4R NUTRIENT STEWARDSHIP IN THE WESTERN LAKE ERIE BASIN PART II: A PANEL STUDY

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

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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.
Using manure from a local livestock operation as a source of nitrogen or phosphorus	Local manure sources represent a source of nutrients within the watershed that could be used strategically to both solve the issue of waste disposal and nutrient application.

In order for BMPs 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 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 first version of the Wave 1 survey was finalized and sent to farmers between the end of December of 2015 and early March 2016. For the Wave 2 survey data presented here, those farmers who responded to the Wave 1 survey were re-contacted in January through March 2016 with a very similar version of the survey to create a panel sample for analysis.

Updated names and mailing addresses for 689 of the 748 farmers living in the Maumee Watershed who completed the Wave 1 survey were obtained from the company Farm Market ID (http://www.farmmarketid.com). Recent contact information for 59 farmers who originally responded to the first version of this survey was no longer available.

Survey implementation followed the Tailored Design Method (Dillman, Smyth, & Christian, 2009). For those farmers with only mailing contact information available, they first received a postcard indicating that a mailed copy of the survey was coming and included a link to an online version of the survey. A week later, paper copies of the survey were mailed to potential respondents in the sample. A couple weeks after receiving the paper survey, a second postcard was mailed reminding respondents to complete the survey. Finally, a second paper copy of the survey was mailed to those who had not yet completed the survey online or via paper. For those whose email address was provided by Farm Market ID, they received five emails that included links to the survey over the course of two months. Two of these emails were very brief reminders (similar to the postcards), while the other three included more detail about the study. The respondents in the online group who did not respond to the survey online were then mailed a paper version of the survey at the end of the two months. The surveys provided to the online and mail groups were identical.

Of the 689 farmers who were contacted to participate, 41 surveys were returned as being invalid either because of issues with the address or because the farmer of interest no longer lived at the address. Another 10 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 638 farmers that we contacted, 381 returned usable surveys accounting for an adjusted response rate of 59.7%.

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Concern about Nutrient Loss

Farmers were asked to identify how concerned they were about nutrient loss in agriculture. This section offers insight into farmers' concern about their farm's contribution to environmental and nutrient loss issues.

Concern about Nutrient Loss Issues

To see how concerned farmers were about the impact of nutrient loss we asked farmers 16 questions. Responses ranged from 0 (not at all concerned) to 6 (extremely concerned). The feedback, summarized in Table 2, 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 2), and most concerned with potential governmental rules and regulations related to nutrient stewardship.

A sizable minority of farmers, ranging from 4% to 32% depending on the issue, indicated they were not very concerned (answered 0 to 2) about each issue. Farmers were on average 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 on average 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.

Table 2. 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 2018	378	4.0	2.7	5.6	10.6	14.6	23.0	22.8	20.9
Your farm contributing to algal blooms in Lake Erie	380	3.5	8.4	11.1	12.4	14.5	17.9	19.0	16.9
The negative impacts of nutrient loss on Lake Erie	378	4.1	1.9	5.0	7.9	17.5	21.4	25.7	20.6
The negative impacts of nutrient loss to your farm's profitability	378	4.3	1.3	4.8	7.4	13.2	18.5	27.3	27.5
Nutrient loss occurring on your farm in 5 to 10 years	375	3.8	2.9	6.4	13.9	12.8	24.0	23.7	16.3
Additional government regulation or rules related to nutrients	375	5.0	1.9	1.3	2.1	6.7	11.7	26.7	49.6
Your farm's impact on local water quality	378	4.0	4.0	7.4	7.9	11.9	22.5	24.9	21.4
A lawsuit targeted to farmers because of nutrient loss to Lake Erie	374	4.4	2.7	4.0	5.1	15.5	16.3	20.9	35.6

Nutrients lost from your farm during a heavy spring rain	377	4.1	2.4	5.6	7.7	16.2	21.8	25.7	20.7
Nitrogen loss from nitrification	374	3.8	2.9	6.7	8.0	19.5	23.8	25.9	13.1
Nutrient prices increasing in the future	377	4.8	1.9	1.9	1.1	7.2	23.1	29.2	35.8
Certain forms of phosphorus being removed from the market	376	4.3	1.9	3.2	5.9	14.4	22.1	29.3	23.4
Your ability to pass on your farm to the next generation	377	4.4	3.2	3.7	8.8	13.0	13.8	22.6	35.0
Soil health on your property	379	4.7	1.9	1.6	3.2	9.2	21.1	28.0	35.1
The management decisions of other farmers in my community	378	3.9	3.4	4.8	9.0	18.3	26.2	23.5	14.8
Your ability to make an annual profit	378	5.1	0.8	1.3	2.1	5.3	12.4	26.5	51.6

