SOIL TESTING AND NUTRIENT APPLICATION PRACTICES OF AGRICULTURAL RETAILERS IN THE GREAT LAKES REGION

by

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ABSTRACT

Agricultural runoff containing phosphorus is believed to be a major contributor of algae blooms in the Western Lake Erie Basin. However, the implementation of best management practices (BMPs) can be used to help reduce the runoff of phosphorus.

This research involved conducting surveys to analyze the current implementation of BMPs in Michigan and Indiana. The hypothesis is that the survey results are similar between the two states. An additional hypothesis is that the Michigan and Indiana results are similar to results from two other studies that were previously conducted.

The results from this research generally support the hypothesis that a similar number of farmers in Michigan and Indiana are already implementing best management practices on their farms. In addition to the results being similar across Michigan and Indiana, there is also some evidence that shows that the results are similar to studies from the Ohio State University (LaBarge and Prochaska 2014), *CropLife* magazine (Erickson and Widmar 2015) and NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service 2016); however upon further investigation there are distinct differences before and after media mentions of ramifications from the Lake Erie algal blooms.

While it is difficult to force farmers to implement BMPs, the results of this study may help to educate them, which may cause them to add these practices to their operations.

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CHAPTER I: INTRODUCTION

Phosphorus runoff from agriculture has been thought to be a major contributor to the harmful algal blooms that take place in the Western Lake Erie Basin. An algal bloom in the summer of 2014 compromised the water supply to the city of Toledo, Ohio and caused people to be unable to drink water from the city (Chappell 2014). Regardless of the source, the media frenzy created by this event has led to a renewed focus on reducing phosphorus runoff from farms. Many involved in agriculture understand that implementing best management practices (BMPs) can help to reduce phosphorus runoff. However, it is challenging to find data on practices that are currently being implemented.

The objective of this research is to study the current implementation of BMPs in Michigan and Indiana and test the hypothesis that the results are similar between states. One sub-objective is to compare the data from Michigan and Indiana to survey results from Ohio State University (LaBarge and Prochaska 2014), *CropLife* magazine (Erickson and Widmar 2015) and NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service 2016) to determine if they are similar. Additional sub-objectives are to provide data that can be used to educate farmers what are not implementing BMPs in the hope that they will start utilizing these practices and to have data available on current practices for studies that may be conducted on the impact agriculture has on phosphorus runoff.

Chapter 2 will review the previous research on the implementation of agricultural BMPs. Chapter 3 will discuss the theory and the conceptual model. Chapter 4 will present the methods used to collect data. Chapter 5 will present the data, Chapter 6 will present an analysis of the data and Chapter 7 will summarize the results and review the study's conclusions.

CHAPTER II: LITERATURE REVIEW

The implementation of agricultural best management practices (BMPs) is one of the tools that farmers can use to reduce phosphorus runoff from their fields. This thesis analyzes the adoption rates of BMPs across three states, Michigan, Indiana and Ohio. Previous research that is related to these topics is summarized in this chapter.

Tillage practices that will be discussed throughout this review are conventional tillage, conservation tillage and no-till. According to the Conservation Technology Information Center (2002), conventional tillage disturbs the entire soil surface and is done prior to and/or during planting. Less than 15 percent of crop residue cover is left after planting. Conservation tillage is any system that leaves at least 30 percent of crop residue cover after planting. No-till leaves the soil undisturbed from harvest to planting.

There have been many studies done to try and determine specific reasons that farmers either choose to implement BMPs or not to implement them. Baumgart-Getz et al. (2012) summarized 45 studies on the adoption of BMPs and found that access to and quality of information, financial ability, and connection to agency or local networks of farmers or watershed groups, have the largest impact on adoption rates. Additional important findings show that awareness of environmental issues has a positive influence on adoption rates. This was deemed to have a significant role and of the sub-categories related to this, individual knowledge and familiarity with a specific program showed the most positive contributions to adoption rates. Another significant factor was farm size. Age was also found to have a large, but inversely related, impact. Education as a whole was insignificant in determining adoption rates but extension training specifically, has a positive impact. The data also showed that time plays a role in adoption because the adoption of

BMPs is believed to be less of a risk as time goes on. Understanding the reasons behind implementation is critical to maximize the adoption of BMPs.

While knowing why farmers implement BMPs is very important to increase adoption rates, it is also critical to know what practices are already being implemented. LaBarge and Prochaska (2014) surveyed ag retailers in two major watersheds in Ohio, the Lake Erie basin and the Ohio River basin, to benchmark adoption rates of specific BMPs. Practices discussed in the survey included soil sampling, type of sampling and placement and timing of nutrient application. The results found that 82 percent of the soil sampled was done using BMPs. In relation to nutrient application, 36 percent of farmers in the Lake Erie basin surface broadcasted phosphorus with no tillage while 23 percent of farmers in the Ohio River basin followed the same practice. Starter fertilizer that is incorporated with a planter accounted for 30 to 33 percent of applied phosphorus. In addition, 77 percent of phosphorus was applied in either the fall or spring. Winter application was utilized for 21 percent of the phosphorus application in the Ohio River basin. Understanding what practices are currently utilized allows for more realistic goals to be created because there is a better understanding of what percent of land can still adopt BMPs.

As stated earlier, once farmers have a better awareness of the environment and the benefits that BMPs can provide, they are more likely to implement them. However, there are many different BMPs that can provide different benefits and give farmers flexibility in how they address phosphorus runoff. Sharpley et al. (July 2006) discussed many different BMPs including practices that are pertinent to this thesis such as soil testing; rate, method, and timing of phosphorus applications; soil amendments; and tillage. They stated that USDA's Natural Resources Conservation Service (NRCS) recommends taking soil samples at least every three years. Samples are recommended be taken down to the bottom of the plow depth for cultivated fields and shallower for conservation and no-till fields. The report also noted that phosphorus runoff increases as application rates increase and that avoiding application prior to a large rainfall event can reduce the potential for phosphorus loss. Conservation tillage and no-till were also discussed but the results were less conclusive with these practices. They found that using tillage to incorporate fertilizer reduced total phosphorus loss when compared to no-till areas where fertilizer was broadcast applied, and not incorporated into the soil. However, they also found that converting conventional till farmland to no-till decreased total phosphorus concentrations in surface runoff but increased dissolved phosphorus due to the fact that fertilizer is broadcast on the surface and not incorporated which leaves it more susceptible to runoff during rainfall. Table 2.1 shows the general impact on phosphorus loss from implementing specific BMPs. In addition to reviewing the impacts of BMPs the report also looked at the cost effectiveness of some of the practices. The results showed that manure management including chemical amendments, improved storage, waste treatment and barnyard runoff reduction, have the potential to reduce phosphorus runoff more than tillage management. However, conservation tillage is often more cost-effective which may make it more preferable to these other practices.

Table 2.1: Phosphorus runoff impacts of specific best management practices

Practice	Description	Impact on Phosphorus
Rate of application	Match crop needs	Decrease
Timing of application	Avoid application to frozen ground and apply during season with low runoff probability	Decrease
Method of application	Application can be through incorporation, banding, or injecting in soil	Decrease
Conservation tillage	Reduced and no-till cropping can increase infiltration and reduce soil erosion	Decrease total phosphorus Increase dissolved phosphorus

Source: Sharpley et al., 2006

Another cost effectiveness and cost benefit study was conducted in Iowa in a row crop system of corn and soybeans by Zhou et al. (2009). Chisel plowing six inches deep and leaving 30 percent of the crop residue after corn harvest in the fall and field cultivation in the spring before planting was used as a baseline tillage system in the study. Results were gathered from switching to disk tillage or no-till. The disk tillage system included tandem disking four inches deep and leaving 50 percent of the crop residue after corn harvest in the fall and field cultivation in the spring. Results from comparing the three different tillage systems with no additional conservation practices are shown in Table 2.2. Positive values show extra costs while negative values represent savings or returns.

Table 2.2: Cost effectiveness analysis of tillage practices compared to chisel plowing

	Production Cost ($ per hectare per year)	Yield Return ($ per hectare per year)	Net Cost (+) or Net Return (-) ($ per hectare per year)	Sediment Reduction (tons per hectare per year)
Disk Tillage	-15.8	6.4	-9.4	4.8
No-Till	-33.0	56.9	23.9	19.4

Source: Zhou et al., 2009

A comprehensive study done on the effectiveness of BMPs was conducted by Devlin (February 2003). The study lists recommended BMPs and their effectiveness in reducing runoff, and the estimated cost of implementation. The effectiveness is measured in percent reduction of runoff and is for implementing a single new BMP. The effectiveness of combining multiple practices was not studied. The cost figure is the expected loss in profitability that is caused by adopting the new practice. Both conventional and no-till systems were evaluated. Practices of interest to this thesis included, pre-plant incorporation of fertilizer, subsurface application of fertilizer, changing from conventional to conservation tillage, changing from conventional tillage to no-till, proper soil sampling and testing and using sound fertilizer recommendations. The results of these practices are listed in Table 2.3.

Table 2.3: Effectiveness of reducing phosphorus runoff and implementation costs of adopting specific best management practices

	Cost per Acre ($)	Percent Reduction of Soluble Phosphorus	Percent Reduction of Total Phosphorus
Pre-plant incorporation of fertilizer in conventional tillage	7.15	60	20
Subsurface fertilizer application in conventional tillage	3.50	60	30
Subsurface fertilizer application in no-till	3.50	70	50
Switching to conservation tillage from conventional tillage	0	0	35
Switching no-till from conventional tillage	0	0	40
Proper soil sampling and testing	1.00	0 – 25	0 – 25
Using sound fertilizer recommendations	0	0 – 25	0 – 25

Source: Devlin, 2003

The abovementioned previous research provides a better understanding of why farmers implement BMPs, adoption rates and effectiveness of these practices. This information helps to provide a better understanding of the results from a survey that was conducted in Michigan and Indiana and will be discussed in later chapters.

CHAPTER III: THEORY AND CONCEPTUAL MODEL

According to Ajzek, “the theory of planned behavior is based on the assumption that human beings usually behave in a sensible manner; that they take account of available information and implicitly or explicitly consider the implications of their actions” (2005, 117). The theory of planned behavior (TPB) can be used to provide a better understanding of why farmers choose to implement agricultural best management practices (BMPs). The TPB can also be used to determine concepts that can be used to change behaviors and increase farmer adoption rates of agricultural best management practices.

Behaviors are a result of personal factors, social influence and control. The personal factor is described as a person’s attitude toward the behavior. This is a positive or negative opinion that they have towards performing the behavior. Social influence is the perceived social pressure that the person feels to either perform or not perform the behavior. This pressure is based on perception, not necessarily reality, so it is deemed subjective and it comes from their peers as well as society. Control is the ability to perform the behavior. Typically, people intend to perform a specific behavior when they have a positive feeling towards the behavior, there is social pressure to perform the behavior and they feel they have the ability and opportunities to perform the behavior (Ajzek 2005).

