat poor understanding. When combining those that were unsure with those that disagreed, there is evidence that a sizeable portion (25-50%) could benefit from an increased understanding of the principles.

Farmers were prompted about whether they often thought about nutrient stewardship on their farm as it relates to profitability and water quality. Responses across the two questions were very similar with about

80% indicating they thought often about nutrient stewardship as it relates to *both* profitability and water quality. In both cases, about 14% indicated they neither agreed nor disagreed with the statement, while less than 5% disagreed with the statement. The issue is clearly top of mind for most farmers, but there is perhaps room to improve the significance of this issue in on-farm management for about one fifth of the population.

Overall, those that were less informed, with lower understanding, etc. tended to be older, and were less concerned about nutrient loss and the threat of regulation.[1]

Awareness of Agricultural and Environmental Issues

Farmers were asked how often they heard about several agricultural and environmental issues over the past three years. The responses are summarized in Table 3.

Table 3. Responses and valid percentages for farmers' exposure to agricultural and environmental issues

Survey Prompt	N	Not at all (%)	1.0 (%)	2.0 (%)	A moderate amount (%)	4.0 (%)	5.0 (%)	A great deal (%)
Algal blooms in Lake Erie	742	0.9	0.8	0.9	8.4	9.8	20.6	58.5
4R Nutrient Stewardship principles	741	3.5	3.2	8.5	18.9	22.3	21.7	21.9
Nutrient loss in agriculture	741	1.2	1.9	4.0	11.7	20.6	28.9	31.6

Over half (58.5%) stated they had heard or read about algal blooms a great deal in the past three years. The second largest percent of farmers (20.6%) chose five on a 0 to 6 scale, indicating most farmers are exposed to information about algal blooms in Lake Erie.

Respondents were more evenly distributed when asked how much exposure they have had to 4R Nutrient Stewardship principles. Just over one fifth of farmers chose four (22.3%), five (21.7%), and six (21.9%) on the scale. Overall, farmers were less exposed than Lake Erie issues, but still very aware of the issue.

Farmers were asked about nutrient loss in agriculture. Again, the majority indicated they felt exposed to information regarding nutrient loss with 31.6% believing they had a great deal of exposure and 28.9% believing they had a five out of six on the exposure scale.

[1] Based on an independent samples t-test

Obtaining Information about Nutrient Stewardship

Famers were asked how frequently they received information about nutrient stewardship from various sources during a typical year. They rated each source from 0 (never) to 4 (very frequently) and results are summarized in Table 4.

Table 4. Responses and valid percentages for frequency of receiving nutrient stewardship information

Information Source	N	Mean	% Never	% Rarely	% Sometimes	% Frequently	% Very frequently
Your County Extension Agency	735	1.801	13.7	20.8	40.0	22.4	3.0
University Extension Generally	731	1.824	9.3	22.7	45.6	21.2	1.2
Farm Bureau	726	1.679	17.1	23.6	35.7	21.8	1.9
Your County Soil and Water Conservation District	734	2.162	8.2	14.4	37.9	32.0	7.5
Your Crop Adviser/Consultant	718	2.064	15.7	13.5	30.8	28.6	11.4
Your Fertilizer Applicator or Retailer	732	2.208	9.6	16.3	29.9	32.4	11.9
USDA NRCS	722	1.796	14.3	21.9	38.9	19.8	5.1
Professional/Industry Magazines	732	2.425	4.6	10.8	32.7	41.3	10.7
Commodity Group	725	1.364	23.0	32.8	30.6	11.7	1.8
A Family Member or Farm Partner	727	1.631	20.1	25.0	31.4	18.7	4.8
Other Farmers in your Community	734	1.766	11.0	26.4	40.2	19.6	2.7

Farmers' responses indicate they frequently or very frequently receive information regarding nutrient stewardship from professional/industry magazines (52%), their fertilizer applicator or retailer (44.3%), crop advisors/consultants (40%) and their County Soil and Water Conservation District (39.5%). These four information sources standout as the most frequent avenues of receiving information, although we didn't explicitly measures to what extent they used or trusted these sources, there is evidence that farmers often turn to their consultants in agribusiness for advice. The sources that are least frequently used (those where respondents indicated "never" or "rarely" used) include commodity groups (55.9%), a family member or farm partner (45.1%) and the Farm Bureau (40.6%). A substantial percentage of farmers (at least 29%) indicated they "sometimes" received information from each information source. Each listed source appears to be a somewhat effective means of transmitting nutrient stewardship information but several stand out as more or less effective in comparison.

Farmers were asked to indicate whether several statements pertaining to Ohio nutrient management laws, 4R practices, and their use of fertilizers on their farm pertained to them. Responses have been summarized as the percent who indicated the statement applied to them (Table 5).

Table 5. Valid percentages for farmers indicating the particular statement applied to them (n = 748)

Survey Prompt	Valid %
I am aware of the Ohio law requiring fertilizer applicators to be certified.	89.2
I have already participated in the private fertilizer applicator certification training.	50.0
I am aware of the Ohio law restricting application on saturated/frozen ground, and before storms.	89.0
I work with a consultant to make my nutrient management decisions.	60.2
I have noticed changes in 4R related practices in the past three years among farmers in my community.	46.9
I have changed 4R related practices on my farm in the past three years.	56.4
I use manure as a source of fertilizer on my farm.	32.9

Farmers appear to be familiar with Ohio laws pertaining to fertilizers as ~90% said they were aware of laws requiring fertilizer applicator certification as well as fertilizer restrictions on saturated/frozen ground and before storms. Only 1/3 indicated that they use manure as a source of fertilizer on their farm at any given time on a given field.

About half of the respondents indicated they participated in certification training, changed 4R related practices on their farm, or noticed 4R practices change in their community in the past three years. This could indicate about half of the farmers are actively adopting new nutrient management practices while the other half may be less aware of changes being made in terms of nutrient stewardship techniques. It is possible that some changes are not noticed because they are not easily visible (e.g., adjusting the timing of application in light of spring storms), while others are more readily visible (e.g., cover crops). However, noticing changes does not necessarily limit to those practices farmers have personally seen, but it could include those that they have heard about through conversations with others in their community.

Consultants appear to be used by 60% of farmers for making nutrient management decisions. Ensuring consultants are abiding by (and communicating) best-practice techniques could have a widespread impact on nutrient stewardship practices.

Concern about Nutrient Loss Issues

To see how concerned farmers were about the impact of nutrient loss we asked farmers nine questions. Responses ranged from 0 (not at all concerned) to 6 (extremely concerned). The feedback, summarized in Table 6, primarily consisted of responses of 4's, 5's, and 6's (extremely concerned). The majority of farmers appear to be concerned about each listed issue (Table 6), and most concerned with potential governmental rules and regulations related to nutrient stewardship.

A sizable minority of farmers, ranging from 6% to 28% depending on the issue, indicated they were not very concerned (answered 0 to 2) about each issue. Farmers were the least concerned about their farm contributing to algal blooms in Lake Erie, reflecting the idea that it is a collective problem and either their individual contribution is minimal or perhaps they feel that others in the watershed are more responsible. Farmers were the most concerned about additional governmental regulation or rules related to nutrients, which is a likely motivation to voluntarily adjust practices now to avoid being forced to take a particular approach in the future. This could be a key focus of future education and outreach, that acting now is a way to avoid future regulation under less than ideal terms. It seems that the individuals who are most concerned about regulation are two to three times as likely to be innovators or current adopters across a range of recommended practices, indicating that this belief is a major driver of adoption.

Table 6. Responses and valid percentages for farmers' concern about various farm related issues

Issue	N	Mean (0-6)	Not at all concerned (%)	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)	Extremely concerned (%)
Nutrient loss occurring on your farm in 2016	739	4.1	3.0	6.9	6.9	13.3	22.7	25.7	21.5
Your farm contributing to algal blooms in Lake Erie	739	3.5	6.9	10.4	11.0	17.7	18.0	20.0	16.0
The negative impacts of nutrient loss on Lake Erie	733	4.1	3.1	5.0	9.0	15.3	21.8	24.6	21.1
The negative impacts of nutrient loss to your farm's profitability	736	4.4	3.0	4.2	4.9	11.5	20.7	27.9	27.9
Nutrient loss occurring on your farm in 5 to 10 years	739	4.0	3.4	7.4	7.6	14.7	20.7	26.5	19.6
Additional government regulation or rules related to nutrients	737	5.1	2.2	1.1	2.4	6.0	8.0	23.3	57.0
Your farm's impact on local water quality	740	4.1	4.5	6.1	7.0	14.7	18.9	26.1	22.7
A lawsuit targeted to farmers because of nutrient loss to Lake Erie	737	4.5	3.8	4.5	4.7	12.5	14.4	24.0	36.1
Nutrients lost from your farm during a heavy spring rain	741	4.2	4.0	4.6	6.2	14.6	17.8	26.9	25.9

Beliefs about Best Management Practices

Respondents were asked to what extent they believed recommended 4R practices would reduce phosphorus runoff (Table 7). They were also asked their opinion on the extent to which each practice could improve water quality in Western Lake Erie (Table 8). Lastly, respondents were asked to rate their confidence that each practice could be implemented in the upcoming season on most of their fields (Table 9). The results in Tables 7 through 9 offer a picture as to how much farmers believe various 4R practices are effective in reducing runoff (i.e., individual response efficacy) and improving water quality (i.e., collective response efficacy) and their perceived ability to implement the practice (i.e., self-efficacy).