Beliefs about Best Management Practices

Respondents were asked to what extent they believed recommended 4R practices would reduce phosphorus runoff (Table 3). They were also asked their opinion on the extent to which each practice could improve water quality in Western Lake Erie (Table 4). Lastly, respondents were asked to rate their confidence that each practice could be implemented in the upcoming season on most of their fields (Table 5). The results in Tables 3 through 5 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

Survey responses (Table 3) 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. Farmers had the least confidence in incorporating wheat or cereal rye into their rotations with over 21% 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 over 80% indicating these practices would reduce nutrient loss a good deal or to a great extent.

Table 3. Responses and valid percentages for farmers' beliefs about effectiveness of various 4R practices at reducing nutrient runoff from fields.

Agricultural Practice	N	Mean	Not at all (%)	A little (%)	Some what (%)	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	376	2.9	1.6	6.7	20.0	41.8	30.1
Avoiding surface application of phosphorus on frozen ground	375	3.3	2.4	2.7	10.7	34.9	49.3
Incorporating broadcast fertilizer (via tillage)	375	2.8	4.8	8.5	18.9	36.8	30.9
Subsurface placement of fertilizer (via banding, 2x2, or in-furrow with seed)	373	2.9	4.0	8.6	16.9	36.5	34.1
Determining rates based on regular soil testing once within the rotation (or every 3 years)	376	3.2	1.6	2.7	13.3	39.9	42.6
Incorporating winter wheat or a cereal rye cover into your rotation	374	2.5	8.3	12.8	25.1	25.4	28.3

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 4) would also be effective in improving water quality in Western Lake Erie as a collective solution. However, a minority of farmers expressed skepticism as to whether the farm-level changes could improve water quality in Lake Erie, with anywhere from 7 to 19% 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 solve the issues in Lake Erie.

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

Agricultural Practice	N	Mean	Not at all (%)	A little (%)	Some what (%)	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	375	2.8	1.1	9.6	24.0	35.7	29.6
Avoiding surface application of phosphorus on frozen ground	377	3.2	1.1	5.8	14.9	31.8	46.4
Incorporating broadcast fertilizer (via tillage)	376	2.7	4.3	8.8	26.1	34.0	26.9
Subsurface placement of fertilizer (via banding, 2x2, or in-furrow with seed)	376	2.8	2.7	10.1	22.1	31.1	34.0
Determining rates based on regular soil testing once within the rotation (or every 3 years)	377	3.1	1.1	5.6	17.5	35.3	40.6
Incorporating winter wheat or a cereal rye cover into your rotation	374	2.6	6.4	12.8	23.0	28.9	28.9

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 5). 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 (91.7) and using soil testing once within the rotation or every 3 years (87.8). These were also the practices that famers believed were the most effective for the farm and the Lake (Tables 3 and 4). Subsurface placement of fertilizer (70.0) and incorporating winter wheat or cereal rye into the rotation (61.0) 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 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.

Table 5. 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	372	78.3	21.9
Avoiding surface application of phosphorus on frozen ground	367	91.7	17.4
Incorporating broadcast fertilizer (via tillage)	363	68.4	32.3
Subsurface placement of fertilizer (via banding, 2x2, or in-furrow with seed)	363	70.0	34.7
Determining rates based on regular soil testing once within the rotation (or every 3 years)	373	87.8	20.1
Incorporating winter wheat or a cereal rye cover into your rotation	368	61.0	33.0

Potential Barriers

Farmers were asked to what extent they agreed or disagreed with statements pertaining to potential barriers to adoption of nutrient stewardship practices on their farm. Responses ranged from -2 (strongly disagree) to 2 (strongly agree) with each statement. Results are summarized in Table 6. 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 (78.6% combined) that the profit margins for winter wheat are too small. Similarly, respondents were concerned that injecting nutrients was a form of tillage (53.6%) and that the equipment needed to inject nutrients into the soil is too expensive (52.2%). 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. There were also barriers identified with cover crops (~40%). 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.