In terms of farmers’ attitudes towards implementing BMPs there is a wide range of both positive and negative feelings. In casual conversations with farmers, some feel they are already doing what is best and that implementing these BMPs will not provide any additional benefit. On the opposite end of the spectrum are farmers who feel that implementing BMPs is a great idea that can provide many benefits and all farmers should be adopting BMPs. In the middle are farmers who feel some BMPs are good and others are not useful because they provide no real benefit. According to TPB, farmers who are most likely to already be implementing BMPs or to implement them in the future are those that fall in the middle group or on the highly positive side.

The social pressure for farmers to implement BMPs has been increasing with more news coverage about algae blooms in the Western Lake Erie Basin, the Gulf of Mexico hypoxia zone, Des Moines Waterworks and other stories about nutrient runoff that is linked to agriculture. Social pressure from those outside of agriculture is high for farms that are situated close to large urban populations and bodies of water that are already considered to be unhealthy. Social pressure from other farmers is also increasing as more and more farms are implementing BMPs and realizing the benefits of these practices. The comparisons of BMP implementation rates across Michigan, Indiana and Ohio that are discussed in this thesis could be used to educate farmers who are not currently using BMPs.

In terms of control, or ability to implement BMPs, one of the main considerations is economics. Implementation and maintenance of these practices can be costly so farmers need to have excess funds available to implement them. However, some of the practices may not cost a lot of additional money but implementation may lead to less land in production or lower yields. This would lead to decreased income so there still must be enough cash flow available to make implementing these practices make sense. In addition to economics, efficacy of the practices is important. If their goal is to reduce runoff, then farmers will implement practices that actually control nutrient runoff and soil erosion. Having a better understanding of the number of farmers currently using BMPs may not help an individual understand the economics of implementing a practice but it can provide them with confidence that they have the ability to implement a practice.

This thesis uses survey results to gain a better understanding of the social pressure factor, from the theory of planned behavior, which is being applied to farmers in order to try and improve the implementation rates of BMPs. They survey results can be used to explain to farmers how many of their neighbors are already implementing practices and by understanding how many other farmers are currently implementing BMPs they may feel pressure to implement these practices. Based on concepts of TPB the survey results may apply enough social pressure to convince farmers to implement BMPs by educating them about how many others are already implementing these practices. The thesis also uses concepts of hypothesis testing to determine if the survey results from each state are similar to each other and if they are similar to other surveys that have been conducted.

CHAPTER IV: DATA COLLECTION METHODS

This chapter discusses the methods used in this study. In order to evaluate best management practices that are being used on farms in each state, a survey (see Appendix I for survey instrument) was sent to ag retailers in Michigan and Indiana. The survey was modeled after previous work that had been done in Ohio (LaBarge and Prochaska 2014) so that data could be compared across all three states. In addition, some of the data will be compared to results from a survey sponsored by *CropLife* magazine and conducted by Purdue University (Erickson and Widmar 2015) and a survey from NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service 2016).

4.1 Michigan and Indiana Data Collection

The survey was mailed on August 22, 2015 to all licensed fertilizer dealers in the state of Michigan and licensed fertilizer applicators and businesses in the state of Indiana. In the letter that accompanied the survey a web link was provided so they could take the survey online, if they preferred. Ninety-seven percent of the completed surveys were returned before October 1, 2015. The remaining four surveys were returned by December 7, 2015. In total, 538 surveys were sent out and 176 were returned for a total response rate of 32.7 percent. A few of the surveys that were returned provided responses for multiple retail locations but in the dataset, they were treated as one response. There were 184 surveys mailed to Michigan businesses and 60 returned for a response rate of 32.6 percent. In Indiana, 354 surveys were mailed and 116 returned for a response rate of 32.7 percent. Forty-nine of the respondents answered that they do not supply fertilizer for corn and soybean production so the final dataset includes 127 responses. Forty-one of the responses in the final data set are from Michigan and 86 are from Indiana. The average retailer size in

Michigan was 59,550 acres and the average size in Indiana was 39,202 acres. A comparison of the summary responses from Michigan and Indiana is provided in Table 4.1.

Table 4.1: Summary for Michigan and Indiana survey responses

	Michigan	Indiana
Response rate	32.6	32.7
Number of responses included in the final data set	41	86
Average retailer acres	59,550	39,202
Percent providing services in the Lake Michigan watershed	55	16
Percent providing services in the Lake Huron watershed	45	0
Percent providing services in the Lake Erie watershed	17	11
Percent providing services in the Mississippi River watershed	0	80

The first part of the survey was used to determine if the respondents provided soil testing services or sold fertilizer to farmers. Those who do not provide these services were excluded from the data. The next section gathered information about their location so that respondents could be assigned to Michigan or Indiana. Respondents were also asked about the number of acres that they service. The majority of the survey asked questions about the production practices of their clients as related to soil sampling, tillage and fertilizer application. The soil sampling practices were reported as the percent of samples taken and the tillage and fertilizer application practices were reported as the percent of acres that the practices are adopted on. A question about yield goals was included on request of the author's employer and was for their internal use. The final question asked about the watersheds that they provided services in and was used to provide a better understanding of where they were located in each state. Maps of the watersheds are shown in Figures 4.1 and 4.2. Fifty-five percent of Michigan respondents and 16 percent of Indiana respondents provide services in the Lake Michigan watershed while 45 percent of Michigan respondents and zero percent of Indiana respondents work in the Lake Huron watershed. Seventeen percent of respondents from Michigan and 11 percent of respondents from

Indiana provide service in the Lake Erie watershed. None of the Michigan respondents provide services in the Mississippi River watershed while 80 percent of the Indiana respondents work in this watershed.

Figure 4.1: The Upper Mississippi, Ohio and Great Lakes Watersheds

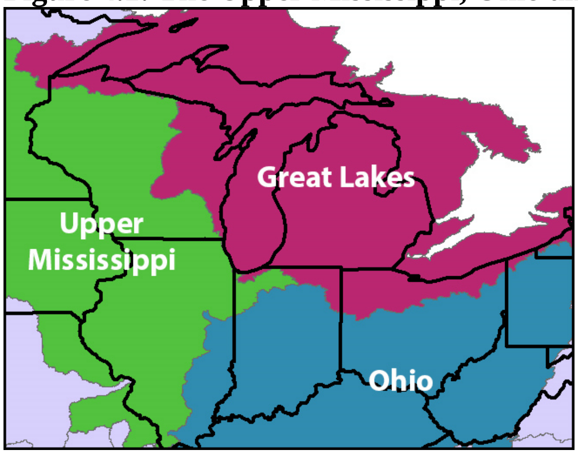


Figure 4.2: Watersheds in the Great Lakes Basin

Source: ODNR Division of Water Resources

4.2 Ohio Data Collection

The data from Ohio that will be used for comparison was gathered from a study conducted by Ohio State University. According to the Ohio study, surveys were mailed to 250 members of the Ohio Agribusiness Association and 100 surveys were returned for a response rate of 40 percent (LaBarge and Prochaska 2014). Fifty-two of the Ohio respondents supply fertilizer to their customers. Due to the surveys being slightly different, not all of the results are expected to be comparable across all three states.

4.3 *CropLife* Survey

CropLife magazine and the Departments of Agricultural Economics and Agronomy at Purdue University sent their survey to crop input dealers in the spring of 2015 (Erickson and Widmar 2015). The survey asks questions about their use of agricultural precision technologies. The survey was mailed to 2,500 retail crop input dealership across the United States who subscribe to the magazine. A total of 261 surveys were returned, a response rate of 10.4 percent. Of the 261 total respondents, 101 provided the state of their location. States represented include Illinois, Iowa, Minnesota, Wisconsin, Indiana, Kansas, Michigan, South Dakota, Nebraska, Ohio, Missouri, North Dakota and one other state that was not named.

4.4 NRCS Survey

The NRCS study looked at the adoption of different farm management and conservation practices in the Western Lake Erie Basin (WLEB) in 2003-06 and 2012. Data was gathered via a voluntary farmer survey and the information was confidential. The 2012 study included 1,019 sampling points. The 2012 data was used for comparison in this thesis.

CHAPTER V: SURVEY DATA

This chapter presents the results of the survey that the author sent to ag retailers in Michigan and Indiana. Results of the survey provide better understanding into the adoption rates of best management practices (BMPs) across the Great Lakes Region. The survey results from this chapter were compared to results from the Ohio survey conducted by Ohio State University (LaBarge and Prochaska 2014), the *CropLife* survey conducted by Purdue (Erickson and Widmar 2015) and the NRCS survey (U.S. Department of Agriculture, Natural Resources Conservation Service 2016); and the statistical analysis is discussed in Chapter 6.

Respondents from Michigan provide services on 2,322,450 acres. This represents 40 percent of the state's total corn, soybean, wheat and hay acreage in 2012, which was 5.78 million acres (USDA NASS 2014). Table 5.1 shows pertinent Michigan and Indiana acreage numbers. Respondents reported servicing between 5,000 and 200,000 acres in Michigan (Table 5.2) and averaged nearly 60,000 acres. Respondents from Indiana provide services on 3,214,600 acres. This represents 27 percent of the state's total cropland acreage in 2012 which was 11.96 million acres (USDA NASS 2014). Indiana respondents serviced between 100 and 200,000 acres (Table 5.3). Additional summary statistics from the Michigan and Indiana survey data are provide in Tables 5.2 and 5.3. The Ohio data had results for 3.8 million acres, which represented 39 percent of their 9.65 million acres of corn, soybeans, wheat and hay (LaBarge and Prochaska 2014). Results of the survey used in comparisons are weighted averages, not the means. The weighted average was calculated by taking the number of acres each retailer supplies and multiplying it by the percent that they reported for each practice. The calculated acres from each retailer were then added together for each individual practice and divided by the total acres that were reported for that state. The *CropLife* survey did not report the number of acres that respondents provided services on (Erickson and Widmar 2015). The NRCS survey uses data from the National Resources Inventory-Conservation Effects Assessment Project Cropland Farmer Survey but does not report the acreage that was reported on.