Effectiveness and Ease of Implementation

Table 7. Responses and valid percentages for farmers' beliefs about effectiveness of various 4R practices at reducing phosphorus runoff from fields

Survey Prompt	N	Mean	Not at all (%)	A little (%)	Somewhat (%)	A good deal (%)	To a great extent (%)
Avoiding broadcasting when the forecast predicts a 50% or more chance of at least 1 inch of total rainfall in the next 12 hours	735	2.75	3.8	7.2	23.1	42.2	23.7
Avoiding surface application of phosphorus on frozen ground	735	3.10	4.5	4.4	12.4	34.6	44.2
Incorporating broadcast fertilizer (via tillage)	730	2.76	5.8	7.5	19.0	40.0	27.7
Subsurface placement of fertilizer (via banding or in-furrow with seed)	726	2.76	6.5	8.3	17.9	37.7	29.6
Determining rates based on regular soil testing once within the rotation (or every 3 years)	736	3.14	2.9	4.3	11.5	38.7	42.5
Incorporating winter wheat or a cereal rye cover into your rotation	733	2.58	8.6	9.5	22.9	33.6	25.4

Survey responses (Table 7) showed that the majority of farmers believed the practices were a good deal to a great extent helpful in reducing phosphorous runoff from their fields (0 indicates "not at all" and 4 indicates "a great extent"). Farmers had the least confidence in incorporating wheat or cereal rye into their rotations with almost 20% indicating they did not think it would help at all or would only help a little. Farmers had the most confidence in avoiding application on frozen ground and determining rates based

on regular soil testing, with approximately 80% indicating these practices would reduce nutrient loss a good deal or to a great extent.

Table 8. Responses and valid percentages for farmers' beliefs about effectiveness of various 4R practices at improving water quality in western Lake Erie

Survey Prompt	N	Not at all (%)	A little (%)	Somewhat (%)	A good deal (%)	To a great extent (%)
Avoiding broadcasting when the forecast predicts a 50% or more chance of at least 1 inch of total rainfall in the next 12 hours	727	3.3	10.3	26.1	39.3	20.9
Avoiding surface application of phosphorus on frozen ground	726	2.9	7.3	15.7	33.3	40.8
Incorporating broadcast fertilizer (via tillage)	721	4.4	9.3	24.1	39.8	22.3
Subsurface placement of fertilizer (via banding or in-furrow with seed)	717	4.6	9.1	21.9	39.6	24.8
Determining rates based on regular soil testing once within the rotation (or every 3 years)	726	2.5	6.1	15.0	39.0	37.5
Incorporating winter wheat or a cereal rye cover into your rotation	723	5.5	10.5	24.3	34.0	25.6

Similar to beliefs about the efficacy of recommended practices at reducing nutrient loss from the field, the majority of farmers seem to believe that each listed practice (Table 8) would also be effective in improving water quality in Western Lake Erie as a collective solution. However, a minority of farmers is still a bit skeptical as to whether the farm-level changes could improve water quality in Lake Erie, with anywhere from 9 to 16% of farmers indicating that the practices are either not at all or only a little effective. These results indicate that the majority of farmers accept the idea that changing agricultural practices are a potential solution to the issues in the Lake.

Table 9. Farmers' mean and standard deviation of confidence in implementing 4R strategies

Agricultural Practice	N	Mean (0-100)	Std. Deviation
Avoiding broadcasting when the forecast predicts a 50% or more chance of at least 1 inch of total rainfall in the next 12 hours	717	72.6	26.0
Avoiding surface application of phosphorus on frozen ground	712	87.0	23.7
Incorporating broadcast fertilizer (via tillage)	713	66.4	31.5
Subsurface placement of fertilizer (via banding or in-furrow with seed)	710	61.6	35.0
Determining rates based on regular soil testing once within the rotation (or every 3 years)	717	85.7	22.9
Incorporating winter wheat or a cereal rye cover into your rotation	712	61.5	32.1

Some practices are easier for farmers to implement than others. Farmers were asked how confident they were they could implement each practice in the upcoming season (Table 9). They responded with a number from 0 (cannot at all) to 100 (absolutely can do it), with 50 as a benchmark (may be able to do it).

The two highest means, and therefore easiest to implement, were avoiding surface application on frozen ground (87.0) and using soil testing once within the rotation or every 3 years (85.7). These were also the practices that famers believed were the most effective for the farm and the Lake (Tables 7 and 8). Subsurface placement of fertilizer (61.6) and incorporating winter wheat or cereal rye into the rotation (61.5) were the two practices that were considered to be the most difficult to implement. Confidence was however highly variable across the respondents indicating there are some individuals who are may need additional technical support to successfully implement a practice. The greatest variation in response was around subsurface placement, indicating there may be varied opinions on how easy this would be to implement.

Potential Barriers

Farmers were asked to what extent they agreed or disagreed with statements pertaining to potential barriers to adopting nutrient stewardship practices on their farm. Responses ranged from -2 (strongly disagree) to 2 (strongly agree) with each statement. Results are summarized in Table 10.

Table 10. Potential barriers to the adoption of nutrient stewardship practices

Survey Prompt	N	Mean	Strongly disagree (%)	Disagree (%)	Neither agree nor disagree (%)	Agree (%)	Strongly agree (%)
Weather is too unpredictable to avoid applying nutrients before heavy rain.	725	0.14	5.1	25.5	28.0	32.7	8.7
Nutrients must be applied to a field in the winter if that field floods in fall or spring.	717	-1.00	34.2	40.4	18.1	5.9	1.4
Nutrients must be applied in the winter if it's too wet to spread them in the fall.	723	-0.76	23.9	41.6	22.0	10.9	1.5
Manure must be applied in the winter if there is a lack of manure storage space.	717	-0.10	14.8	19.8	32.8	26.1	6.6
Injecting nutrients into the soil is a form of tillage.	724	0.41	3.5	14.0	28.9	45.6	8.1
The equipment needed to inject nutrients into the soil is too costly to purchase.	723	0.49	2.9	11.8	33.7	36.4	15.2
Alternatives to broadcasting are too slow.	725	0.09	4.3	20.8	41.9	27.9	5.1
Soil tests are too costly to use on my fields.	725	-1.20	44.7	36.6	14.5	2.8	1.5
I do not need a soil test to determine rates.	725	-1.28	49.2	36.3	10.1	2.3	2.1
It is necessary to apply more nutrients than the soil tests recommend in order to maintain very robust crops.	727	-0.96	30.7	43.1	19.1	5.8	1.4
The profit margins for winter wheat are too small.	726	0.79	3.4	10.1	20.7	36.1	29.8
Establishing winter cover crops is too difficult due to uncertain planting windows.	727	0.13	6.1	22.3	32.3	31.1	8.3
The risks of winter cover crops interfering with spring planting are too great.	727	-0.18	8.7	31.1	35.6	18.3	6.3
The near-term cost of cover crops is too great for the uncertain long-term payback.	727	0.08	6.7	21.9	35.9	27.6	7.8

Most of the barriers were perceived as moderate in importance, with only a few clearly identified as critical. A large percentage of respondents agreed or strongly agreed (65.8% combined) that the profit margins for winter wheat are too small. Similarly, respondents were concerned about establishing cover crops in the fall (~40%), as felt there was too much uncertainty associated with the long-term benefits to justify the initial cost (~35%). Current research is underway to better quantify and promote the benefits of cover crops (e.g., see soilhealthpartnership.org), but additional research and outreach in this area is needed to build confidence in this practice. About half of respondents believed that injecting nutrients into the soil is a form of tillage, which would prevent those in a no-till system from wanting to use the practice, and a similar percentage believed that the equipment required for injecting nutrients into soil is too costly to purchase. The barriers related to soil tests were clearly very minimal, as most farmers did

not believe that soil tests were too costly or unnecessary. Similarly, the majority (~70%) does not feel constrained to apply nutrients in the winter due to variable conditions in spring or fall. However, at least 40% do not think that forecasts are reliable enough to adjust the timing of application in the spring, suggesting that focusing on the accuracy of forecasts and the ability to use this information in timing related decisions could be critical.

Farm Characteristics

For this section, farmers were asked to pick a typical field on their farm and answer the following questions specific to that field for the 2015 growing season.

Typical Crop

Farmers were asked what crop they planted on the representative field in the 2015 growing season (Table 11). Corn was the most common at 56.1%, soybeans were second at 38.7%, and wheat was the lowest at 4.7%[1]. Some farmers (0.8%) stated that they had planted a different crop than the three listed.

Table 11. Crop planted in 2015 (n = 719)

Crop Type	Valid %
Corn	56.1
Soybeans	38.7
Wheat	4.5
Other crop	0.8

Current Established Rotation

Farmers were asked what crop rotation they currently used in the particular field (Table 12). The rotation of corn/soybeans (52.7%) and corn/soybeans/wheat (34.0%) were overwhelmingly the most popular. All other options were at or below 6.0%.

Table 12. Farmers current established rotations (n = 717)

Crop Rotation	Valid %
None or continuous single crop	2.6
Corn/Soybeans	52.7
Corn/Soybeans/Wheat	34.0
Soybeans/Wheat	4.6
Other	6.0

Cover Crop

Respondents were asked if they planted a cover crop on this field in 2015 (including both winter wheat and other types of cover for purely conservation purposes). Slightly less than one third (27.2%, n = 729)

[1] NASS shows substantially more soybean acres than corn in the Maumee watershed (1.9 versus 1.3 million acres). Producers may have felt some bias to select the crop they fertilize, increasing the relative proportion of corn acres included in the results.

of farmers planted a cover crop while the majority of farmers did not. These ranged from cereal rye to wheat to radishes[1].

Tillage

Farmers were asked what type of tillage they used in this field based on crop residue after planting (Table 13). Tillage types were based on conventional (<30% residue), conservation (30-90% residue), or no-till (>90% residue). Responses indicated conservation tillage and no-till were the most popular but conservation tillage was highest for corn, while no-till was higher for soybeans and wheat. 77.2% of the farmers had at least 30% cover on the farm fields.