Table 6. 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	373	-0.02	3.8	32.4	31.1	27.1	5.6
Manure must be applied in the winter if there is a lack of manure storage space	335	-0.06	11.0	24.2	32.2	24.8	7.8
Injecting nutrients is a form of tillage	366	0.40	2.7	15.6	28.1	46.5	7.1
The equipment needed to inject nutrients into the soil is too costly to purchase	366	0.52	2.5	10.9	34.4	36.3	15.9
Alternatives to broadcasting are too slow	365	0.21	3.3	14.5	45.5	31.5	5.2
The profit margins for winter wheat are too small	373	1.05	3.0	7.2	11.3	38.9	39.7
Establishing winter cover crops is too difficult due to uncertain planting windows	372	0.25	5.7	19.6	28.8	36.3	9.7
The risks of winter cover crops interfering with spring planting are too great	371	0.11	6.5	25.9	28.6	28.8	10.2
The near-term cost of cover crops is too great for the uncertain long-term payback	374	0.22	5.1	21.4	32.4	28.9	12.3
Applying manure as a source of nutrients is cost-prohibitive	339	-0.34	7.1	35.7	44.0	10.9	2.4
The recommendations for best management practices change too rapidly over time	368	-0.15	3.0	29.9	49.2	15.2	2.7
Water quality issues related to agriculture are caused by a small number of farmers	369	-0.08	5.7	30.1	36.6	22.0	5.7
There is too much contradictory information about the effectiveness of best practices	368	0.27	1.1	15.5	45.4	31.0	7.1

I would implement more conservation practices if my landlord cover some cost	338	-0.04	5.0	24.0	44.7	23.1	3.3
Approaching my landlord about cost-sharing may result in me losing the land	332	0.26	3.6	19.3	35.8	29.8	11.5
There is too much uncertainty about how long I will farm my rented ground to engage in conservation practices	334	0.11	4.8	22.2	39.8	24.0	9.3

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 2017 growing season.

Cover Crop

Respondents were asked if they planted a cover crop on this field in 2017 (including both winter wheat and other types of cover for purely conservation purposes). Slightly less than one third (28.7%, n = 376) of farmers planted a cover crop while the majority of farmers did not. These ranged from cereal rye to wheat to radishes.[1]

Timing and Method of Application

Farmers were asked when they applied phosphorus on this typical field. Of the 291 individuals reporting just one method of application sometime during the previous two seasons, the most popular time for phosphorus application was spring (~48%), followed by fall (~34%), and winter (~1%) (Table 7). Farmers were asked to indicate all methods they used to apply phosphorus to their most recent crop (Table 7). Surface broadcasting and incorporation with tillage within seven days was the most commonly used application method (~45%). The least common method was surface banding at ~3%.

Table 7. Timing and method of phosphorus application (n = 291)

			COUNTS			
Method of P Application	***Fall***	***Winter***	***Spring***	***Previous Season***	**TOTALS**	**Valid %**
Surface banding	3	0	2	3	8	2.76
Subsurface banding	9	0	8	4	21	7.22
In furrow with seed or 2x2	1	0	59	6	66	22.68
Broadcast (no incorporation)	32	1	21	11	65	22.34
Broadcast & incorporated with tillage within 7 days	54	2	51	24	131	45.02
TOTALS	99	3	141	48	291	
Valid %	34.02	1.03	48.45	16.49		100%

[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).

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 (94.4%, n = 360) indicated they used soil testing for this purpose. They were then asked how often they used soil testing (Table 8). Of the farmers that stated they did use testing, over half (59.5%) said they did so every 3 years. The remaining farmers tested every 2 years (26.0%) or every 4 years or more (14.5%).

Table 8. Soil test frequency (n = 338)

Soil Test Frequency	Valid %
Every 2 years	26.0
Every 3 years	59.5
Every 4 years	14.5

4R Practice Likelihood of Implementation

Farmers were asked whether they had used various 4R practices in the past two years and then if they plan to use that practice in the next year (Table 9). The majority of farmers have used most of the listed practices within the past two years. Adding subsurface tile drainage management technology stands out as the least popular with only ~30% of farmers having done so in the last two years, although one-quarter report a willingness to do so in the future. Regular soil testing to determine rate (93.6%), avoiding broadcasting with likely rain within the next 12 hours (88.9%), and avoiding surface application of phosphorus on frozen ground (86.5%) 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 two years. Each practice appears to be remaining approximately the same or growing in use by farmers except for changing crop rotation which had a ~13% decrease in likelihood of use compared to those that have used it in the past two years. This could be related to changes in cost- sharing programs for cover crops. Importantly, 17 to 43% of farmers are considering the use of each practice, while 7 to 65% 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 9. Valid percent of farmers' previous 4R practice usage and likelihood of future use