Table 5.1: Michigan, Indiana and Ohio crop acreage

	Michigan	Indiana	Ohio
Total corn, soybean, wheat and hay acreage	5,777,897	11,955,997	9,654,485
No-till acres	1,518,492	4,952,131	4,278,556

Source: USDA NASS, 2014

Table 5.2: Summary statistics for Michigan survey results

	Minimum	Maximum	Mean	Std. Dev.
Percent of samples taken by method				
Field areas of more than 25 acres per soil sample	0.00%	87.38%	7.92%	19.61%
Field areas of less than 25 acres per soil sample that are not done by management zone or soil type	0.00%	80.00%	15.36%	20.22%
Grid soil samples (example: 2.5 acres per soil sample)	0.00%	95.00%	43.84%	34.16%
Management zone soil sampling	0.00%	100.00%	19.96%	29.79%
Customers not soil sampling or using samples that are more than 5 years old	0.00%	71.43%	14.35%	13.47%
For how many crop acres does your business supply phosphorus and potassium fertilizer? (acres)	5,000	200,000	59,550	52,567
At what depth are soil samples taken for conservation tillage? (inches)	3.00	10.00	6.18	1.74
At what depth are soil samples taken for conventional tillage? (inches)	3.00	12.00	7.34	1.85
What percent of acres have been soil tested within the past 5 years?	50.00%	100.00%	89.36%	12.27%
Percent of recommendations by source				
We make recommendation on % of acres	10.00%	100.00%	74.17%	18.63%
Farmer or other adviser provides recommendations on % of acres	0.00%	90.00%	25.83%	18.63%
Percent of acres using				
Broadcast P then till within one week	0.00%	100.00%	63.44%	36.01%
Broadcast P then till a week or more later	0.00%	100.00%	30.67%	38.57%
Broadcast P but do not incorporate in a conventional tillage system	0.00%	100.00%	22.10%	32.95%
Broadcast P in a no-till system	0.00%	100.00%	31.95%	33.68%
Incorporate P utilizing strip tillage	0.00%	100.00%	9.10%	20.06%
Apply P with the planter as a starter fertilizer	0.00%	100.00%	60.54%	34.79%
Deep band of P	0.00%	100.00%	7.67%	21.02%
Fall P application	0.00%	100.00%	63.72%	41.91%
Winter P application	0.00%	100.00%	17.74%	35.64%
Spring P application	45.00%	100.00%	96.13%	10.39%

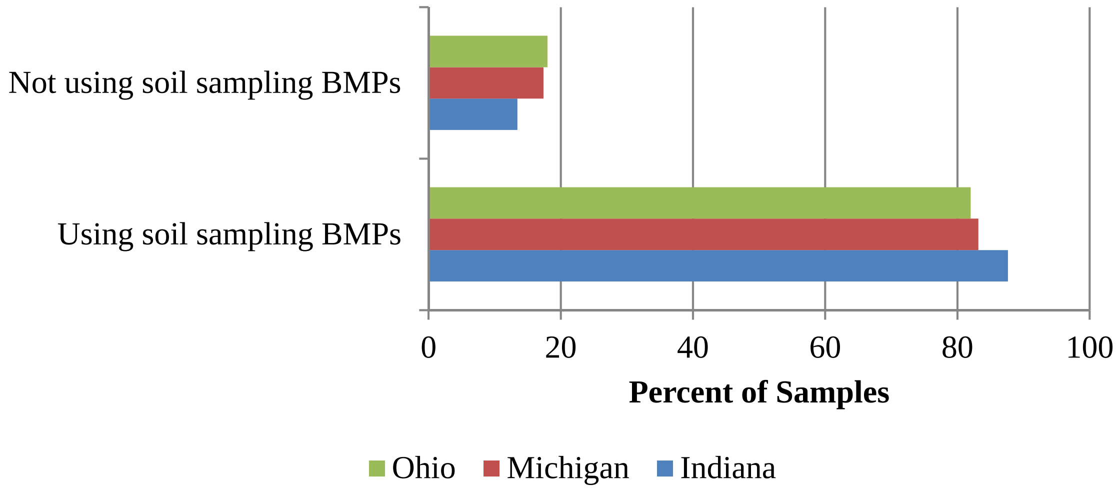
Table 5.3: Summary statistics for Indiana survey results

	Minimum	Maximum	Mean	Std. Dev.
Percent of samples taken by method				
Field areas of more than 25 acres per soil sample	0.00%	45.45%	4.15%	10.19%
Field areas of less than 25 acres per soil sample that are not done by management zone or soil type	0.00%	90.91%	17.25%	23.53%
Grid soil samples (example: 2.5 acres per soil sample)	0.00%	100.00%	50.42%	34.27%
Management zone soil sampling	0.00%	100.00%	18.91%	31.39%
Customers not soil sampling or using samples that are more than 5 years old	0.00%	33.33%	9.61%	8.89%
For how many crop acres does your business supply phosphorus and potassium fertilizer? (acres)	100	200,000	39,202	33,654
At what depth are soil samples taken for conservation tillage? (inches)	2.00	8.00	5.68	1.86
At what depth are soil samples taken for conventional tillage? (inches)	4.00	10.00	6.93	1.25
What percent of acres have been soil tested within the past 5 years?	50.00%	100.00%	87.71%	12.00%
Percent of recommendations by source				
We make recommendation on % of acres	0.00%	100.00%	76.40%	20.74%
Farmer or other adviser provides recommendations on % of acres	0.00%	100.00%	23.48%	20.84%
Percent of acres using				
Broadcast P then till within one week	0.00%	100.00%	59.70%	37.76%
Broadcast P then till a week or more later	0.00%	100.00%	35.89%	37.03%
Broadcast P but do not incorporate in a conventional tillage system	0.00%	100.00%	20.27%	34.45%
Broadcast P in a no-till system	0.00%	100.00%	54.57%	38.30%
Incorporate P utilizing strip tillage	0.00%	100.00%	3.96%	15.80%
Apply P with the planter as a starter fertilizer	0.00%	100.00%	50.35%	36.55%
Deep band of P	0.00%	100.00%	2.24%	11.44%
Fall P application	0.00%	100.00%	61.57%	36.95%
Winter P application	0.00%	100.00%	23.76%	34.88%
Spring P application	0.00%	100.00%	89.77%	23.29%

5.1 Soil Sampling Methods

Retailers were asked about what methods were used for soil sampling and what percent of customers are not sampling at all or using samples that are more than five years old. According to the Tri-State Fertilizer recommendations, which cover Michigan, Indiana and Ohio, samples should be taken in areas less than 25 acres and be sampled every three to four years (Vitosh, Johnson and Mengel 1995). The weighted average of customers who are either not soil sampling or using samples more than five years old in Michigan was 12 percent and 10 percent in Indiana. The minimum in Michigan and Indiana was zero percent and the maximum in Michigan was 71 percent while the maximum in Indiana was 33 percent. Of the respondents who do soil sample, five percent of the weighted average acres in Michigan and four percent in Indiana use soil samples from areas of more than 25 acres. The minimum for both states was zero percent and the maximum in Michigan was 87 percent while the maximum in Indiana was 45 percent. The remaining 83 percent of acres in Michigan and 88 percent of acres in Indiana are soil sampled according to methods that meet or exceed the Tri-State Fertilizer recommendations. In Ohio, 82 percent of the soil samples taken met recommendations from Ohio State University (LaBarge and Prochaska 2014). Figure 5.1 compares the percent of soil samples taken according to BMPs across all three states.

Figure 5.1: Percent of soil samples taken using best management practices



Retailers were also asked about the depth at which they take samples for conservation tillage, including no-till, and conventional tillage. In Michigan, the weighted average depth for samples from conservation tillage was 6.63 inches and 7.62 inches for conventional tillage. Indiana retailers reported a weighted average sampling depth of 6.14 inches for conservation tillage and 7.12 inches for conventional tillage. The frequency of responses to the soil sampling depth questions are graphically represented in Figures 5.2 and 5.3. The data is presented as a histogram created using smoothed lines to connect the frequency of responses at each depth.

Figure 5.2: Frequency graph of the soil sampling depth responses from Michigan

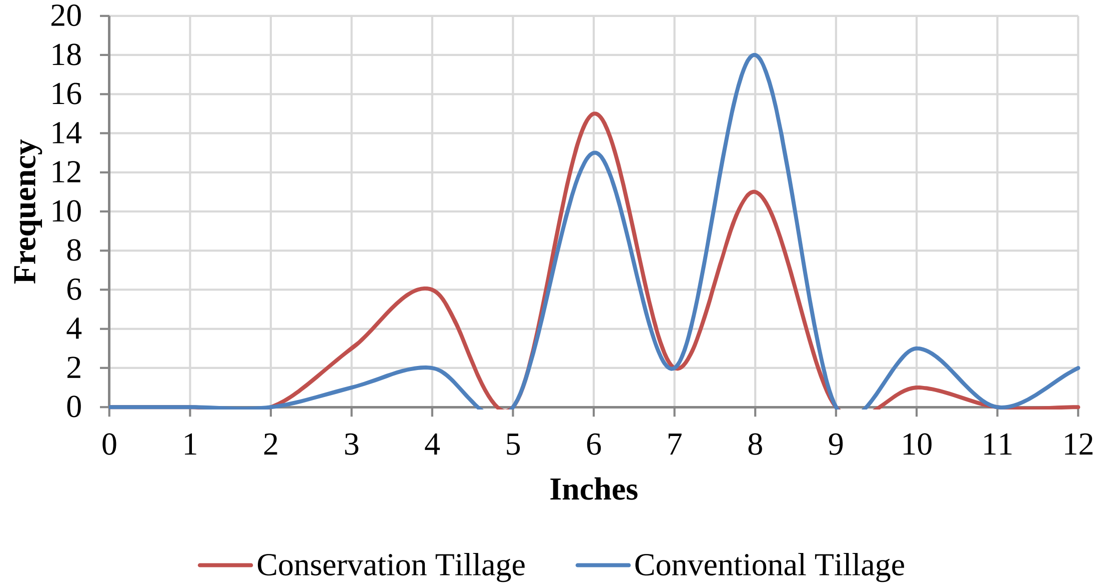
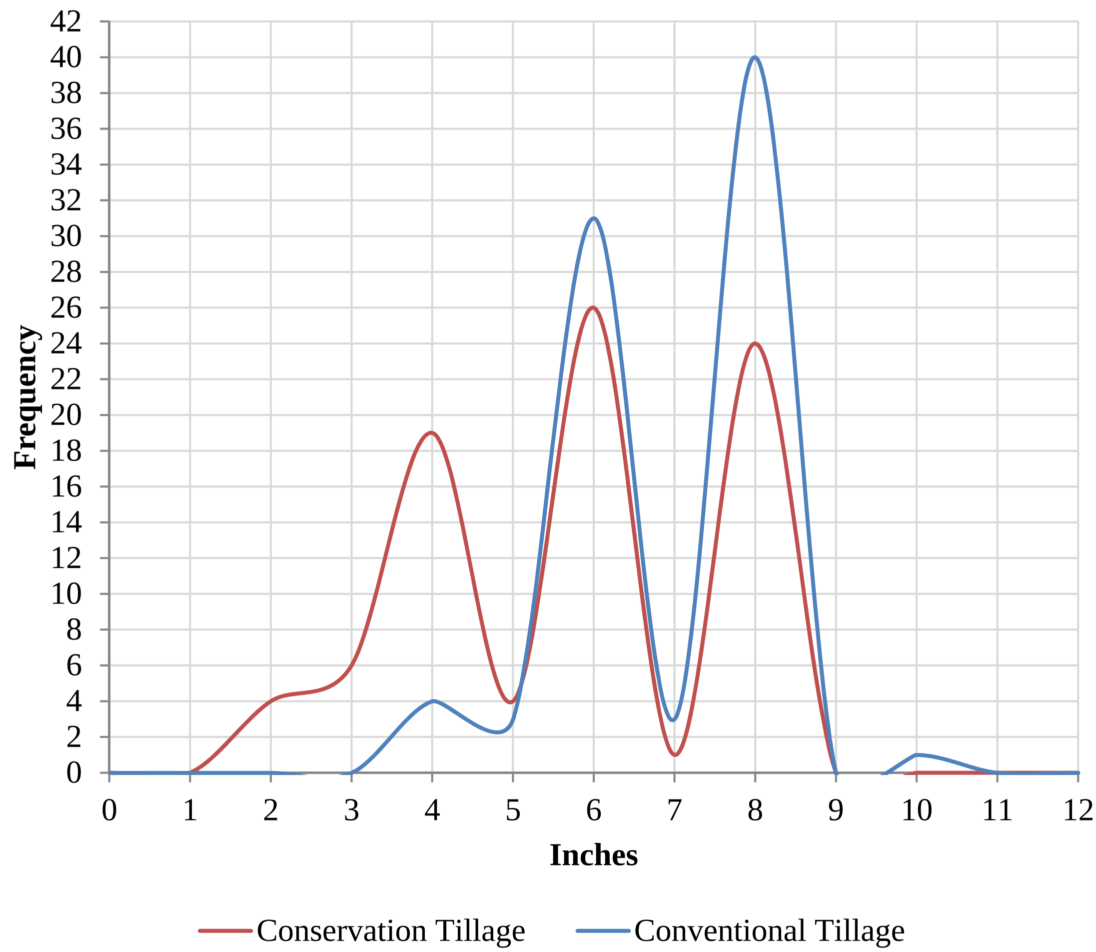
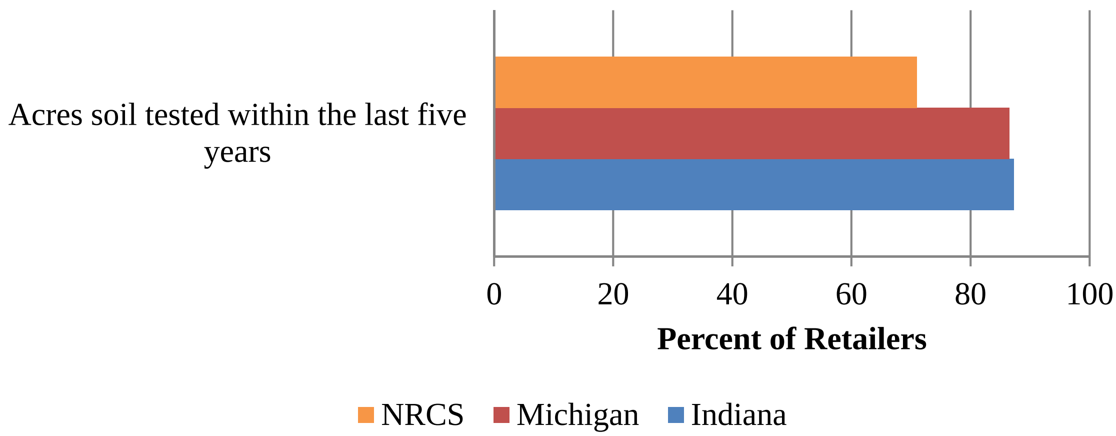