Table 13. Tillage based on crop residue

Tillage Type	Valid %		
	Corn N = 398	**Soybeans N = 276**	**Wheat N = 32**
Conventional (<30% residue)	20.4	25.2	25.0
Conservation (30-90% residue)	51.5	36.0	34.4
No-till (>90% residue)	27.8	38.1	40.6

Field Size

Farmers were asked the size of the field in acres (Table 14). There was a wide range of acreage but the mean size of the field was ~66 acres.

Table 14. Size of field in acres (n = 708).

	Min	**Max**	**Mean**	**Median**	**Std. Deviation**
Size of Field (Acres)	4	800	63.5	50.0	56.0

Custom Application

Farmers were asked if they had phosphorus custom applied. The number of farmers was split with about half that had their phosphorus custom applied (52.1%) and half that had not (47.9%).

[1] NASS indicates that about 12% of farmers across the Maumee watershed are planting winter wheat, while estimates of other types of cover for purely conservation purposes are more difficult to find. Reports of cover crops used strictly for conservation across the upper Midwest range from 8 to 12% of farmers, but only 2% of the total acreage farmed (Bryant et al. 2013).

Past Application Intent

Respondents were asked about the previous year's phosphorus application intent (Table 15). Of the 715 respondents, the majority applied enough phosphorus for the current year (62% of farmers planting corn, 47% of farmers planting beans), while the next most common application intent was enough for two years for corn (27.2%) and no application for soybeans (30.5%).

Table 15. Previous year's phosphorus application intent

Phosphorus Application	Valid %		
	Corn (n=394)	Soybeans (n=272)	Wheat (n=31)
No application	9.4	30.5	16.1
Enough for the current year	61.9	47.4	71.0
Enough for the next two years	27.2	19.5	12.9
Enough for the next three years	1.5	2.2	0.0
Enough for the next four years	0.0	0.4	0.0

Phosphorus and Nitrogen Form

Considering all commercial fertilizer sources, farmers were asked to state what form of phosphorus (Table 16) and nitrogen (Table 17) they had applied to their field in the previous year. They were also asked to state how much fertilizer they had used in lbs/acre (Table 18). The most common form of phosphorus was MAP (49.2%), while the most common form of nitrogen was NH_3 (37.5%) followed closely by UAN (32.0%). The average amount of P_2O_5 applied was 89.2 lbs/acre and the average amount of nitrogen applied was about 163.9 lbs/acre.

Table 16. Form of phosphorus used in 2015 (n = 439)

Form (P)	Valid %
MAP	49.2
DAP	23.0
Fluid	19.6
Other	8.2

Table 17. Form of nitrogen used in 2015 (n = 416)

Form (N)	Valid %
Urea	15.9
UAN	32.0
NH_3	37.5
Other	14.7

Table 18. Rate of commercial fertilizer used on field in 2015 (by application intent)

Fertilizer Type	N	Min	Max	Mean			Median		
				1 yr	*2 yr*	*3 yr*	*1 yr*	*2 yr*	*3 yr*
P_2O_5 (lbs/acre)	329	1.3	400	87.5	104.8	117.0	75.0	91.0	110.0
N (lbs/acre)	380	2	878	158.2	201.3	140.0	175.0	180.0	140.0

Timing and Method of Application

Farmers were asked when they applied phosphorus on this field. Of the 681 individuals who answered this question, 18% reported no application and another 20% indicated multiple answers making it difficult to match timing with the method. Of the 420 individuals reporting just one method of application sometime during the previous two seasons, the most popular time for phosphorus application was winter (~31%), followed by fall (~26%), and spring (~21%) (Table 19). Farmers were asked to indicate all methods they used to apply phosphorous to their most recent crop (Table 19). Surface broadcasting and incorporation with tillage within 7 days was the most commonly used application method (~54%). The least common method was surface banding at ~4%.

Table 19. Timing and method of phosphorus application (n = 583)

	Counts					
Method of P Application	**Fall**	**Winter**	**Spring**	**Previous Season**	**TOTALS**	**Valid %**
Surface banding	4	3	6	4	17	4.05
Subsurface banding	3	8	14	41	66	15.71
In furrow with seed	4	1	4	13	22	5.24
Broadcast (no incorporation)	25	34	17	13	89	21.19
Broadcast & incorporated with tillage within 7 days	73	84	47	22	226	53.81
TOTALS	109	130	88	93	420	
Valid %	25.95	30.95	20.95	22.14		100%

Manure Application

Farmers were asked if they applied manure to their most recent crop. Of 721 farmers, 12.5% applied manure for their most recent crop (n=89). Overall, 15% of farmers reported no manure or commercial P application, while 73% reported commercial P application but no manure application. Of the remaining 13% who report using manure, 10% reported both manure and commercial P application while only 3% reported using solely manure. If farmers had applied manure, they were asked to state how much liquid manure in gallons/acre or solid manure in tons/acre they applied (Table 20). The mean liquid manure applied was 4538 gallons/acre and the mean solid manure applied was about 4 tons per acre.

Table 20. Amount of manure applied for most recent crop

	N	Mean	Std. Deviation
Liquid Manure (gallons/acre)	40	4538	4231
Solid Manure (tons/acre)	57	3.956	9.0570

Farmers were asked what time of year they had applied manure to their field (Table 21). Winter and fall were the most common times for manure application. The previous season and spring at planting were the least common among respondents.

Table 21. Time of manure application for most recent crop

Time of Manure Application	N	Frequency	Valid %
No application	80	6	8
Spring pre-planting	85	22	26
Fall	82	31	38
Previous season	80	4	5
Spring at planting	80	1	1
Winter	83	34	41
After planting	81	9	11

Lastly, farmers were asked how the manure was applied (Table 22). Surface application with tillage incorporation was the most common method of manure application while surface banding and subsurface banding or injection were the least popular methods. The results indicate that about 30% of the manure applied is not incorporated, while 60% is surface applied and incorporated while 10% is banded.

Table 22. Method of manure application for most recent crop

Method of Manure Application	N	Frequency	Valid %
None applied	80	4	5
Surface applied, incorporated with tillage	87	47	54
Surface applied, no incorporation	81	25	31
Subsurface banding or injection	81	5	6
Surface banding	80	2	3

Soil Testing

Farmers were asked a series of questions on soil testing. First, they were asked if they use soil testing to aid in their nutrient management decisions. The vast majority of farmers (88.5%, n = 710) indicated they used soil testing for this purpose.

They were then asked how often they used soil testing (Table 23). Of the farmers that stated they did use testing, over half (55.2%) said they did so every 3 years. The remaining farmers tested every 2 years (26.7%) or every 4 years or more (18.1%).

Table 23. Soil test frequency (n = 629)

Soil Test Frequency	Valid %
Every 2 years	26.7
Every 3 years	55.2
Every 4 years	18.1

Survey respondents were also asked to state the field's last Bray P1 (Table 24) and Mehlich-3 (Table 25) phosphorus reading in parts per million (ppm). A large percentage of farmers did not know their last soil test reading (39.3% for the Bray P1 test and 65.5% for Mehlich-3). Of the farmers that did know, most Bray P1 results indicated phosphorus levels of at least 15 ppm with over 20% reading greater than 30 ppm. Most Mehlich-3 test results indicated phosphorus levels were at 28-46 ppm.

Table 24. Bray P1 phosphorus in soil reading (n = 463)

Phosphorus Reading	Valid %
< 15 ppm	3.9
15-30 ppm	35.2
> 30 ppm	21.6
I don't know	39.3

Table 25. Mehlich-3 phosphorus in soil reading (n = 345)

Phosphorus Reading	Valid %
< 28 ppm	5.8
28-46 ppm	19.7
> 46 ppm	9.0
I don't know	65.5

The type of sampling (Table 26) farmers used varied between random (24.9%), zone (29.7%), and grid sampling (45.4%).

Table 26. Type of sampling used (n = 599)

Sampling Type	Valid %
Random	24.9
Zone	29.7
Grid	45.4

Land Rental

When prompted about land rental, about 1/4 (n=177) of farmers indicated they rented the selected field. Of those renting (Table 27), the majority (82%) of farmers were responsible for the nutrient management decisions while the remaining percent share the nutrient management decision responsibility with their landlord or have another arrangement. A rental agreement (Table 28) of *rent for cash* (90 respondents) was more common than a *rent for crop share* agreement (32 respondents).

Table 27. Party responsible for nutrient management decisions (n = 169)

Responsible Party	Valid %
Me alone	81.7
Me and my landlord	12.0
Other	7.0

Table 28. Farmers' rental agreement with landlord for field (n = 175)

Agreement	Valid %
Rent for cash	51.4
Rent for a share of crop	18.3

4R Practice Likelihood of Implementation

Farmers were asked whether they had used various 4R practices in the past three years and then if they plan to use that practice in the next year (Table 29). The majority of farmers have used most of the listed practices within the past three years. Adding subsurface tile drainage management technology stands out as the least popular with only one-fourth of farmers having done so in the last 3 years, although one-third report a willingness to do so in the future. Regular soil testing to determine rate (90.1%), avoiding broadcasting with likely rain within the next 12 hours (84.8%), and avoiding surface application of phosphorus on frozen ground (81.5%) were the most popular among respondents.

As expected, the percentage of respondents that would likely or definitely use each respective practice is similar to the percentage of those that have used the practice in the past 3 years. About 33% more respondents indicated they would likely or definitely use subsurface fertilizer placement compared to those that have used it in the past three years. Each practice appears to be remaining the same or growing in use by farmers except for changing crop rotation which had a ~10% decrease in likelihood of use compared to those that have used it in the past three years. This could be related to changes in cost-sharing programs for cover crops. Importantly, 20 to 50% of farmers are considering the use of each practice, while 10 to 60% report plans to use the practice in the next year. By far the majority is amenable to the recommendations, but may need additional technical assistance to follow through with implementation.