	In the last two 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	361	88.9	351	6.8	6.6	42.5	44.2
Avoiding surface application of phosphorus on frozen ground	362	86.5	345	13.6	3.8	22.0	60.6
Incorporating broadcast fertilizer (via tillage)	346	72.8	337	19.6	10.4	31.8	38.3
Subsurface placement of fertilizer (via banding, 2x2 or in-furrow with seed)	357	80.7	335	15.5	9.9	23.6	51.0
Determining rates based on regular soil testing once within the rotation (or every 3 years)	358	93.6	347	2.6	3.2	29.4	64.8
Installing or updating subsurface tile	350	69.4	331	26.6	23.9	29.0	20.5
Adding subsurface tile drainage management (via blind inlets)	339	28.6	319	40.1	35.4	17.2	7.2
Adding subsurface tile drainage management (via controlled drainage)	343	32.2	325	39.1	31.7	20.0	9.2
Planting cover crops after fall harvest, assuming the weather is favorable	357	55.7	340	18.2	26.8	33.2	21.8
Changing the crop rotation from soybean/corn to include wheat, regardless of wheat prices	356	52.0	338	36.4	24.6	25.7	13.3
Using manure from a local livestock operation as a source of nitrogen or phosphorus	354	34.5	341	34.3	29.6	20.5	15.5

Farmer Characteristics

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

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 10. About 3/4 (76%, n = 368) of respondents indicated they or their spouse received off-farm income. Table 11 summarizes respondents' off-farm household annual income. A large percentage (45.9%) 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 10. Respondent annual farm net income (n = 345)

Farm Annual Net Income	Valid %
Less than 50,000	27.8
50,000- 99,999	28.1
100,000-249,999	21.2
250,000-499,999	10.7
500,000 or greater	12.2

Table 11. Respondent off-farm household income (n =257)

Off-Farm Household Income	Valid %
Less than $10,000	7.0
$10,000 - $49,999	45.9
$50,000-$99,999	36.6
$100,000 or more	10.5

A total of 21.3% of 375 respondents indicated they have retired from a previous occupation other than farming. Of 372 respondents, only 2% indicated their farm is registered as a Concentrated Animal Feeding Operation (CAFO).

Table 12 displays the average number of acres owned and rented among respondents. The average owned farm size was 487.9 acres while the average rented acreage was 738.8 acres. A larger proportion of acreage among respondents was rented rather than owned. Respondents fell across five categories of total acreage: 50-249 acres (20%), 250-499 acres (13%), 500-999 acres (25%), 1000-1999 acres (25%), and over 2000 acres and up (18%).

Table 12. Farm size

Farm Size	N	Mean	Std. Deviation
Acres Owned	325	487.9	470.4
Acres Rented	293	738.8	779.0

Appendices

Panel Comparison

Since the same farmers completed this survey in two different years, there are opportunities to compare their responses over time in panel analyses (manuscripts and more detailed analyses forthcoming). Below are two tables presenting initial results across waves of the data.

Changes in adoption and intention over time

The adoption rates for subsurface placement of fertilizer (~35%) and planting cover crops (~29%) remained approximately the same over time (Table 13). Behavioral intention to use subsurface placement increased over time for subsurface placement, but decreased over time for cover crops (Table 13).

Table 13. Changes in adoption and intention for subsurface placement of fertilizer and planting cover crops between 2015 and 2017.

Variable	Subsurface Placement Mean (SD) Wave 1 / Wave 2	Cover Crops Mean (SD) Wave 1 / Wave 2
Adoption rate	0.36 (0.48) / 0.34 (0.47)	0.30 (0.46) / 0.28 (0.45)
Future intention to use the practice [A]	1.91 (1.08)* / 2.10 (1.11)*	1.71 (0.92)* / 1.57 (1.01)*

[A] Response options: Will not do it (0), Am unlikely to do it (1), Am likely to do it (2), Will definitely do it (3)
*Significant difference between mean values at $p < 0.01$ level within a single practice between survey waves.

For both subsurface placement and planting cover crops, approximately half of the sample did not use the practice in either iteration of the survey. Similar percentages of individuals began using each respective practice and stopped using the practice.

Table 14. Groupings for behavior change in subsurface placement and cover crops over time.

Wave 1 Behavior	Wave 2 Behavior	Subsurface Placement (%)	Cover Crops (%)
Used practice	Did not use practice	16.3	13.8
Did not use practice	Did not use practice	48.8	58.6
Used practice	Used practice	19.5	16.1
Did not use practice	Used practice	15.4	11.5