Figure 5.3: Frequency graph of the soil sampling depth responses from Indiana



In addition, retailers were asked about what percent of the acres they supply had been soil tested within the past five years. The weighted average of acres that was soil tested within the past five years was 87 for both states with a minimum of 50 percent and a maximum of 100 percent. The NRCS study reported that 71 percent of acres in the Western Lake Erie Basin were soil tested within the past five years (U.S. Department of Agriculture, Natural Resources Conservation Service 2016). Figure 5.4 compares the results from Michigan and Indiana to the NRCS study.

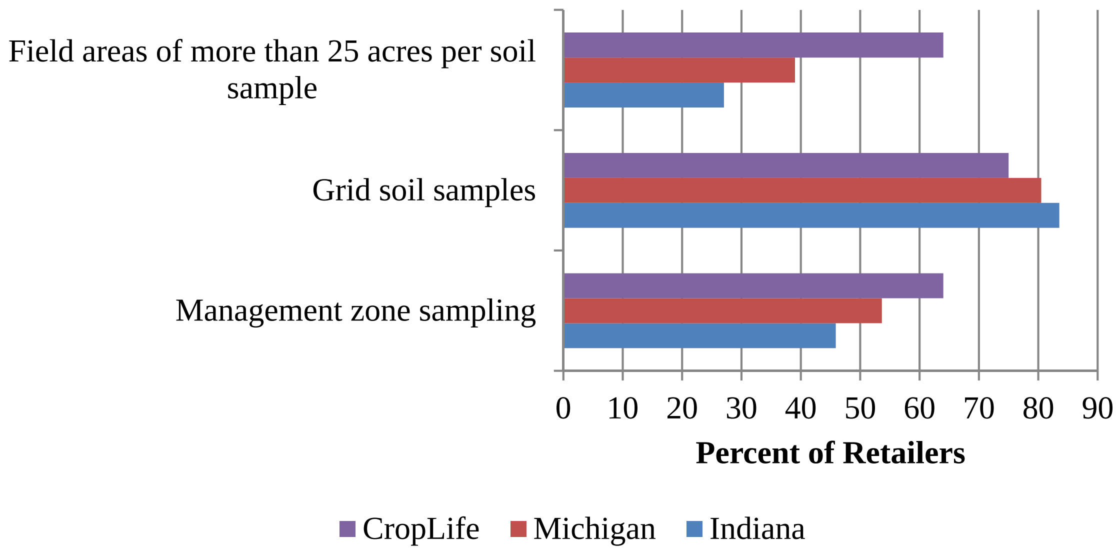
Figure 5.4: Percent of acres soil sampled within the past five years



Retailers were asked about the different soil sampling techniques they use and from this the author was able to determine that 39 percent of Michigan respondents offer the service of sampling areas larger than 25 acres while the practice is offered by 27 percent of respondents from Indiana. Eighty percent of Michigan respondents offer sampling by grids and 54 percent offer management zone sampling. Grid sampling is done by dividing the field into areas of specific size and then taking soil samples within each of those grids (Winstead 2009). Management zone sampling divides the field into regions based on different properties, such as soil type or yield, and samples are then taken within each zone (Winstead 2009). Eighty-four percent of Indiana respondents offer sampling by grids and

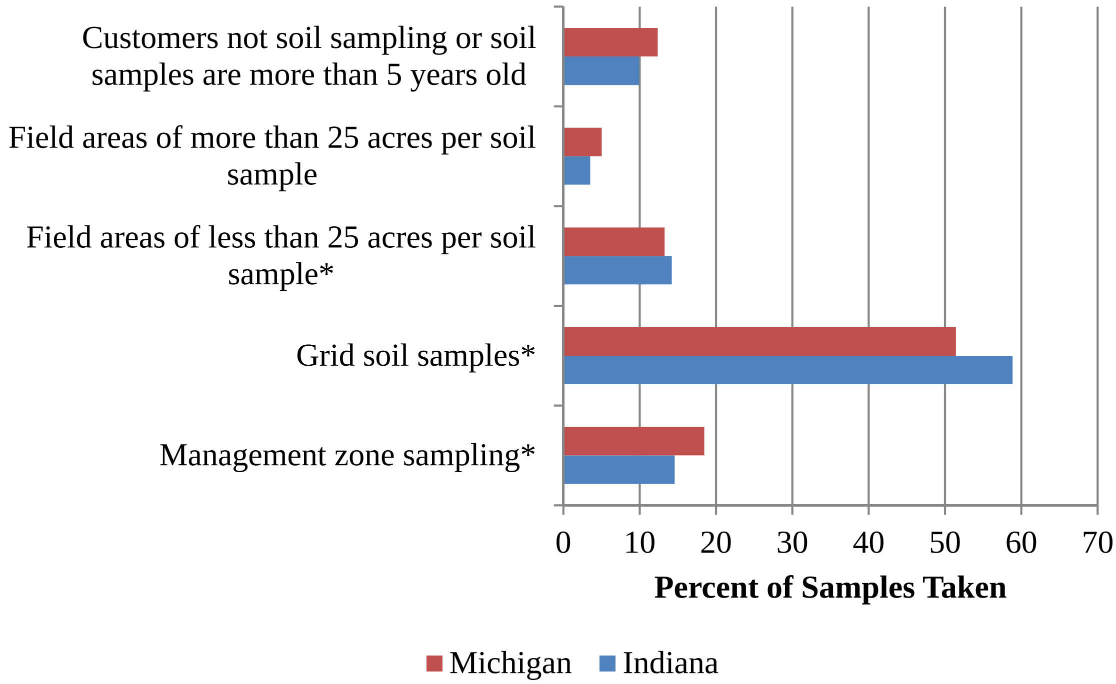
46 percent offering management zone sampling. According to the *CropLife* survey, 64 percent of respondents offer sampling of whole fields, 75 percent offer grid sampling and 64 percent offer management zone sampling (Erickson and Widmar 2015). Figure 5.5 compares the results from Michigan and Indiana with the *CropLife* survey.

Figure 5.5: Percent of retailers offering different types of soil sampling



In Michigan, 18 percent of soil samples were taken according to management zones, 51 percent of samples were based on grids and 13 percent of samples were of field areas that are less than 25 acres. In Indiana, 15 percent use management zones, 59 percent use grids and 14 percent sample areas less than 25 acres. The minimum response for the percent of soil samples taken by each type across both states was zero percent. The maximums in Michigan were 80 percent for field areas less than 25 acres, 95 percent for grid samples and 100 percent for management zone sampling. The maximums in Indiana were 91 percent for field areas less than 25 acres, 100 percent for grid samples and 100 percent for management zone sampling. It should be noted that there are retailers in each state who offer only zone or grid sampling. Figure 5.6 compares the Michigan and Indiana results from the soil sampling questions and BMPs are signified with an asterisk.