Table 29. Valid percent of farmers' previous 4R practice usage and likelihood of future use

	In the last three years, I...		In the next year, I…				
Practices	**N**	**have used this practice (%)**	**N**	**I will not use it (%)**	**Am unlikely to use it (%)**	**Am likely to use it (%)**	**Will definitely use it (%)**
Avoiding broadcasting when the forecast predicts a 50% or more chance of at least 1 inch of total rainfall in the next 12 hours	709	73.8	682	7.0	8.2	47.4	37.4
Avoiding surface application of phosphorus on frozen ground	712	81.5	682	13.3	5.1	28.4	53.1
Incorporating broadcast fertilizer (via tillage)	699	71.4	676	16.1	13.2	35.7	35.1
Subsurface placement of fertilizer (via banding or in-furrow with seed)	701	64.1	672	17.7	17.7	28.7	35.9
Determining rates based on regular soil testing once within the rotation (or every 3 years)	708	88.6	684	5.6	4.4	30.4	59.6
Installing or updating subsurface tile	698	62.8	666	24.5	20.4	29.1	26.0
Adding subsurface tile drainage management (via blind inlets or controlled drainage)	691	25.9	655	31.8	34.4	22.4	11.5
Planting cover crops after fall harvest, assuming the weather is favorable	708	47.9	684	14.2	27.6	38.2	20.0
Changing the crop rotation from soybean/corn to include wheat, regardless of wheat prices	707	53.3	678	27.1	28.3	26.7	17.8

Nutrient Service Providers and 4R Certification

This section looks at Nutrient Service Providers (NSP), which are any agricultural retailers, service providers and other certified professionals who provide sales or services related to nutrients applied to crops. Farmers were asked various questions pertaining to NSP distribution, service satisfaction, and considerations they would take into account when working with a NSP.

Products and Services

Respondents were asked about the products and services they obtain from Nutrient Service Providers (Table 30). About half of farmers obtained each listed service from an NSP across the board while the other half did not.

Table 30. Services obtained from primary NSP

Obtained from NSPs	N	Valid %
Soil testing	744	47.8
Nutrient recommendations	744	47.3
Fertilizer application services	744	48.1
Bulk fertilizer sales	744	47.6
Bagged fertilizer sales[1]	745	54.4
Sales or application of other chemical	745	46.6
Other	745	55.0

Nutrient Service Provider Satisfaction and Influence

Respondents were asked the number of NSP's that could feasibly provide service to their operation, how many NSP's they worked with in the past year, how long they have been working with their longest serving NSP, and the cost of services for corn and soybeans (Table 31). Most farmers could use about 2 to 3 NSP's to provide service to their operation, 1.84 was the mean number of NSPs farmers worked with in the past year and 21.2 years was the mean amount of time for farmers' longest serving NSPs. The mean cost for corn and soybeans from farmers' primary NSP were $356.90 per acre and $420.90 per acre, respectively[2].

[1] This number seems a bit high given most P products are purchased in build, but it could include micronutrients or specialty fertilizers delivered in bulk bags, or even lawn fertilizers purchased at the coop.

[2] It is not typical for corn to have lower costs per acres than soybeans, but it is unclear here if farmers are reporting the costs of service or products, or both.

Table 31. Nutrient Service Provider information means and survey responses

Survey Prompt	N	Mean	Std. Deviation
NSPs that could feasibly provide service to your operation	660	2.31	1.58
NSPs that have you worked with during the past 12 months	681	1.84	1.37
Time with longest serving NSP (years)	671	21.2	12.1
Cost of services for *corn* crop from primary NSP (dollars/acre)	401	356.90	2669.4
Cost of services for *soybean* crop from primary NSP (dollars/acre)	405	420.90	5113.8

Respondents were asked whether they had switched their primary NSP in the past two years and only 7% (n = 710) indicated they had switched. Of those that switched, price was the most popular reason that farmers switched their NSP, followed by quality and timeliness of service (Table 32).

Table 32. Respondent's reason for switching NSP in past two years

Aspect of service that led to change in NSP	N	Frequency
Price	240	46
Range of products and services	211	14
Quality of service	226	31
Timeliness of service	224	27
Other	210	10

Farmers were asked how much influence their primary Nutrient Service Provider has on their nutrient application practices (Table 33). Most farmers said it played a large role in the practices they implement as 48.0% answered that their NSP had a moderate influence and 34.6% said it had a strong influence.

Table 33. NSP influence on nutrient application practices

Survey Prompt	N	No influence (%)	Weak (%)	Moderate (%)	Strong (%)
How much of an influence does your primary NSP have on the nutrient application practices you implement?	713	9.6	7.9	48.0	34.6

Farmers were also asked how satisfied they were with their current Nutrient Service Provider (Table 34). The majority of respondents appear to be content with their current NSP as 48.9% answered they were satisfied with their NSP and 39.9% said they were very satisfied.

Table 34. Farmers' satisfaction with primary NSP

Survey Prompt	N	Not at all satisfied (%)	Somewhat satisfied (%)	Satisfied (%)	Very satisfied (%)
Overall how satisfied are you with your current NSP?	709	4.1	7.1	48.9	39.9

Nutrient Service Provider Certification

Farmers were asked whether they were aware of the 4R Nutrient Stewardship Certification Program for NSPs and whether any of the NSPs working with their farm are certified by it (Table 35). Sizable percentages of respondents indicated they were not aware of the certification program (16.5%) or were unsure (10.7%), leaving room for slightly under 1/3 of farmers that could benefit from education about the certification program. Though many farmers were aware of the program, only ~44% of farmers said their NSP was certified while the rest were either not certified (22.4%) or their customers were unsure (33.5%).

Table 35. Farmers' awareness of Nutrient Service Provider certification

Survey Question	N	% Yes	% No	% Unsure
Prior to this survey, were you aware of the 4R Nutrient Stewardship Certification Program for NSPs?	713	72.8	16.5	10.7
Are any of the NSPs who work with your farm certified by the 4R Nutrient Stewardship Certification Program?	626	44.1	22.4	33.5

When asked how likely they would be to work with a certified NSP if they followed various requirements, respondents indicated how each requirement effected their decision by answering -2 "very unlikely" to 2 "very likely" (Table 36). Firms that maintain field-by-field records of nutrient application, offer personalized fertilizer recommendations based on current science and yields, and avoid nutrient application on frozen ground or prior to expected precipitation have a greater percentage of respondents indicating they would work with them.

Firms that require customers' signatures confirming customer support of 4R nutrient practices had a large percentage (44.6%) of respondents indicating that would have no impact on their decision. Most listed requirements in Table 36 had a small percentage of respondents that said they would be unlikely or very unlikely to work with the firm. However, for a firm that completes a private third party audit every 3 years to ensure 4R practices are followed, 26.9% of respondents indicated they would be very unlikely or unlikely to work with them and 43.6% said it would have no impact on their decision.

Table 36. Farmers' likelihood to work with NSP if they follow various requirements

How likely are you work with the firm if they…	N	Mean	Very unlikely (%)	Unlikely (%)	No impact on decision (%)	Likely (%)	Very likely (%)
Maintain field-by-field records of nutrient applications	703	0.973	1.7	2.3	23.6	41.8	30.6
Acquire customers signatures that confirm customer support of 4R Nutrient practices	698	0.456	3.4	6.9	44.6	30.9	14.2
Recommend fertilizer rates based on current science and your yields	701	1.098	1.1	1.6	14.3	52.4	30.7
Avoid nutrient applications on frozen ground or if weather forecasts call for heavy precipitation	700	1.104	1.9	3.0	17.0	39.1	39.0
Use variable rate planning and application of nutrients	698	0.963	2.4	5.2	20.8	37.0	34.7
Complete an audit to a private third party auditor every 3 years to ensure 4R practices are followed	697	0.022	11.8	15.1	43.6	18.4	11.2
Recommend using setback in field areas that have a high potential for nutrient loss	695	0.528	3.3	8.3	36.4	36.1	15.8

Farmers were asked how likely hiring an NSP with 4R Nutrient Stewardship Certification would lead to several positive outcomes (Table 37). Respondents had a great deal of confidence hiring a certified NSP would help their farm meet regulatory requirements and make meeting new regulations easier. A large percentage of respondents indicated that hiring a certified NSP would have no impact on farm profitability (35.8%) and reputation in their community (41.7%). Across each listed outcome, only a small percentage of farmers believe it would be unlikely or very unlikely that hiring a certified NSP would lead to the respective positive outcome. Overall, the results indicate that farmers have a neutral to positive view of the certification program.

Table 37. Influence of NSP program certification on farmers' anticipated outcome

How likely is it that hiring an NSP with this program certification will…	N	Very unlikely (%)	Unlikely (%)	No impact on decision (%)	Likely (%)	Very likely (%)
Help your farm meet any new regulatory requirements	699	3.4	4.3	28.5	48.2	15.6
Make meeting any new regulations easier	695	3.3	4.3	24.0	51.7	16.7
Improve your farms profitability	698	4.9	9.0	35.8	36.4	13.9
Improve your operations reputation in the community	698	5.6	6.0	41.7	34.8	11.9

Farmers were asked if their current NSP has already been certified by the 4R Nutrient Stewardship Certification program. Of 679 respondents, 48.6% indicated their NSP was certified. For those who did not have a certified NSP, they were then asked whether they would keep business with their current NSP if they were to be certified, and the price stayed the same (Table 38). The majority of farmers would

continue to do business with their current NSP if prices stayed the same (60.8%) with about one-third becoming unsure and less than 6% refusing to stay with their current NSP.