Figure 5.6: Percent of soil samples taken by each method



*Indicates best management practices

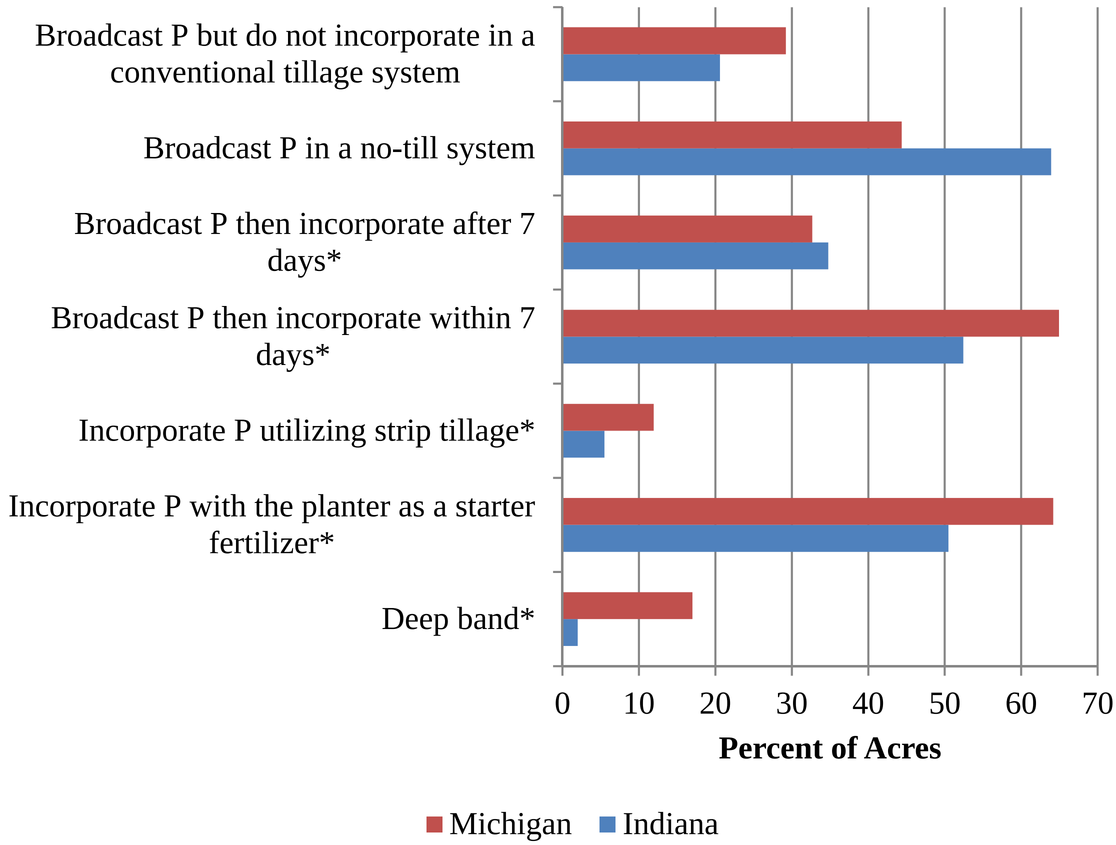
5.2 Phosphorus Application Methods

The survey asked respondents to estimate what percent of their total customer's acres utilize different phosphorus application methods. The phosphorus application methods they could choose from included broadcast then till within one week, broadcast then till a week or more later, broadcast but do not incorporate in a conventional tillage system, broadcast in a no-till system, incorporate utilizing strip tillage, apply with the planter as a starter fertilizer or deep band (see Appendix I for survey instrument). The recommended best management practices for phosphorus application are incorporation, banding or soil injection (Sharpley, et al. July 2006). Methods from question 14 of the survey that do not meet the BMPs of phosphorus application include broadcasting but not incorporating in a conventional tillage system and broadcasting in a no-till system. Twenty-nine percent of Michigan acres in conventional tillage have phosphorus broadcast applied but not incorporated. Forty-four percent of no-till acres in the state have phosphorus broadcast applied. In Indiana, 21 percent of acres in conventional tillage have phosphorus broadcast applied but not incorporated and 64 percent of no-till acres utilize phosphorus that is broadcast applied. The remaining application methods included in the survey all qualify as BMPs. The NRCS survey reported that 40 percent of acres have phosphorus broadcast applied with no incorporation but it did not report conventional acres versus no-till (U.S. Department of Agriculture, Natural Resources Conservation Service 2016).

In Michigan, 33 percent of acres have phosphorus broadcast applied and then incorporated after seven days while 65 percent utilize broadcast application that is incorporated within seven days. Twelve percent of acres have phosphorus incorporated using strip tillage. Phosphorus is incorporated with the planter as a starter fertilizer on 64 percent of acres. The deep banding of phosphorus is used on 17 percent of acres.

In Indiana, 35 percent of acres have phosphorus broadcast applied and then incorporated after seven days while 52 percent utilize broadcast application that is incorporated within seven days. Five percent of acres have phosphorus incorporated using strip tillage. Phosphorus is incorporated with the planter as a starter fertilizer on 50 percent of acres. The deep banding of phosphorus is used on two percent of acres. The range for the percent of customer acres utilizing each phosphorus application method was zero to 100 percent for both states. Figure 5.7 compares phosphorus application methods in Michigan and Indiana and BMPs are signified with an asterisk.

Figure 5.7: Use of phosphorus application methods by percent of customer acres

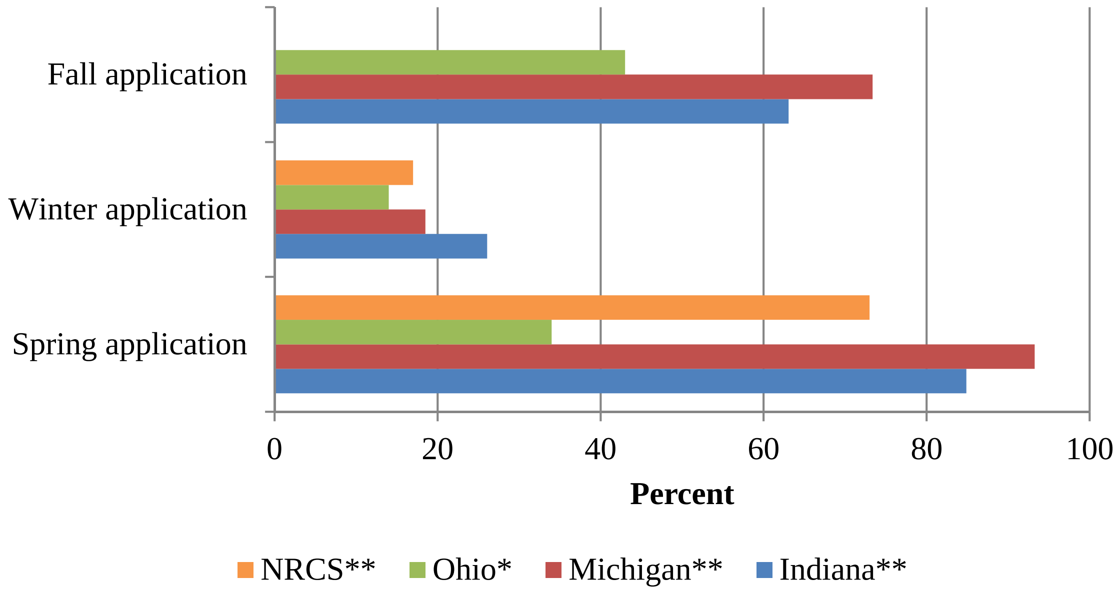


*Indicates best management practices

5.3 Seasonality of Phosphorus Application

Respondents were asked during which time of year phosphorus is applied. Options included fall (September through November), winter (December through February), or spring (March through May). While there are no recommendations on specific seasons or months that phosphorus should be applied, one best management practice is to not apply on frozen ground (Sharpley, et al. July 2006). Due to weather uncertainty it is difficult to determine when the ground will be frozen such that applications should be avoided but the general consensus is that the ground will be frozen during the winter months and phosphorus should not be applied during this time. According to survey results, 19 percent of acres in Michigan and 26 percent of in Indiana have phosphorus applied during the winter. Fall and spring application timing are the preferred methods to help prevent reduce phosphorus runoff. Seventy-three percent of acres in Michigan and 63 percent in Indiana use fall application. Spring application is used on 93 percent of acres in Michigan and 85 percent in Indiana. The range for the seasonal application of phosphorus was zero to 100 percent for fall and winter application in both states. The minimum for spring application was 45 percent in Michigan and zero percent in Indiana. The maximums were 100 percent for both states. The NRCS study asked farmers about the percent of acres that had phosphorus applied relative to planting date. Any application within 21 days of planting was classified as during the spring season, which equaled 73 percent. The study also reported that 17 percent of acres had phosphorus applied during the winter (U.S. Department of Agriculture, Natural Resources Conservation Service 2016). The Ohio survey results reported the percent of total phosphorus applied during each time period. According to the survey, 34 percent is applied in the fall, 14 percent in the winter and 43 percent in the spring (LaBarge and Prochaska 2014). Figure 5.8 compares timing of phosphorus applications across all the surveys.

Figure 5.8: Timing of phosphorus application

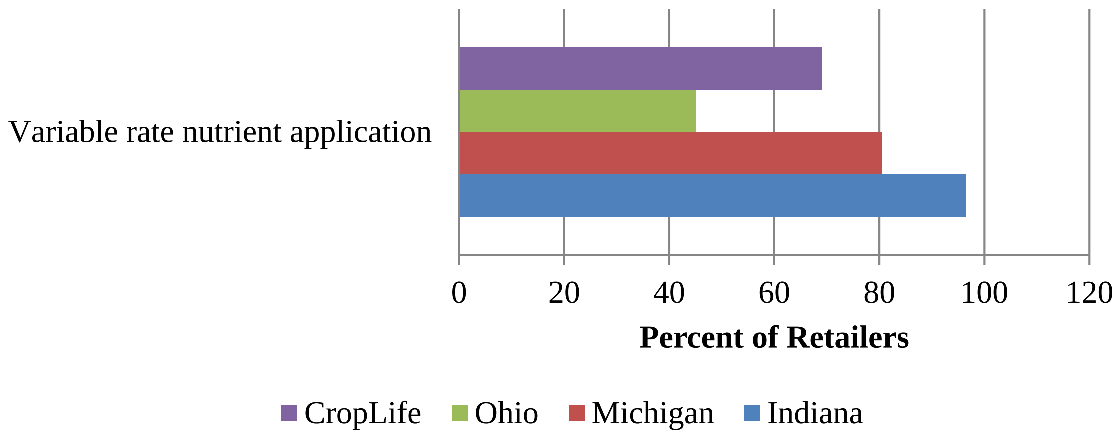


*Percent of phosphorus applied
**Percent of acres

5.4 Variable Rate Application

In addition to being asked how and when phosphorus was applied, retailers were also asked about their use of variable rate application (VRA) for phosphorus. VRA is a method of applying varying rates of inputs in appropriate zones throughout a field (Grisso, et al. 2011). Eighty percent of respondents from Michigan and 96 percent from Indiana offer VRA of phosphorus. The Ohio survey reported the adoption of VRA at 45 percent (LaBarge and Prochaska 2014). The study sponsored by *CropLife* reported that 69 percent of respondents offer VRA as a service (Erickson and Widmar 2015). Figure 5.9 shows a comparison of the results across all three states and the *CropLife* survey. The NRCS survey did not mention the percent of retailers offering VRA but it was reported that the technology is only used on 14 percent of acres (U.S. Department of Agriculture, Natural Resources Conservation Service 2016).

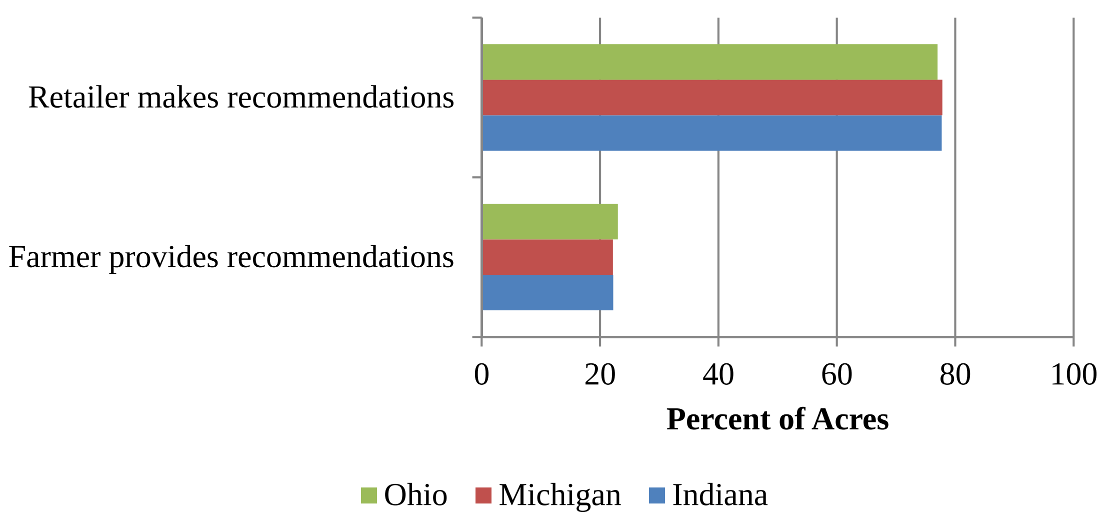
Figure 5.9: Percent of retailers offering variable rate nutrient application services



5.5 Fertilizer Recommendation Sources

Lastly, the survey asked about who provides fertilizer recommendations. The results from Michigan and Indiana were identical with recommendations being provided by farmers for 22 percent of the acres and recommendations for 78 percent of the acres coming from the retailer. In Ohio, 77 percent of acres use fertilizer recommendations from the retailer and the remaining use recommendations from the farmer (LaBarge and Prochaska 2014). Figure 5.10 shows a comparison of the results across all three states.

Figure 5.10: Percent of acres using fertilizer recommendations provided by each source



The survey data detailed in this chapter helps to provide a better understanding of the different types of management practices that are currently being implemented across the Great Lakes Region. This also includes a better understanding of the implementation rates of practices that are considered to be BMPs. Chapter 6 provides comparisons and statistical analysis of these results.

CHAPTER VI: ANALYSIS

The statistical tests on survey data are presented in this chapter. Statistical tests were conducted to determine if survey results differed between Michigan and Indiana. Results from the Michigan and Indiana survey were compared to previously reported results from Ohio (LaBarge and Prochaska 2014), *CropLife* (Erickson and Widmar 2015) and NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service 2016).

A two sample t-test using groups was used to compare the Michigan and Indiana survey results. The null hypotheses was that there were no differences between the population means from Michigan and Indiana. Due to no information on the variance of results from other studies, a series of one sample t-tests were conducted to compare MI-IN results to previous results from Ohio, *CropLife* and NRCS. Chi-square tests, or Fisher's exact test were also used to compare MI-IN results against those from Ohio (LaBarge and Prochaska 2014), *CropLife* (Erickson and Widmar 2015) and NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service 2016). The null hypothesis that MI-IN data were no different from Ohio, *CropLife* and NRCS were tested. Equations for the null hypotheses are shown below.

Equation #1

$$Ho: MI_i = IN_i$$

Equation #2

$$Ho: MI/IN_j = OH_j$$

Equation #3

$$Ho: MI/IN_k = CropLife_k$$

Equation #4

$$Ho: MI/IN_l = NRCS_l$$

In Equation #1, *i* is the variable of interest. In Equations #2 - 4 *j, k and l* are subsets of *i* that were pertinent to the Ohio, *CropLife* and NRCS surveys.

6.1 Soil Sampling Methods

Chi-squared tests were conducted on the usage of soil sampling best management practices (BMPs) in Michigan, Indiana and Ohio. The combined weighted average of the MI-IN survey was compared to the Ohio results. The null hypothesis that BMP usage was no different between the MI-IN data and Ohio was failed to be rejected at any conventional significance level (Pearson Chi2(1) = 0.36 and Pr = 0.55). As a result, there is strong evidence that the usage of soil sampling best management practices did not differ between MI-IN and Ohio.

A paired t-test and Welch two sample t-test were conducted with alternative hypotheses that conservation tillage sampling depth is less than conventional tillage sampling depth. The null hypotheses for the one-sided Welch two sample t-test and one sided paired t-test were rejected at the one percent significance level. Therefore, sampling depths for conservation tillage systems were shallower than sampling depths for conventional tillage systems. Welch two sample t-tests were also conducted on sampling depth for both tillage practices and states. The null hypothesis that sampling depth for conservation tillage did not differ between Michigan and Indiana was failed to be rejected at any conventional significance level. The null hypothesis that sampling depth for conventional tillage did not differ between Michigan and Indiana was failed to be rejected at any conventional significance level. Therefore, it can be stated that retailers sample to similar depths for both tillage practices in Michigan and Indiana.

The percent of acres that had been soil tested within the last five years was tested against the null that there were no differences between the population means of Michigan and Indiana; and the null was failed to be rejected at any conventional significance level (t = 0.6933 and Pr = 0.4894). This indicates that there was no statistical difference between Michigan and Indiana in the percentage of acres that was soil tested within the last five years. A one sample t-test was used to determine if the percent of acres sampled within the last five years from the MI-IN survey was similar to the NRCS survey. The null was rejected (t = 7.54 and Pr = <0.01) which indicates that there is a difference between the studies in the acres soil sampled within the past five years. One reason for the difference may be the age of the data. The NRCS data was collected in 2012 (U.S. Department of Agriculture, Natural Resources Conservation Service 2016).

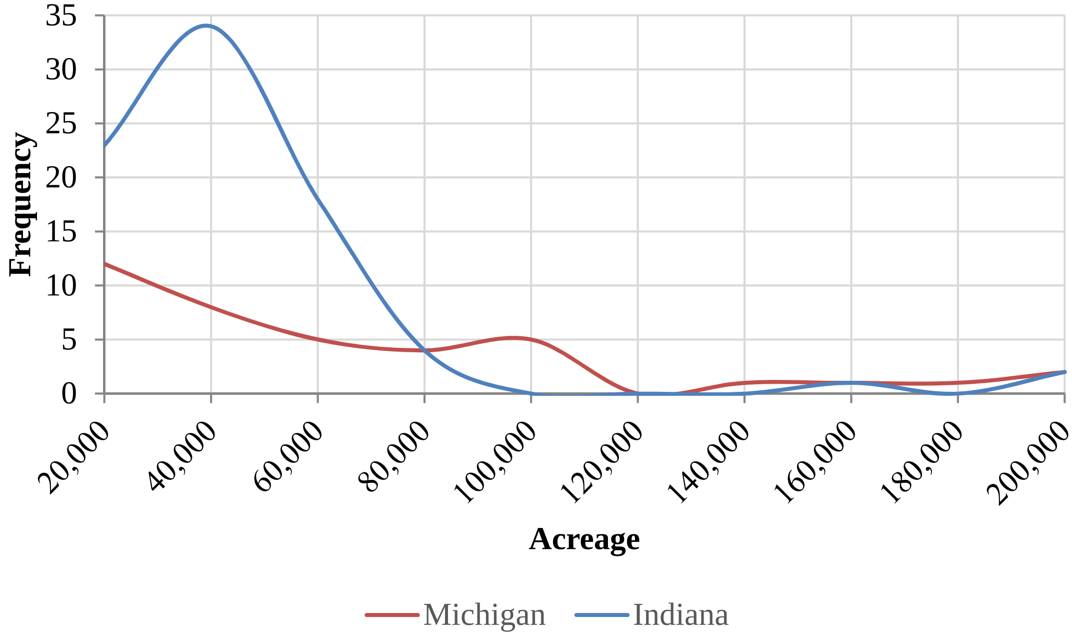
In addition, a chi-square test was conducted to compare the MI-IN results to the *CropLife* survey results for the percent of retailers offering different types of soil sampling. The null hypothesis that soil sampling methods were independent between the MI-IN survey and *CropLife* was rejected at the one percent level (Pearson Chi2(2) = 8.69 and Pr = 0.01). This means that there is strong evidence that the offering of different types of soil sampling by retailers differed between MI-IN and *CropLife*. The results may not be similar because questions were asked differently between the surveys. The *CropLife* survey specifically asked which services were offered and the Michigan and Indiana survey asked what percent of samples were taken using each method. From the percentage, the principle investigator was able to determine which retailers offered those services. There may have been retailers who offered a specific service but do not have any clients that utilize it which would skew the data.

The percent of soil samples collected by each method were tested against the null that there were no differences between the population means of Michigan and Indiana; and the null was failed to be rejected for four of the five collection methods (Table 6.1) which means the percent of soil samples collected by those methods did not differ between Michigan and Indiana. Farmers not soil sampling or using samples more than 5 years old was rejected ($p< 0.01$, Table 6.1). Therefore, there is strong evidence that the percent of farmers not soil sampling or using old samples differed between Michigan and Indiana. However, the alternative hypothesis that farmers do not soil sample or that they use samples older than five years old was greater in Michigan than in Indiana was supported. As a result there is evidence that there are more farmers in Michigan who are not soil sampling or using old samples. One reason that the results from the two states may not be similar for those not soil sampling is because the retailers in Michigan cover more acres so it may be more difficult for them to sample all of the acres they service which would explain the higher percent of acres in Michigan that are not soil sampled. According to the survey, Michigan retailers serviced an average of 59,550 acres each while Indiana retailers cover only 39,202 acres. In addition, there are fewer total soil samples taken in Michigan. According to the International Plant Nutrition Institute, 269,045 soil samples were taken in Michigan during either the fall of 2014 or the spring of 2015 while nearly twice as many samples (594,335) were taken in Indiana during the same time period (International Plant Nutrition Institute 2015). The frequency of retailers servicing each acreage range is graphically represented by state in Figure 6.1 as a histogram created using smoothed lines to connect the frequency of responses at each acreage.

Table 6.1: T-test results of the Michigan and Indiana comparison for soil sample collection methods

	t-test	Pr
Customers not soil sampling or using samples that are more than 5 years old	-2.64	0.01
Soil samples taken using field areas of more than 25 acres per soil sample	-1.37	0.17
Soil samples taken using field areas of less than 25 acres per soil sample	0.51	0.61
Soil samples taken using grids	1.12	0.26
Soil samples taken using management zones	-0.31	0.75

Figure 6.1: Frequency graph of the acres Michigan and Indiana retailers supply fertilizer



6.2 Phosphorus Application Methods

The percent of customer acres using each phosphorus application method were tested against the null hypothesis that there were no difference between the population means of Michigan and Indiana. The null hypotheses were failed to be rejected at any conventional level of significance for six of the seven application methods (Table 6.2) which means that for these methods the results did not differ between Michigan and

Indiana. The percent of customer acres that broadcast phosphorus in a no-till system differed between Michigan and Indiana ($p<0.01$, Table 6.2) because the null hypothesis was rejected. However, the alternative hypothesis that the percent of no-till acres with phosphorus broadcast applied was greater in Indiana than in Michigan was supported. As a result there is evidence that there are more no-till acres in Indiana with phosphorus broadcast applied. One reason for this could be because there is more acreage using no-till in Indiana (USDA NASS 2014).