Table 38. Stay with current NSP if it became certified and prices stayed the same

	N	%
No	11	5.7
Unsure	65	33.5
Yes	118	60.8

For those that said no or were unsure about continuing with their NSP if they became 4R certified, we explored whether this answer would change if the certification was accompanied by a price decrease (either 4%, 8% or 16% reduction in price, where the reduction was randomly assigned to respondents). Table 39 displays the results for each group.

Table 39. Stay with current NSP if it became certified and prices were lowered

	If prices were lowered			If prices were increased		
Response if prices unchanged	**No**	**Unsure**	**Yes**	**No**	**Unsure**	**Yes**
Originally said 'No' (N=11)	30%	30%	40%	--	--	--
Originally said 'Unsure' (N=65)	0%	75.4%	24.6%	--	--	--
Originally said 'Yes' (N=116)	--	--	--	40.5%	44.8%	14.7%

All farmers were also asked whether they would continue with their current NSP if a competing NSP offered a long term price quote that matched their current provider, or was above or below by a certain amount by 4% to 16% (Table 40). A large percent of farmers (42%) said they were unsure whether they would switch if a competitor's price were lower than their current provider's price, while 30% said they would switch. If they matched their current NSP's price, 60% would not change NSPs and 32% were unsure, indicating other factors may affect farmers' NSP decisions in addition to price.

Table 40. Effect of competing NSP price on farmers' choice to remain with current NSP

Would accept competing offer if competitor's price…	N	% Yes	% No	% Unsure
…is below current provider	542	31.9	25.6	42.4
…matches current provider	538	8.2	59.7	32.2
…is higher than current provider	533	0.8	79.5	19.7

Respondents were asked how strictly following the recommendations of certified NSPs would affect their crop yield (Table 41). Few farmers believed it would lead to lower yield at 5.3%, while 57.5% believed it would remain about the same. Around 1/4 was unsure and only 12% believed it would be higher.

Table 41. Farmers' beliefs about certified NSPs effect on crop yield

	N	Lower (%)	About the same (%)	Higher (%)	Not sure (%)
Do you think strictly following the recommendations of the NSPs who are certified by the 4R Program would lead to crop yields that are…	590	5.3	57.5	12.0	25.3

Farmer Characteristics

Respondents were asked standard questions about gender, age, education, and basic farm characteristics. This demographic information demonstrates what portion of the population is best represented by the data presented in this report.

Gender and Age

The majority of respondents were male (97.7%), while females constituted only 2.3% of respondents (Table 42). The mean age was 57.6 years with most farmers in their 50's, although ages ranged from 19 to 95 for both men and women combined.

Table 42. Respondent gender and age

Farmer Demographics	N	Valid %	Mean	Std. Deviation
Male	748	97.7	-	-
Female	748	2.3	-	-
Age	694	-	57.6	11.8

Education and Experience

Farmers' level of education is summarized in Table 43. A large percentage of respondents (44.6%) have a high school degree or equivalent and only 0.6% of respondents did not complete high school. Over half of all respondents (54.9%) studied in college to some extent. The mean number of years respondents have been farming was 36.8 years (SD = 13.5, n = 685).

Table 43. Respondent's highest level of education (n = 702)

Education Completed	Valid %
Some high school	.6
High school degree or equivalent	44.6
Some college, no degree	18.1
Associate's degree	13.1
Bachelor's degree	18.7
Graduate or professional degree	5.0

Farm and Income

Farm annual net incomes were spread fairly evenly with the majority of farms falling under $250,000 as seen by the breakdown in Table 44. About 3/4 (71%, n = 748) of respondents indicated they or their spouse received off-farm income. Table 45 summarizes respondents' off-farm household annual income. A large percentage (45.1%) of farming households bring in between $10,000 to $49,999. One-third of farming households bring in $50,000 to $99,999 annually.

Table 44. Respondent annual farm net income (n = 624)

Farm Annual Net Income	Valid %
Less than 50,000	28.4
50,000- 99,999	23.9
100,000-249,999	22.3
250,000-499,999	10.3
500,000 or greater	15.2

Table 45. Respondent off-farm household income (n = 455)

Off-Farm Household Income	Valid %
Less than $10,000	8.1
$10,000 - $49,999	45.1
$50,000-$99,999	33.8
$100,000 or more	13.0

A total of 21.3% of 691 respondents indicated they have retired from a previous occupation other than farming. Of 692 respondents, only 4% indicated their farm is registered as a Concentrated Animal Feeding Operation (CAFO).

Table 46 displays the average number of acres owned and rented among respondents. The average owned farm size was 463.2 acres while the average rented acreage was 746.6 acres. A larger proportion of acreage among respondents was rented rather than owned. Respondents fell across five categories of total acreage: 50-249 acres (15%), 250-499 acres (13%), 500-999 acres (22%), 1000-1999 acres (31%), and over 2000 acres and up (19%).

Table 46. Farm size

Farm Size	N	Mean	Std. Deviation
Acres Owned	603	463.2	501.6
Acres Rented	526	746.6	823.9

Appendices

Farmers were separated into three categories based on how likely they were to adopt each 4R practice the upcoming year: *laggards* responded they would not use or were unlikely to use the practice, *future adopters* indicated they were likely to use the practice, and *innovators* indicated they will definitely use the practice. Differences between the three groups, across a variety of variables, were assessed using a one-way ANOVA or non-parametric equivalent. The variables that differed significantly across the three groups are summarized in Tables 47 through 55.

Storm-Delayed Broadcasting

Farmer responses to how likely they would be to avoid broadcasting fertilizer when the weather forecast predicts a 50% or more chance of at least 1 inch of rainfall in the next 12 hours (hereafter referred to as storm-delay broadcasting) were compared with their individual response to various variables (significant differences listed in Table 47). Almost half (47.4%) of the respondents fell into the future adopter category while the laggards and innovators were comprised of 15.2% and 37.4%, respectively. Innovators manage 41% of the total reported acreage, while future adopters and laggards manage 46% and 13% respectively. The proportion of rented versus owned acreage is similar in each category.

There appears to be a general trend that innovators and future adopters receive more nutrient stewardship information from a variety of information sources. However, innovators are significantly more likely to be informed by public sources when compared to future adopters and laggards. It may be that innovators are, as a result, receiving more information about the conservation or social benefits of recommended practices rather than the more individual and profit based focus of the private sector, commodity groups, etc.

When it comes to motivations, the innovators have the greatest awareness of 4R principles, are the most attentive to the issue in general, are the most concerned about nutrient loss, and have the highest levels of perceived efficacy in the practice when compared to future adopters and laggards. Future adopters, in turn, have higher levels of awareness, concern, etc. than the laggards. In addition, innovators are significantly more concerned about potential regulation than both of the other groups, perhaps contributing to their early adoption of the practice as a means of avoiding regulation.

When it comes to constraints, the innovators do not view unpredictable weather to be as big of a barrier to storm-delay broadcasting compared to the future adopters and innovators, perhaps indicating greater trust in the current weather forecasting technology. Innovators also have a significantly greater awareness of the rules and regulations surrounding nutrient stewardship, and are more likely to have already participated in the mandatory certification program.

When it comes to farm and farmer characteristics, innovators are more likely to accept input and advice from outside sources such as consultants, and are more likely to have changed their 4R related practices in the last 3 years when compared to laggards. Innovators also tend to have larger farms compared to future adopters. Future adopters were more likely to have phosphorus custom applied than both innovators and laggards, which do not vary significantly from each other. Laggards were more likely than innovators and future adopters to not apply phosphorus at all the previous year, while the innovators conduct soil testing more frequently than laggards.

Table 47. Summary of variables that differ by adoption of storm-delay broadcasting

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Information Source Use	**Public Sector**[1]	Lower		Higher
	Private Sector[2]	Lower	Higher	
	Professional/industry magazines	Lower	Moderate	Higher
	Commodity groups	Lower	Higher	
Motivations	**4R Awareness**	Lower	Moderate	Higher
	Issue Attentiveness	Lower	Moderate	Higher
	Nutrient Loss Concern	Lower	Moderate	Higher
	Regulatory Concern	Lower		Higher
	Storm Delay Efficacy	Lower	Moderate	Higher
Constraints	**Unpredictable weather concerns**	Higher		Lower
	Awareness of Ohio regulatory requirements	Less	More	
	Likelihood of participating in applicator certification training	Lower	*N/A	Higher
Farm and farmer characteristics	**Likelihood of working with a nutrient mgmt. consultant**	Lower	*N/A	Higher
	Likelihood of having changed 4R practices in past 3 years	Lower	*N/A	Higher
	Likelihood of custom application	Lower	Higher	Lower
	Soil testing frequency	Lower	*N/A	Higher
	Farm Size: Owned Acreage	*N/A	Smaller	Larger

*N/A means that group did not vary significantly from other two groups

Summary: Education and information about the 4R principles from a variety of professional sources appears to play a role in the adoption of storm-delay broadcasting. As the likelihood of adoption increases, so too does individual concern, awareness about the issue and beliefs in the efficacy of the specific practice. However, significant barriers (e.g., concern about the reliability of weather forecasts) could outweigh the positive influence of effective education and outreach for some segments of the population. The only farm characteristic that seems to differ across the groups is owned acreage, which does not seem to be a barrier as having more owned acreage is in fact a characteristic of innovators.

[1] Public sector information sources include county and university Extension, the Farm Bureau, County Soil and Water Conservation District, and USDA NRCS

[2] Private sector sources include crop advisors/consultants, fertilizer retailers, family members, farm partners, and other farmers in the community

Avoiding Winter Surface Fertilizer Application

Farmers' responses to how likely they would be to avoid applying fertilizer on frozen soil were compared with their responses to a set of variables (significant differences listed in Table 48). Innovators comprised the largest percentage of respondents at 53.1% while the future adopters and laggards made up the other half at 28.4% and 18.5%, respectively. Innovators manage 57% of the total reported acreage, while future adopters and laggards manage 29% and 14% respectively. The proportion of rented versus owned acreage is similar in each category.