Table 6.2: T-test results of the Michigan and Indiana comparison for phosphorus application methods

	t-test	Pr
Broadcast apply phosphorus then till within one week	-0.43	0.67
Broadcast apply phosphorus then till one week or more later	0.85	0.40
Broadcast apply phosphorus but do not incorporate in a conventional tillage system	-0.15	0.88
Broadcast apply phosphorus in a no-till system	3.20	<0.01
Incorporate phosphorus utilizing strip tillage	-1.45	0.15
Apply phosphorus with the planter as a starter fertilizer	-1.39	0.17
Deep band phosphorus	-1.78	0.08

6.3 Seasonality of Phosphorus Application

The timing of phosphorus applications were tested against the null that there were no differences between the population means of Michigan and Indiana; and the null was failed to be rejected for all time periods at any conventional significance level (Table 6.3). This indicates that there was no statistical difference between Michigan and Indiana in the percentage of customers that apply phosphorus in each season.

Table 6.3: T-test results for the comparison of Michigan and Indiana responses about the timing of phosphorus application

	t-test	Pr
Fall application of phosphorus	-0.23	0.82
Winter application of phosphorus	0.99	0.33
Spring application of phosphorus	-0.89	0.38

A one sample t-test was used to determine if the seasonality of phosphorus application from the MI-IN survey was similar to the Ohio and NRCS surveys. For the comparison to NRCS, the null hypothesis that there were no differences between the surveys was failed to be rejected for winter application and rejected for spring application at the five percent level (Table 6.4). Therefore, there is evidence that there is no difference between the surveys for winter application but the results differ for spring application. The null hypotheses were rejected at the five percent level of significance for all seasons when comparing the MI-IN results to Ohio (Table 6.4). This means that there is strong evidence that the seasonality of phosphorus application differed between the two surveys. The MI-IN results may differ because the questions asked were slightly different from each other. The MI-IN question asked about the percent of acres that have phosphorus applied during that time period, while the Ohio survey asked about percent of total phosphorus applied during each time period. The MI-IN results may differ from the NRCS data because of the age of the surveys. The NRCS survey was conducted before the harmful algae bloom in Lake Erie so timing of phosphorus application may have changed since then.

Table 6.4: One sample t-test results to compare the seasonality of phosphorus application across the MI-IN, Ohio and NRCS surveys

	t-test	Pr
Fall Application		
MI-IN compared to Ohio survey	5.51	< 0.01
Winter Application		
MI-IN compared to Ohio survey	2.45	0.02
MI-IN compared to NRCS survey	1.51	0.13
Spring Application		
MI-IN compared to Ohio survey	31.44	< 0.01
MI-IN compared to NRCS survey	10.23	< 0.01

6.4 Variable Rate Application

Due to the number of observations per category, the Fisher's exact test was used to compare the number of retailers in Michigan and Indiana that offer variable rate application (VRA). The results indicated that a statistically significant relationship (p-value = 0.01) exists between the number of retailers offering VRA and the states where the retailers offer those services (Table 6.5). This indicated that the null of independence between states and VRA offering was rejected at the one percent level. Therefore, there is strong evidence that VRA offering differed between Michigan and Indiana. However, the alternative hypothesis that the percent of phosphorus applied variable rate was greater in Indiana than Michigan was supported. As a result there is evidence that there are more acres with phosphorus variable rate applied in Indiana.

Table 6.5: Frequency table of retailers offering variable rate application in Michigan and Indiana

	MI	IN	Total
No	8	3	11
Yes	33	82	115
Total	41	85	126

Correlation coefficients were used to compare the percent of phosphorus applied via VRA to corn yield goal and percent of acres soil sampled within the past five years. The hypothesis was that there would be a positive correlation between the offering of VRA and each of the variables. In Indiana, very little correlation (0.21) was shown between the offering of VRA and corn yield while in Michigan a medium amount of correlation (0.41) was found. In regards to the percent of acres soil sampled within the last five years, very little correlation was shown in both Indiana (0.26) and Michigan (0.11). The correlation coefficients for both states did not provide strong evidence that the variables are related.

One sample t-tests were used to compare the percent of retailers offering VRA services across three surveys, but two at a time. The combined weighted average of the MI-IN survey was compared to the Ohio survey and the null hypothesis that the offering of VRA was no different between the surveys was rejected (p-value < 0.01, Table 6.6). The combined weighted average of the MI-IN survey was then compared to the *CropLife* survey and the null hypothesis that the offering of VRA was no different between the surveys was rejected (p-value < 0.01, Table 6.6). Therefore, there is strong evidence that the percent of retailers offering VRA services differed between MI-IN and both Ohio and *CropLife*. One reason that the data may not be similar across the surveys is because of how data were reported. The Ohio survey did not provide specific detail on this question so the data may be slightly different than what was reported in the other surveys.

Table 6.6: One sample t-test results to compare the percent of retailers offering variable rate application services across the MI-IN, Ohio and *CropLife* surveys

	t-test	Pr
MI-IN compared to Ohio survey	16.06	< 0.01
MI-IN compared to *CropLife* survey	7.33	< 0.01

6.5 Fertilizer Recommendation Sources

The source of fertilizer recommendations were tested against the null that there were no differences between Michigan and Indiana; and the null was failed to be rejected at any conventional significance level (Table 6.7). As a result, there is strong evidence that the source of fertilizer recommendations did not differ between Michigan and Indiana.

Table 6.7: T-test results for the comparison of Michigan and Indiana responses about the source of fertilizer recommendations

	t-test	Pr
Retailer makes the recommendations	0.76	0.45
Farmer provides the recommendations	-0.57	0.57

A one sample t-test was used to determine if the Ohio results were statistically different from the MI-IN results. For both sources of recommendations (farmer and retailer), the null was failed to be rejected (Table 6.8). This indicates that farmers and retailers have similar roles with respect to making fertilization application recommendations across states.

Table 6.8: One sample t-test comparing the source of fertilizer recommendations from MI-IN to Ohio

	t-test	**Pr**
Retailer makes recommendations	-0.74	0.46
Farmer makes recommendations	0.70	0.49

6.6 Tillage Types

Respondents were asked about what percent acres use conventional tillage, reduced tillage or no-till and this was compared to the percent of acres using VRA and the yield goal for corn. Correlation coefficients were used for these comparisons. In Indiana, very little correlation (Table 6.9) was shown between the offering of VRA and each tillage type. While in Michigan, a slightly greater correlation (Table 6.9) was found. In regards to the yield goal for corn, little correlation (Table 6.10) was shown in both Indiana and Michigan. The correlation coefficients for both states did not provide strong evidence that the variables are related.

Table 6.9: Correlation between the percent of acres using variable rate and different tillage practices.

	Indiana	Michigan
Conventional tillage	-0.25	0.38
Reduced tillage	0.24	-0.33
No-till	0.10	-0.11

Table 6.10: Correlation between the percent of acres using variable rate and the yield goal for corn.

	Indiana	Michigan
Conventional tillage	0.34	0.10
Reduced tillage	-0.20	0.05
No-till	-0.26	-0.05

6.7 Summary

The statistical tests discussed in this chapter were performed to determine if survey results differed between Michigan and Indiana. The majority of the tests failed to reject the null hypothesis that the data was similar between states. The MI-IN results were also compared to data from Ohio (LaBarge and Prochaska 2014), *CropLife* magazine (Erickson and Widmar 2015) and NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service 2016). In the comparisons across surveys, the null hypothesis was failed to be rejected for comparisons of the use of soil sampling BMPs, timing of phosphorus application and source of fertilizer recommendations, which means that the data for those variables was similar across the compared surveys. For comparisons of the percent of acres soil sampled within the last five years, soil sampling methods offered by retailers and the percent of retailers offering VRA the null hypothesis was rejected which means that there is strong evidence that the data differed between the different surveys.

The comparison of the MI-IN results to the NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service 2016) data serves as a test for the effects of social pressure on farmer decision making. The percent of acres soil sampled within the last five years was not similar between the two surveys. However, the alternative hypothesis that more acres have been soil sampled within the last five years from the MI-IN survey when compared to the NRCS survey was supported. As a result there is evidence that the percent of acres soil sampled within five years has increased over time and one reason for this may be the effect of social pressure. The NRCS survey was done in 2012, before the water crisis in Toledo, while the MI-IN results were gathered in 2015 after there had been media attention on phosphorus runoff for multiple years. Figure 6.2 shows a timeline of when the survey data was gathered, when the water crisis happened and media mentions. The search terms for media mentions (LexisNexis 2016) included both “Lake Erie” and “algae” in the articles. The media mentions of the 4R program were included because this is believed to be a key educational tool that has helped to increase the implementation rates of BMPs. The 4R program uses the concepts of the right fertilizer source, at the right rate, at the right time, with the right placement to implement BMPs (The Fertilizer Institute 2016). Figure 6.3 shows Google Trends (2016) results for the search term “Lake Erie algae”, and indicates that interest peaked in August 2014. Google Trends analyzed the percentage of Google web searches and the points on the chart show total searches for Lake Erie algae relative to the total number of searches done on Google over time. Both Figure 6.2 and 6.3 show that interest in Lake Erie algal blooms increased after the NRCS survey was taken in 2012. This may have created more social pressure and affected farmer and retailer practices that led to the differences among the survey results.