The innovators and future adopters reported higher frequencies of receiving information from sources such as the private sector, professional/industry magazines, and commodity groups when compared to the laggards. For public sector information sources, the innovators were more likely to report using those sources than the laggards but neither differed significantly from future adopters.

Concerning the motivations of farmers, the innovators have the greatest awareness of 4R principles, are most attentive to the issue, most concerned about nutrient loss and potential regulation, and reported the greatest efficacy toward the timing of nutrient application and the use of incorporation when applying fertilizer. In fact, these differences were significant when compared to both the laggards and future adopters. Awareness of 4R principles was the one factor that differed across all three groups, where future adopters were more aware than laggards, and innovators were more aware than both future adopters and laggards.

Regarding constraints, innovators were more aware of the current regulations than laggards, and were more likely to have participated in the fertilizer application certification program. The future adopters did not differ from either the innovators or laggards for these particular factors.

Regarding farm and farm characteristics, innovators are more likely to work with a consultant, have already changed 4R practices in the last 3 years, and planted a cover crop. They, along with laggards, are also less likely to custom apply phosphorus when compared to future adopters. Innovators and future adopters are less likely to have retired from another occupation other than farming.

Table 48. Summary of variables that differ by adoption of avoiding winter surface fertilizer application

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Information Source Use	**Public Sector**[1]	Lower	*N/A	Higher
	Private Sector[2]	Lower	Higher	
	Professional/industry magazines	Lower	Higher	
	Commodity groups	Lower	Higher	
Motivations	**4R Awareness**	Less	Moderate	More
	Issue Attentiveness	Lower		Higher
	Nutrient Loss Concern	Lower		Higher
	Regulatory Concern	Lower		Higher
	Nutrient Timing Efficacy	Lower		Higher
	Fertilizer Incorporation Efficacy	Lower		Higher
Constraints	**Awareness of Ohio regulatory requirements**	Lower	*N/A	Higher
	Likelihood of participating in certification training	Lower	*N/A	Higher
Farm and farmer characteristics	**Likelihood of working with a nutrient mgmt. consultant**	Lower	*N/A	Higher
	Likelihood of having changed 4R practices in past 3 years	*N/A	Lower	Higher
	Likelihood of planting cover crop	Lower	*N/A	Higher
	Likelihood of custom application	Lower	Higher	Lower
	Likelihood of being retired from other occupation	Higher	Lower	

*N/A means that group did not vary significantly from other two groups

Summary: Educational outreach and awareness of existing rules and regulations appear to play a role in the likelihood of avoiding fertilizer application to frozen ground. Innovators have consistently greater access to a variety of information sources, as well as consistently higher awareness and concern as well as greater belief in the efficacy of nutrient timing and fertilizer incorporation. Increasing awareness of existing regulation and the reasons why avoiding winter application is effective and important may diminish barriers to implementation.

[1] Public sector information sources include county and university Extension, the Farm Bureau, County Soil and Water Conservation District, and USDA NRCS

[2] Private sector sources include crop advisors/consultants, fertilizer retailers, family members, farm partners, and other farmers in the community

Broadcast Fertilizer Incorporation

Farmers were asked how likely they would be to incorporate broadcast fertilizer (via tillage). Their responses were then compared to various variables (significant differences summarized in Table 49). Farmers were more or less evenly distributed among laggards (29.3%), future adopters (35.7%), and innovators (35.1%). Innovators manage 43% of the total reported acreage, while future adopters and laggards manage 33% and 24% respectively. The proportion of rented versus owned acreage is similar in each category.

Concerning how much 4R nutrient information farmers are receiving, those that have already adopted broadcast fertilizer incorporation (innovators) show significantly higher use among both public and private information sources when compared to the laggards. Future adopters and laggards appear to have similar use of industry magazines while the innovators show a higher use.

Concerning farmers' motivations, innovators show significantly greater awareness of 4R principles, attentiveness to environmental issues, and concern for nutrient loss on their farm compared to the laggards and future adopters. They also indicate greater concern for regulations surrounding 4R stewardship when compared to the laggards. As expected, the innovators have the greatest efficacy toward incorporating fertilizer, significantly higher than future adopters who in turn also show significantly higher efficacy than the laggards.

The constraints that may further inhibit adoption show a similar trend to the motivations among each variable. The innovators are more likely to participate in fertilizer applicator certification training, work with a nutrient management consultant, to notice changes in the community regarding 4R practices, and to have changed their own 4R practices in the past three years when compared to the laggards. These constraints correlate well with the information source use and motivations of farmers in which the innovators appear to be more educated and informed about 4R practices as well as more willing to adopt new farming techniques. The future adopters do not differ from the laggards or innovators, indicating that perhaps the barriers are not as critical for them as they will be for the laggards.

Regarding farm and farmer characteristics, laggards were more likely to plant a cover crop, leave more crop residue on the field, and apply manure[1] when compared to the innovators and future adopters. Given their tendency to use cover crops in a conservation or no-till system, it is perhaps not surprising they are hesitant to incorporate fertilizer. Comparing Mehlich-3 phosphorus level test results between adoption groups, the innovators showed significantly higher levels of phosphorus in their soil when compared to the laggards. Innovators tended to own significantly more acreage than both future adopters and laggards, while they also rented more acreage than laggards.

[1] Of those applying manure, 60% were broadcast applying and incorporating, while 30% were broadcast applying without incorporation with the remaining 10% using some form of surface or subsurface banding.

Table 49. Summary of variables that differ by adoption of broadcast fertilizer incorporation (via tillage)

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Information Source Use	**Public Sector**[1]	Lower	*N/A	Higher
	Private Sector[2]	Lower	*N/A	Higher
	Professional/industry magazines	Lower		Higher
Motivations	**4R Awareness**	Less		More
	Issue Attentiveness	Lower		Higher
	Nutrient Loss Concern	Lower		Higher
	Regulatory Concern	Lower	*N/A	Higher
	Nutrient Timing Efficacy	Lower		Higher
	Fertilizer Incorporation Efficacy	Lower	Moderate	Higher
Constraints	**Likelihood of participating in certification training**	Lower	*N/A	Higher
	Likelihood of working with a nutrient mgmt. consultant	Lower	*N/A	Higher
	Likelihood of noticing changes in 4R practices in community in past 3 years	Lower	*N/A	Higher
	Likelihood of having changed 4R practices in past 3 years	Lower	*N/A	Higher
Farm and farmer characteristics	**Likelihood of cover crop planted after harvest**	Higher	*N/A	Lower
	Tillage Type (amount of crop residue)	More	Less	
	Likelihood of manure application	Higher	*N/A	Lower
	Mehlich-3 Soil Test Results	Lower	*N/A	Higher
	Farm Size: Owned Acreage	Smaller		Larger
	Farm Size: Rented Acreage	Smaller	*N/A	Larger

*N/A means that group did not vary significantly from other two groups

Summary: Innovators of incorporating broadcast fertilizer (via tillage) tend to use and receive more nutrient stewardship information from public, private, and industry magazine sources. Perhaps because of this, they show a greater awareness and concern for 4R principles, environmental issues, regulations, and the loss of nutrients from their field in addition to a greater belief in the efficacy of fertilizer incorporation to address nutrient loss. Innovators are more likely to seek outside assistance and are more likely to have noticed changes in their community, perhaps indicating greater sensitivity to the behavior of others. Planting a cover crop, applying manure, and leaving a greater amount of crop residue appear to make it more challenging or less practical to adopt broadcast fertilizer incorporation as a means of application.

[1] Public sector information sources include county and university Extension, the Farm Bureau, County Soil and Water Conservation District, and USDA NRCS

[2] Private sector sources include crop advisors/consultants, fertilizer retailers, family members, farm partners, and other farmers in the community

Subsurface Fertilizer Placement

Farmers' likelihood of adopting subsurface fertilizer (via banding or in-furrow with seed) was compared with several variables (significant differences summarized in Table 50). Similar percentages of farmers fall into each category with laggards at 35.4%, future adopters at 28.7%, and innovators at 35.9%. Innovators manage 36% of the total reported acreage, while future adopters and laggards manage 28% and 36% respectively. Innovators have a greater proportion of owned (versus rented) acreage, while future adopters and laggards have relatively more rented (versus owned) acreage.

When it comes to information source use, those that have already adopted subsurface fertilizer placement tend to have significantly higher usage rates across all types of information sources compared to laggards and future adopters. Future adopters and innovators have similarly higher usage rates compared to laggards when looking at the more conservation focused public sector. Laggards and future adopters are however, more similar and tend to have lower rates of usage for professional and industry magazines.

Regarding motivations, the innovators have greater awareness of 4R principles, environmental issue attentiveness, nutrient loss concern, and concern for future regulations and rules when compared to both laggards and future adopters, which do not differ significantly from each other. A clearer distinction between each group can be found when comparing subsurface injection efficacy in which innovators show greater efficacy than both future adopters and laggards. Future adopters, in turn, show a significantly greater level of perceived efficacy than laggards.

Concerning the constraints on farmers adopting the practice, both future adopters and laggards perceive greater barriers to adopting subsurface fertilizer placement than innovators (e.g., alternatives to broadcasting are too slow, the equipment is too costly, injection is form of tillage, etc). Laggards are also less likely to have participated in the certification training when compared to innovators, while both laggards and future adopters are less likely to work with a consultant.

Farm and farmer characteristics indicate that laggards are more likely to have phosphorus custom applied compared to the innovators, and are more likely to broadcast apply fertilizer, indicating that perhaps they are not willing to pay the increased cost of subsurface application. Innovators tend to have significantly more owned acreage than laggards.

Table 50. Summary of variables significantly influencing adoption of subsurface fertilizer placement

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Information Source Use	**Public Sector**[1]	Lower	Higher	
	Private Sector[2]	Lower	*N/A	Higher
	Professional/industry magazines	Lower		Higher
	Commodity groups	Lower	*N/A	Higher
Motivations	**4R Awareness**	Less		More
	Issue Attentiveness	Lower		Higher
	Nutrient Loss Concern	Lower		Higher
	Regulatory Concern	Lower		Higher
	Subsurface Injection Efficacy	Lower	Moderate	Higher
Constraints	**Perceived barriers to subsurface placement**	More		Less
	Likelihood of participating in certification training	Lower	*N/A	Higher
	Likelihood of working with a nutrient mgmt. consultant	Lower		Higher
Farm and farmer characteristics	**Likelihood of custom application**	Higher	*N/A	Lower
	Likelihood of surface broadcasted fertilizer (no incorporation)	Higher	*N/A	Lower
	Likelihood of surface broadcasted fertilizer (incorporated with tillage within 7 days)	Higher	*N/A	Lower
	Farm Size: Owned Acreage	Smaller	*N/A	Larger

*N/A means that group did not vary significantly from other two groups

Summary: Innovators appear to be distinctly different than future adopters and laggards in nearly every respect. Laggards and future adopters have significantly less concern and awareness of nutrient stewardship principles and current issues/regulations than innovators. They also perceive the barriers to implementing subsurface fertilizer placement as much greater than innovators. Laggards tend to be those who broadcast apply fertilizer (with and without incorporation) and are less likely to work with a consultant but more likely to have phosphorus custom applied, while innovators tend to own more acreage.

[1] Public sector information sources include county and university Extension, the Farm Bureau, County Soil and Water Conservation District, and USDA NRCS

[2] Private sector sources include crop advisors/consultants, fertilizer retailers, family members, farm partners, and other farmers in the community

Soil Testing

Farmers' likelihood of using soil testing in the next year to determine fertilizer application rate was compared with their responses to a set of variables (significant differences summarized in Table 51). The innovator group makes up the majority of respondents in this section at ~60%[1] while the future adopters and laggards consist of about 30% and 10% of the total respondents, respectively. Innovators manage 68% of the total reported acreage, while future adopters and laggards manage 27% and 5% respectively. Innovators and future adopters have relatively more rented acreage, while the laggards have relatively more owned acreage.

Concerning information sources, the innovators had significantly higher use of the more conservation focused public sector, profit focused private sector, and professional/industry magazines when compared to the laggards and future adopters. The future adopters were significantly more likely than the laggards to use information from the public sector and industry magazines but were grouped together with the laggards in using private sector sources. They were also similar to the innovators in receiving more information than the laggards from commodity groups.

Farmers' motivations showed significant differences between each group in most of the variables. The innovators had greater awareness of 4R principles, environmental issue attentiveness, concern for nutrient loss on their farm, concern for the regulations pertaining to nutrient stewardship, and soil testing efficacy than the future adopters and laggards. The future adopters were significantly higher than the laggards in their 4R awareness, issue attentiveness, regulatory concern, and soil testing efficacy while the two were similar in their concern for nutrient loss.

Regarding constraints, laggards perceived the greatest barriers associated with soil testing (e.g., soil tests are too costly, robust crops require more nutrients than soil tests recommend, etc) and had the least awareness of Ohio regulatory requirements compared to innovators and future adopters. Innovators perceived the least barriers, showed the greatest awareness of regulatory requirements, and were more likely to have already participated in the mandatory certification training than the laggards and future adopters.

When it comes to farms and farmer characteristics, innovators displayed a greater likelihood of working with a nutrient management consultant, making and noticing changes in 4R practices in their community, and having planted a cover crop compared to the laggards and future adopters (who scored similarly on these factors). Innovators have higher farm net income levels than both other groups while future adopters had a higher net income than laggards. The innovators also tended to be younger, to not be retired from another occupation[2], and have less farming experience than the laggards. In addition, innovators tended to have larger farms than the future adopters.

[1] This 60% represents those who definitely plan to soil test in the upcoming year, if you add in the 30% who are likely to do so you reach a similar ~90% who earlier indicated using soil testing to determine rates (see p. 24).

[2] Generally speaking, age and experience farming (in years) are highly correlated, but whether or not you are retired from another occupation is only weakly correlated with age and experience. Simply stated, people who are retired from another occupation tend to be (slightly) older with more experience.

Table 51. Summary of variables that significantly differ for adoption of soil testing to determine fertilizer application rate

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Information Source Use	**Public Sector**[1]	Lower	Moderate	Higher
	Private Sector[2]	Lower		Higher
	Professional/industry magazines	Lower	Moderate	Higher
	Commodity groups	Lower	Higher	
Motivations	**4R Awareness**	Less	Moderate	More
	Issue Attentiveness	Lower	Moderate	Higher
	Nutrient Loss Concern	Lower		Higher
	Regulatory Concern	Lower	Moderate	Higher
	Soil Testing Efficacy	Lower	Moderate	Higher
Constraints	**Perceived barriers to soil testing**	More	Moderate	Less
	Awareness of Ohio regulatory requirements	Less	Moderate	More
	Likelihood of participating in applicator certification training	Lower		Higher
Farm and farmer characteristics	**Likelihood of working with a nutrient mgmt. consultant**	Lower		Higher
	Likelihood of noticing changes in 4R practices in community	Lower		Higher
	Likelihood of having changed 4R practices in past 3 years	Lower		Higher
	Likelihood of planting cover crop	Lower		Higher
	Likelihood of custom application	Lower	*N/A	Higher
	Soil testing frequency	Lower		Higher
	Farm Net Income	Lower	Moderate	Higher
	Likelihood of being retired from other occupation	Higher	*N/A	Lower
	Age	Older	*N/A	Younger
	Farming Experience	More	*N/A	Less
	Farm Size: Owned Acreage	*N/A	Smaller	Larger
	Farm Size: Rented Acreage	*N/A	Smaller	Larger

*N/A means that group did not vary significantly from other two groups

Summary: Farmers' adoption of soil testing appears to be heavily influenced by a variety of factors distinguishing the innovators from the future adopters and laggards. Those already soil testing tend to receive and use more 4R nutrient stewardship information from public sources, private sources, industry magazines, and commodity groups. They are also more likely to have greater awareness of best practices

[1] Public sector information sources include county and university Extension, the Farm Bureau, County Soil and Water Conservation District, and USDA NRCS

[2] Private sector sources include crop advisors/consultants, fertilizer retailers, family members, farm partners, and other farmers in the community

as well as the regulatory and environmental issues associated with nutrient stewardship. Those willing to adopt soil testing were more open to change and willing to work with outside consultants. They also tend to be younger in age, have less farming experience, have greater farm net income, and own or rent larger fields. Farmers less likely to adopt appear to be less informed of 4R nutrient stewardship practices and perceive a greater number of barriers to soil testing than those who are more willing.

Cover Crop Planting

Farmers' likelihood of planting cover crops after the fall harvest, assuming the weather is favorable, was compared with a set of variables summarized in Table 52. Laggards comprised the largest percentage of the respondent groups at 42%. The future adopters made up 38%, and the smallest group, the innovators, comprised 20%. Innovators manage 24% of the total reported acreage, while future adopters and laggards manage 41% and 36% respectively. The proportion of rented versus owned acreage is similar in each category. Although this trend might suggest that cover crops are hitting a tipping point where adoption will continue purely based on social modeling of behavior, there is evidence that many innovators are dropping cover crops as incentives run out and profit margins become too small to take on the short-term risk given the uncertain benefits.

When it comes to information source use, future adopters and innovators responded similarly. They both showed a higher rate of use for the public sector and industry magazines when compared to the laggards. Future adopters also showed higher use of the private sector than laggards.

Concerning farmer motivations, the three groups varied significantly from each other on many variables. Innovators had the greatest awareness of 4R principles, the greatest attentiveness to environmental issues, and the greatest perceived efficacy toward incorporating winter wheat or a cover crop. The future adopters also reported greater 4R awareness, issue attentiveness, and cover crop efficacy than laggards. The future adopters and innovators do not vary significantly from one another in their concern for nutrient loss and regulations; they both show significantly greater concern than the laggards.

When it comes to constraints, innovators displayed the least amount of concern about barriers to winter cover implementation (e.g., establishing a cover is too difficult, the risks to spring planting are too great, the near-term cost is too great for the uncertain long-term payback). Future adopters were significantly more concerned about the barriers than innovators, and laggards significantly more concerned than future adopters. Innovators were more likely to have participated in applicator certification training than laggards, and both future adopters and innovators indicated similarly more awareness of regulatory requirements compared to laggards.

When it comes to farm and farmer characteristics, innovators are more likely to work with a nutrient management consultant and have greater net farm income compared to laggards. Both innovators and future adopters are more likely to have changed their nutrient management practices in the last three years when compared to the laggards. Innovators leave the most crop residue when tilling soil, followed by future adopters and then laggards, who leave the last residue. Future adopters also leave more crop residue than laggards, but less residue than innovators. Future adopters were more likely than innovators to surface broadcast fertilizer and incorporate it with tillage within 7 days.