Figure 6.2: Toledo Water Crisis Timeline and Media Mentions

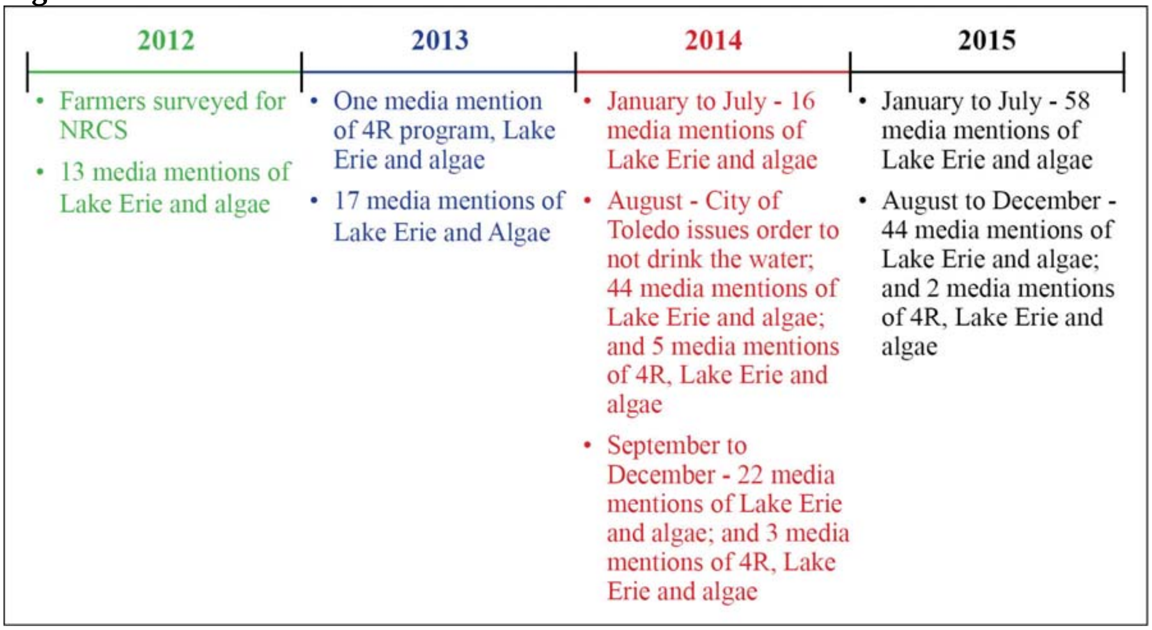
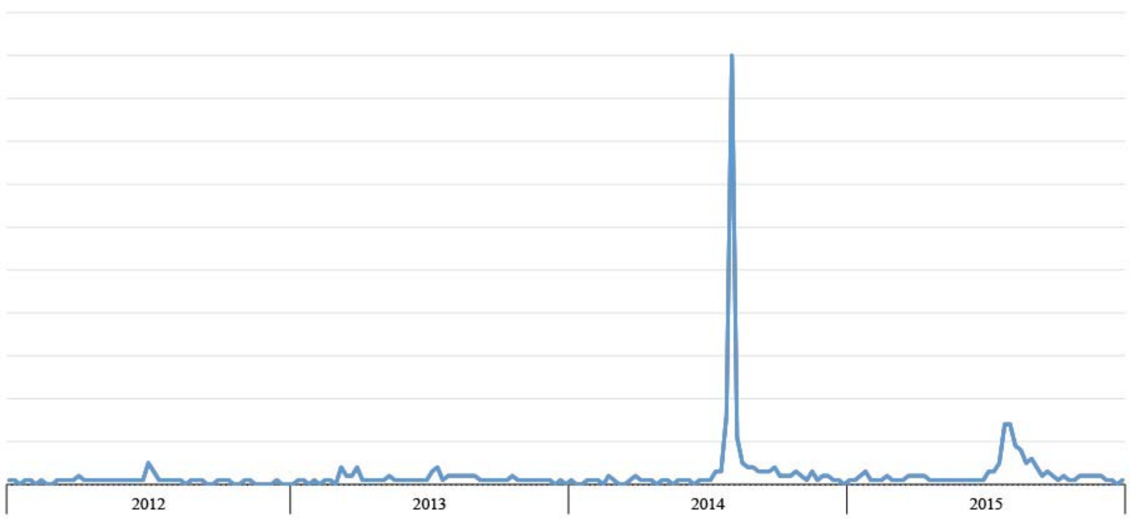


Figure 6.3: Google Trends Results for the Search Terms of Lake Erie Algae



Source: Google Trends https://www.google.com/trends/

CHAPTER VII: RESULTS AND CONCLUSION

The main objective of this research was to study the current implementation of best management practices (BMPs) in Michigan and Indiana and determine of the results are similar between states. In regards to soil sampling, the statistical analysis showed that retailers sample at similar depth for both conservation and conventional tillage in both states. The analysis also showed that the percent of acres that have been soil sampled within the last five years was similar between states. The percent of soil samples that are collected via field areas more than 25 acres, field areas less than 25 acres, grids and management zones did not differ between Michigan and Indiana. However, there was strong evidence to show that the percent of farmers not sampling or using old samples was different between the states and that it was greater in Michigan. In regards to phosphorus application methods, the analysis shows that the results did not differ between states for broadcast application with incorporation, broadcast application with no incorporation in conventional tillage, incorporation in strip tillage, application with the planter or deep banding. The results for broadcast application in a no-till system did show a difference and that more no-till acres in Indiana have phosphorus broadcast applied. The data on seasonality of phosphorus application showed no difference between Michigan and Indiana for all three seasons. However, there was strong evidence that the number of retailers offering variable rate application differed. Finally, there was strong evidence that the source of fertilizer recommendations did not differ between the states.

One sub-objective was to compare the MI-IN survey results to data from Ohio State University (LaBarge and Prochaska 2014), *CropLife* magazine (Erickson and Widmar 2015) and NRCS (U.S. Department of Agriculture, Natural Resources Conservation

Service 2016) to determine if they are similar. In regards to soil sampling, there was strong evidence to show that the use of soil sampling BMPS did not differ between MI-IN and Ohio. However, there was indication that there is a difference between MI-IN and NRCS results on the percent of acres soil sampled within the past five years. The percent of retailers offering different types of soil sampling was compared to the *CropLife* results and it was determined that the data was independent of each other. The seasonality of phosphorus application was compared to data from NRCS and there was evidence that there was no difference between the survey results for winter application but the results did differ for spring application. Fall application was not compared between MI-IN and NRCS. There was also strong evidence that the seasonality of phosphorus application differed for fall, winter and spring between the MI-IN survey and the Ohio survey. In regards to the results differed between MI-IN and both Ohio and *CropLife*. The final comparison dealt with the source of fertilizer recommendations and the analysis indicates that the recommendation sources are similar between MI-IN and Ohio.

An additional sub-objective was to provide data that could be used to apply social pressure, from the theory of planned behavior (TPB), to farmers who are not implementing BMPs in the hope that they will decide to start utilizing these practices. According to TPB people typically have the intent to perform a specific behavior when they have a positive feeling towards the behavior, there is social pressure to perform the behavior and they feel they have the ability to perform the behavior (Ajzek 2005). The data from this thesis can be used to educate farmers because it shows that there are a majority of farmers already implementing BMPs so those who are not, should join the rest of them. The data also shows farmers not implementing these practices that they have the ability to perform BMPs because so many of their neighbors already are.

In general, the results from this research support the hypothesis that a similar number of farmers in Michigan and Indiana are already implementing best management practices on their farms. While there were some results that were not similar across the two states, these exceptions were probably due to the differences in the amount of no-till acreage and the area serviced by retailers and not the acceptance of BMPs. In addition to the results being similar across Michigan and Indiana, there is also some evidence that shows that the results from the Ohio State University (LaBarge and Prochaska 2014), *CropLife* (Erickson and Widmar 2015) and NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service 2016) surveys are also similar. The main reason that there may be differences between the studies is because the surveys were not set up exactly the same and the questions were asked differently. While it is difficult to force farmers to implement BMPs, the results of this study may help to educate which may make them change their behavior on their own. This research should be shared with farmers to explain how many of their peers are already implementing best management practices.

To further expand on this research, a survey could be sent to all farmers in the Western Lake Erie Basin states and Canadian provinces to provide a better comparison across the area. Instead of asking retailers about practices that farmers are implementing the farmers could be asked directly. The data gathered from a future study could be beneficial as more studies are being released on the contributions of agriculture to phosphorus runoff in Lake Erie and more groups are looking at what practices need to be implemented to curb the runoff issue.

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APPENDIX A: RETAILER SURVEY

Soil Testing and Nutrient Application Practices of Agronomy Retailers

1. Does your retail location offer soil sampling services? *(If no, please disregard the rest of this survey and mail it back)*

    ____ Yes ____ No

2. Does your retail location supply fertilizer for corn and soybean production? *(If no, please disregard the rest of this survey and mail it back)*

    ____ Yes ____ No

3. In what state is your retail location?

    ____ Indiana ____ Michigan ____ Ohio

4. In what city is your retail location?

    ____

5. Please list your business name (Optional)

    ____

6. What percent of soil samples taken by your business were done by each sampling method? (Please make sure your responses total to 100)

    Field areas of more than 25 acres per soil sample ________________
    Field areas of less than 25 acres per soil sample that are not done by management zone or soil type ________________
    Grid soil samples (example: 2.5 acres per soil sample) ________________
    Management zone soil sampling ________________

7. What percent of your customers are not soil sampling or using samples that are more than 5 years old?

    ________________ percent

8. At what depth are soil samples taken for the following tillage types

    Conservation tillage (no-till or reduced tillage) ________________ inches
    Conventional tillage ________________ inches

9. For how many crop acres does your business supply phosphorus and potassium fertilizer?

    Estimated Acres ________________

10. For the crop acres that your business supplied phosphorus and potassium fertilizer in 2015, what percentage has been soil tested within the following time frames?

    More than five years ago ________________
    Within the last five years ________________
    Within the last three years ________________ *Please also include these acres in your "Within the last five years" answer*

11. For the crop acres that your business supplied phosphorus and potassium fertilizer in 2015, what percentage uses the following tillage practices?

    No-till ________________
    Reduced tillage ________________
    Conventional tillage ________________

Survey is continued on the back

12. For the estimated acres you supply phosphorus and potassium for, what percentage of the recommendation comes from the following sources. (Please make sure your responses total to 100)

We make recommendation on % of acres ________________

Farmer or other advisor provides recommendations on % of acres ________________

13. Does your business offer variable rate application of phosphorus?

____ Yes ____ No If yes, what percent of total phosphorus that you apply is applied variable rate ________________

14. Below are methods that might be used to apply/incorporate phosphorus (P). What percent of your farm customers utilize the methods below? Indicate by percent total customer's acres in box. Responses may add up to more than 100 percent.

	% acres applied Sept-Nov	% acres applied Dec-Feb	% of acres Mar-June
Broadcast P then till within one week			
Broadcast P then till a week or more later			
Broadcast P but do not incorporate in a conventional tillage system			
Broadcast P in a no-till system			
Incorporate P utilizing strip tillage			
Apply P with the planter as a starter fertilizer (2x2 or pop up)			
Deep band of P (2-6 inch below soil surface)			

15. What is your clients' realistic yield goal for corn for grain and soybean production?

Corn for grain __________ avg. bu/ac Range: _______ to _______ bu/ac

Soybeans __________ avg. bu/ac Range: _______ to _______ bu/ac

16. What major watershed is your primary location in?

____ Lake Erie 100%
____ Lake Huron 100%
____ Lake Michigan 100%
____ Lake Superior 100%
____ Mississippi River 100%
____ Split between Lake Huron and Lake Erie
____ Split between Lake Michigan and Lake Erie
____ Split between Lake Michigan and Lake Huron
____ Split between Mississippi River and Lake Michigan
____ Split between Mississippi River and Lake Erie

17. Do you have any additional comments?

____

____

____

Thank you for taking the time to fill out the survey. Your responses are greatly appreciated.