Table 52. Summary of variables significantly influencing adoption of cover crop planting

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Information Source Use	**Public Sector[1]**	Lower	Higher	
	Private Sector[2]	Lower	Higher	*N/A
	Professional/industry magazines	Lower	Higher	
Motivations	**4R Awareness**	Less	Moderate	More
	Issue Attentiveness	Lower	Moderate	Higher
	Nutrient Loss Concern	Lower	Higher	
	Regulatory Concern	Lower	Higher	
	Winter Wheat/Cover Crop Efficacy	Lower	Moderate	Higher
Constraints	**Perceived barriers to winter cover implementation**	More	Moderate	Less
	Likelihood of participating in applicator certification training	Lower	*N/A	Higher
	Awareness of Ohio regulatory requirements	Lower	Higher	
Farm and farmer characteristics	**Likelihood of working with a nutrient mgmt. consultant**	Lower	*N/A	Higher
	Likelihood of having changed 4R practices in past 3 years	Lower	Higher	
	Tillage Type (amount of crop residue)	Less	Moderate	More
	Likelihood of surface broadcasted fertilizer (incorporated with tillage within 7 days)	*N/A	Higher	Lower
	Farm Net Income	Lower	*N/A	Higher

*N/A means that group did not vary significantly from other two groups

Summary: Farmers more willing to plant a cover crop are more informed about nutrient stewardship practices and have greater concern and awareness for 4R nutrient stewardship principles, regulations, environmental issues, and loss of nutrients from their fields. They also tend to believe more strongly in the effectiveness of cover crops at reducing nutrient loss. Those less likely to adopt tend to use information sources such as family, friends, and other more local community based and profit focused sources. Farmers less willing to plant cover crops tend to have lower farm net income, use a tillage type that includes less crop residue, and to be less open to change and working with a consultant.

[1] Public sector information sources include county and university Extension, the Farm Bureau, County Soil and Water Conservation District, and USDA NRCS

[2] Private sector sources include crop advisors/consultants, fertilizer retailers, family members, farm partners, and other farmers in the community

Subsurface Tile Updates or Installation

Farmers' likelihood of installing or updating subsurface tile was compared with a set of variables summarized in Table 53. Laggards comprised the largest of the three groups at 45%. The future adopters made up 29% and the innovators, 26%. Innovators manage 33% of the total reported acreage, while future adopters and laggards manage 32% and 25% respectively. The proportion of rented versus owned acreage is similar in each category.

Regarding nutrient stewardship information source use, the innovators had a higher usage rate than the laggards for three of the sources: the public sector, private sector, and commodity groups. Future adopters did not differ from either of the other two groups when it comes to information source use.

Regarding farmer motivations, innovators have a higher awareness of 4R principles and concern for nutrient loss from their farm than the laggards. They are also more attentive to environmental issues and have more of a concern for regulatory requirements than both the future adopters and laggards, which do not vary significantly from each other.

Only one constraint was seen to be significantly different between the three groups for the adoption of subsurface tile. Innovators were more likely to have participated in the fertilizer applicator certification training than the laggard group.

Concerning farm and farmer characteristics, innovators had a higher likelihood of having changed 4R practices in the past three years, were more likely to have planted a cover crop the previous year, had higher soil test P results, were likely to soil test more frequently, and had more rented acreage when compared to the laggards. Both the innovators and future adopters were more likely to soil test and had higher net farm income when compared to the laggards. Finally, innovators had more owned acreage than both the future adopters and the laggards. To summarize, the laggards have the smallest farms with the least amount of net farm income, while the innovators have more rented acreage than the laggards, but more owned acreage than both the laggards and the future adopters.

Table 53. Summary of variables significantly influencing adoption installing or updating subsurface tile

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Information Source Use	**Public Sector**[1]	Lower	*N/A	Higher
	Private Sector[2]	Lower	*N/A	Higher
	Commodity groups	Lower	*N/A	Higher
Motivations	**4R Awareness**	Less	*N/A	More
	Issue Attentiveness	Lower		Higher
	Nutrient Loss Concern	Lower	*N/A	Higher
	Regulatory Concern	Lower		Higher
Constraints	**Likelihood of participating in certification training**	Lower	*N/A	Higher
Farm and farmer characteristics	**Likelihood of having changed 4R practices in past 3 years**	Lower	*N/A	Higher
	Likelihood of planting cover crop	Lower	*N/A	Higher
	Likelihood of soil testing	Lower	Higher	
	Mehlich-3 Soil Test Results	Lower	*N/A	Higher
	Soil testing frequency	Lower	*N/A	Higher
	Farm Net Income	Lower	Higher	
	Farm Size: Owned Acreage	Smaller		Larger
	Farm Size: Rented Acreage	Smaller	*N/A	Larger

*N/A means that group did not vary significantly from other two groups

Summary: Farmers more likely to update or install subsurface tile tend to be more informed of nutrient stewardship practices, attentive to environmental issues and regulations, and concerned about nutrient loss. They are more open to changing 4R practices and more likely to plant cover crops. They also report higher levels of phosphorus based on Mehlich-3 soil testing results.. Farmers more likely to adopt subsurface tile tend to have more owned and rented acreage, and more likely to use soil testing on their field.

[1] Public sector information sources include county and university Extension, the Farm Bureau, County Soil and Water Conservation District, and USDA NRCS

[2] Private sector sources include crop advisors/consultants, fertilizer retailers, family members, farm partners, and other farmers in the community

Subsurface Tile Drainage Management

Farmers were asked about their likelihood of adding subsurface drainage management (via blind inlets or controlled drainage). Their responses were then compared to a set of variables in which those that varied significantly were summarized in Table 54. The laggards made up the largest of the three groups as they comprised 66.1% of respondents. The future adopters (22.4%) and innovators (11.5%) made up the remaining percent. Innovators manage 13% of the total reported acreage, while future adopters and laggards manage 29% and 58% respectively. The proportion of rented versus owned acreage is similar in each category.

Concerning nutrient stewardship information source use, the innovators had significantly higher use of public sector, private sector, and professional/industry magazine sources compared to the laggards.

Regarding farmer motivations, innovators are more aware of 4R nutrient stewardship principles, attentive to environmental issues, and concerned for regulatory requirements when compared to laggards. In terms of concern for nutrient loss, both the future adopters and the laggards show lower concern than the innovators. Regarding constraints, innovators are also more likely to work with a nutrient management consultant compared to the laggards.

Concerning farm and farmer characteristics, future adopters and innovators are similarly more likely to soil test than laggards. In addition, laggards are more likely to receive off-farm income than future adopters.

Table 54. Summary of variables significantly influencing adoption of subsurface tile drainage management

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Information Source Use	**Public Sector**[1]	Lower	*N/A	Higher
	Private Sector[2]	Lower	*N/A	Higher
	Professional/industry magazines	Lower	*N/A	Higher
Motivations	**4R Awareness**	Less	*N/A	More
	Issue Attentiveness	Lower	*N/A	Higher
	Nutrient Loss Concern	Lower		Higher
	Regulatory Concern	Lower	*N/A	Higher
Constraints	**Likelihood of working with a nutrient mgmt. consultant**	Lower	*N/A	Higher
Farm and farmer characteristics	**Soil testing frequency**	Lower	Higher	
	Farm Net Income	Lower		Higher
	Likelihood of receiving off-farm income	Higher	Lower	*N/A

*N/A means that group did not vary significantly from other two groups

Summary: Innovators of tile drainage management were more likely to use a variety of nutrient stewardship information sources including: public sector, private sector, and industry magazines. Innovators also showed greater awareness and concern for 4R practices, regulations, nutrient loss, and environmental issues, perhaps due to higher use of information sources. A higher likelihood of receiving off-farm income and having overall lower farm net income may be limiting factor.

[1] Public sector information sources include county and university Extension, the Farm Bureau, County Soil and Water Conservation District, and USDA NRCS

[2] Private sector sources include crop advisors/consultants, fertilizer retailers, family members, farm partners, and other farmers in the community

Including Wheat in Crop Rotation

Farmers' likelihood of changing their crop rotation from soybean/corn to include wheat, regardless of wheat prices was compared with a set of variables summarized in Table 55. The laggards made up the largest percent of respondents at 55.5%. The future adopters and innovators made up 26.7% and 17.8%, respectively. Innovators manage 19% of the total reported acreage, while future adopters and laggards manage 25% and 56% respectively. The proportion of rented versus owned acreage is similar in each category.

In regards to farmers' motivations, the perceived efficacy of winter cover was the greatest for innovators, followed by future adopters, and in turn, the lowest for laggards. The reverse relationship was observed for barriers to adoption, where laggards perceived the greatest barriers to winter cover implementation, while future adopters perceived the barriers as smaller, but still greater than the innovators. Innovators were also more aware of regulatory requirements related to nutrient management than future adopters.

Concerning farm and farmer characteristics, both future adopters and innovators were more likely to have previously planted a cover crop than laggards. Innovators of adopting winter wheat tended to be older and have more farming experience than the laggards.

Table 55. Summary of variables significantly influencing adoption of adding wheat to the current crop rotation

	Variable	LAGGARDS	FUTURE ADOPTERS	INNOVATORS
Motivations	**Winter Wheat/Cover Crop Efficacy**	Lower	Moderate	Higher
Constraints	**Perceived barriers to winter cover implementation**	More	Moderate	Less
	Awareness of Ohio regulatory requirements	*N/A	Less	More
Farm and farmer characteristics	**Likelihood of planting cover crop**	Lower	Higher	
	Age	Younger	*N/A	Older
	Farming Experience	Less	*N/A	More

*N/A means that group did not vary significantly from other two groups

Summary: Innovators of incorporating winter wheat into their crop rotation tend to be more aware of regulatory requirements. They also tend to be older and have more farming experience, perhaps representing familiarity with a practice that has decreased in popularity in recent years. The laggards tended to have lower efficacy toward cover crops, perceive more barriers to adoption, be younger, and have less farming experience in comparison. The information source use did not appear to play a significant role in influencing adoption of winter wheat perhaps indicating that this is not a topic typically addressed through most sources.